OPTIONS méditerranéennes

Forage resources and ecosystem services provided by Mountain and Mediterranean grasslands and rangelands

Edited by:
R. Baumont, P. Carrère, M. Jouven, G. Lombardi,
A. López-Francos, B. Martin, A. Peeters, C. Porqueddu

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In constrained environments such as mountainous and Mediterranean areas the sustainable use of forage resources by domestic herbivores has to combine production, conservation of high environmental value areas and product quality. The sustainability of animal production systems relies on their ability to reconcile economic performance based on the added value of high quality animal products and ecological performance based on the implementation of management practices relying on agro-ecological principles and allowing compensatory payments for the production of public goods.

This publication is the outcome of a joint meeting of the "Mountain Pastures, Mediterranean Forage Resources (FAO/ESCORENA - CIHEAM) and Mountain Cheese" networks entitled **"Forage resources and ecosystem services provided by mountain and Mediterranean grasslands and rangelands"** which was organized in Clermont-Ferrand (France) from 24 to 26 June 2014. This multidisciplinary meeting aimed at sharing/contrasting viewpoints, methods and results of specialised scientists working on grassland and rangeland assessment and use. In a context of climate change and environmental concerns, livestock farming systems in Mediterranean and mountain areas share issues common to harsh environments, which can be dealt with by using similar theoretical and methodological frameworks. Cultivated or spontaneous vegetation, herbaceous or ligneous species, all forage resources should be considered together, as complementary items contributing to the multiple performances of livestock systems.

More than 140 scientific contributions were presented and discussed including introductory and invited papers, short oral communications and posters. The contributions were presented by specialists from 22 different countries of mountain and Mediterranean areas all over the world (Europe, Africa, South-America, Oceania and Asia).

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Foreword

Thirty-five years ago, in the conclusions of a meeting on mountain pastures and Mediterranean rangelands held in Clermont-Ferrand, Robert Jarrige pointed out that the utilisation of these forage resources went beyond agricultural production and addressed biological issues related to conservation of the natural environment and biodiversity as well as socio-economic and cultural issues related to rural and territorial development. Nowadays, these issues and the questions they pose to research are even more important in a context of climate change and economic globalisation!

In constrained environments such as mountainous and Mediterranean areas the sustainable use of forage resources by domestic herbivores has to combine production, conservation of high environmental value areas and product quality. The sustainability of animal production systems relies on their ability to reconcile economic performance based on the added value of high quality animal products and ecological performance based on the implementation of management practices relying on agro-ecological principles and allowing compensatory payments for the production of public goods.

This publication is the outcome of a joint meeting of the "Mountain Pastures, Mediterranean Forage Resources (FAO/ESCORENA - CIHEAM) and Mountain Cheese" networks entitled **"Forage resources and ecosystem services provided by mountain and Mediterranean grasslands and rangelands"** which was organized in Clermont-Ferrand (France) from 24 to 26 June 2014. This multidisciplinary meeting aimed at sharing/contrasting viewpoints, methods and results of specialised scientists working on grassland and rangeland assessment and use. In a context of climate change and environmental concerns, livestock farming systems in Mediterranean and mountain areas share issues common to harsh environments, which can be dealt with by using similar theoretical and methodological frameworks. Cultivated or spontaneous vegetation, herbaceous or ligneous species, all forage resources should be considered together, as complementary items contributing to the multiple performances of livestock systems.

The meeting was jointly organized by the INRA Research Units on Herbivores and Grassland Ecosystems, the Agronomic Engineering Schools of VetAgro Sup Clermont-Ferrand and Montpellier SupAgro, the Mediterranean Agronomic Institute of Zaragoza/International Centre for Mediterranean Advanced Agronomic Studies (IAMZ-CIHEAM) and the coordinators of the FAO-CIHEAM Network and sub-Networks on Pasture and Fodder Crops. The meeting covered a large range of topics related to forage production, ecosystem services, biodiversity, use of forage resources by livestock, and quality of milk, cheese and meat. Special attention was paid to agro-ecological approaches. The spatial scales ranged from plant-animal interactions to paddock, herd, livestock farming systems and landscape. The contributions to the meeting were allocated to three plenary sessions:

1. "Forage services for animal production and product quality"
   A. "Forage production and quality"
   B. "Forage utilisation, animal performances and products"
2. "Ecosystem services, prevention of risks"
3. "Combining and reconciling services on farming system and landscape scales",

complemented by three parallel workshops on future challenges and perspectives for research, introduced by a contribution on agro-ecology and herbivore farming systems.

More than 140 scientific contributions were presented and discussed including introductory and invited papers, short oral communications and posters. The contributions were presented by specialists from 22 different countries of mountain and Mediterranean areas all over the world (Europe, Africa, South-America, Oceania and Asia).

We warmly thank all authors for submitting the invited and offered papers, the members of the International Scientific Committee and the reviewers who carried out the revision of the contributions, the chairpersons of the scientific sessions and all members of the Local Organizing Committee for preparing this conference. Finally, we express our gratitude to the Mediterranean Agronomic Institute of Zaragoza (CIHEAM – IAMZ, Spain) for its support in the proceedings publication and grants, VetAgro Sup, Montpellier SupAgro, the INRA research centre of Clermont-Ferrand – Theix – Lyon, the INRA experimental units of Monts d'Auvergne and of La Fage, the INRA Division on Animal Physiology and Livestock Systems, the 'Conseil Régional d'Auvergne', the 'Conseils Géneraux du Puy-de-Dôme et du Cantal' and the town of Clermont-Ferrand for their logistic and financial support.

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Mid-congress tours

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Opening Session

Supporting HNV extensive livestock systems in Mountain and Mediterranean areas – The need for an adapted European Policy

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Abstract. Extensive livestock systems in Mediterranean and mountainous areas of the European Union are facing many challenges. The majority of these livestock systems are of high nature value and their subsequent decline has many social, economic and environmental consequences. European policies are contradictory on this issue: on the one hand, pieces of environmental and rural development policies acknowledge the irreplaceable role of livestock systems; on the other hand, influential elements of agricultural and hygiene policies cause further problems for extensive livestock graziers and small-scale processors of livestock products. Policy responses to the problems faced by extensive livestock systems vary from one member state to another. The wide range of such answers is explained by different institutional arrangements between farmers, administrations and researchers. The paper argues that the present European policy framework is not satisfactory as long as it globally creates more problems than solutions, and that the solutions are only mobilized and efficient in the presence of strong local political commitment. Considering the importance of extensive livestock systems in Mediterranean and mountainous areas at EU level as a whole, it is crucial to set a cohesive policy framework favourable to their conservation at this level, going against the present policy trends. In this paper we have not limited ourselves strictly to Mediterranean regions, but refer broadly to southern member states of the EU, including Bulgaria and Croatia, and candidate member states such as Macedonia and Montenegro.

Keywords. Extensive livestock – Grazing – Semi-natural pastures – High Nature Value farming – European policy.

Soutenir les systèmes d'élevage extensifs dans les zones montagneuses et méditerranéennes de l'Union Européenne : les enjeux d'une politique européenne adaptée

Résumé. *Les systèmes d'élevage extensifs des zones montagneuses et méditerranéennes sont confrontés à de nombreuses difficultés. Le déclin qui en résulte a de nombreux impacts sociaux, économiques et environnementaux dans la mesure où la plupart de ces systèmes ont une haute valeur naturelle. Par rapport à cet enjeu, les politiques européennes sont contradictoires : d'un côté certain aspects des politiques environnementales et de développement rural reconnaissent le rôle irremplaçable de ces systèmes ; d'un autre côté de nombreux éléments des politiques agricoles et sanitaires, dont le poids est déterminant, causent de sérieux problèmes aux éleveurs extensifs. Au total, la gamme des réponses politiques apportées pour faire face aux enjeux associés à ces élevages varie fortement d'un État membre à l'autre, en fonction des différentes façons de construire les relations entre éleveurs, administrations et chercheurs. L'article montre que le cadre politique européen crée plus de problèmes qu'il n'offre de solutions, celles-ci n'étant effectives qu'au prix d'un fort investissement politique local. Au regard de l'importance des enjeux associés à la conservation des systèmes d'élevage extensifs des zones montagneuses et méditerranéennes à l'échelle de l'Europe, il est crucial d'avoir un cadre politique commun ambitieux à cette échelle, qui prenne le contrepied des tendances politiques actuelles. Les zones couvertes dans cet article dépassent les seules zones méditerranéennes et incluent l'ensemble des États Membres du sud de l'Europe, y compris la Bulgarie, la Croatie ainsi que les pays candidats comme la Macédoine et le Monténégro.*

Mots-clés. *Élevage extensif – Pâturages semi-naturels – Agriculture à haute valeur naturelle – Politique européenne.*

I – Introduction: HNV extensive livestock systems in Mountain and Mediterranean areas and their functions

High nature value farming (HNV) is a concept introduced in the early 1990's (Baldock *et al.,* 1993; Beaufoy *et al.,* 1994). It captures two ideas:

(i) conservation of biodiversity-rich farmed landscapes depends on the continuation of the farming systems that manage them for socio-economic reasons (and not primarily nature conservation reasons – HNV farmers are not "gardeners"); "nature" value goes beyond biodiversity, the term also captures other environmental goods or ecosystem services;

(ii) the economy of HNV farms is, in the modern European context, frequently not sustainable without remuneration of environmental services and there is a need for policy supports to centrally address this issue in order to pursue the objective of ecosystem conservation of biodiversity at a large scale, notably in open landscapes.

HNV farming has since then been a core reference for assessing biodiversity conservation in relation to agricultural development (Oppermann *et al.,* 2012). Two fields of work stem from this concept: a first category tends to describe and understand the complex relationship between farming systems and biodiversity at a landscape level; a second one focuses on socio-economic and policy issues. This paper falls in this second category. Perhaps surprisingly the socio-economic aspects of HNV farming have received little attention from researchers to-date, especially in Mediterranean regions.

Further works have shown the importance of Mediterranean areas and mountain areas for the issue of HNV farmland on which the present paper focuses (Fig. 1; EEA, 2012). At a more specific level, the bulk of HNV farmland and landscapes in these areas is linked with extensive livestock systems.

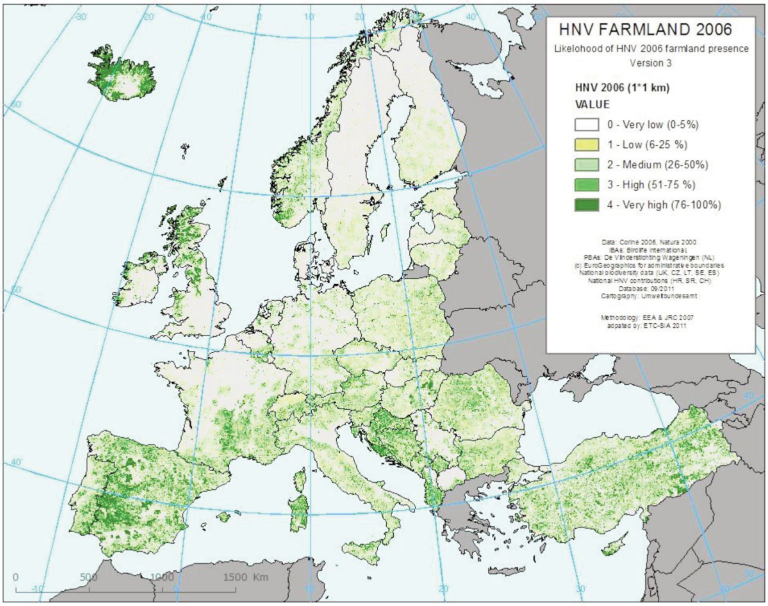

Fig. 1. Likelihood of HNV 2006 presence in Europe (1 km grid) (EEA, 2012).

These extensive grazing systems include those based on the use of permanent pastures, especially in upland and mountain areas; and systems using mixed forage resources, such as arable stubbles, fallows and permanent pastures, especially in the plains. A smaller area of HNV farming in Mediterranean regions consists of permanent crops (e.g. olives, almonds) and arable crops under traditional low-intensity farming systems.

Extensive grazing systems across southern Europe share a number of characteristics, including:

- Use of large-scale permanent pastures, generally of low productivity, often with a mix of herbaceous and non-herbaceous forage.
- Large areas of pasture are predominantly ligneous.
- High seasonality of pastures, and associated seasonal movements of livestock.
- Highly variable annual yield of pastures.
- Absence of fencing and importance of shepherding (a very significant cost).
- High presence of common land.
- Large variations in holding size – some very large, many very small (part-time employment).
- High presence of sheep and goats relative to bovines, including dairy sheep and goats.
- In dairy systems, importance of on-farm and other small-scale processing and value- added.

This combination of characteristics creates very particular farming and environmental conditions that generally are not shared by mainstream agriculture in the EU, and that consequently are not recognised in the design of EU policies. And yet in many regions of southern Europe these extensive grazing systems represent a large proportion and even the majority of all farmland.

From a European perspective, the broad image of these livestock areas is their low productivity and marginal role in EU agricultural and livestock economy. Their designation as Areas facing Natural Constraints (previously Less Favoured Areas) puts them at the margin of the core of productive farming, this core being located in the “favoured” areas of the European lowlands. We find it significant that DG agriculture webpage on milk and milk products[1] does not mention ewe and goat milk, which accounts indeed for less than 4% of the overall milk production in Europe when looking in more detailed publications (Eurostat, 2013). This marginality will also concern the meat sector, in which sheep meat represents 2% of the overall EU28 production and goat meat 0.1%. In contrast, sheep and goat are by far the main type of livestock in Mediterranean HNV areas, with these areas representing more than 50% of this sector at EU level (Pflimlin, 2013).

While being marginal from a sector perspective, HNV farmers in the Mediterranean and mountainous areas are true economic agents, able to produce with a minimum level of inputs and a maximum use of natural resources, making them agro-ecological farmers (Dumont *et al.,* 2012). In addition, the quality of the product is frequently valued under quality labels (PDO), notably in EU15 member states (Pflimlin *et al.,* 2005), although it cannot be assumed that PDO products are from HNV farming systems.

Beyond their micro-economic and sectorial dimension, such systems render many irreplaceable environmental services in addition to their interest for biodiversity: fire prevention, landscape management –with value for tourism for example– cultural life and, more generally, rural vitality (Pflimlin and Poux, 2005). We find here the multifunctionality of those systems (Andersen *et al.,* 2004), which can be another way of naming environmental services or the provision of public goods (Cooper *et al.,* 2009).

[1] http://ec.europa.eu/agriculture/milk/index_en.htm

This tension between the many good reasons to conserve HNV farming systems on the one hand and their overall economic marginality on the other hand is the problematic addressed in this paper. While public policy is recognized as the way to cover the “market failure”, this market being unable to reward the (HNV) farming systems at the level of their public interest, there is a need to better understand what are the policy needs and to assess the current policy supply in the present Common Agricultural Policy (CAP) against these needs. Thus, the paper is organised as follows:

– A first section analyses the different contexts associated with HNV livestock systems in Mediterranean and Mountainous areas; its goal is to identify the different policy needs arising from those different situations;

– A second section briefly describes the different policy instruments available and analyses how they generally –but not always– do not meet the needs and might even worsen the situation in some cases;

– The last and concluding section sets out why the current approach at EU level is not satisfactory and calls for a clear and consistent European policy.

II – Understanding the different contexts and threats on HNV systems

Extensive HNV livestock systems have one major asset, which is their low costs, as measured in terms of bought inputs. Meanwhile, the management of complex and highly variable agro-ecosystems requires a large amount of work relative to the amount of meat or milk produced, when compared with lowland systems. On this basis, the economic sustainability of HNV farming systems stands on two fundamental conditions: access to land and access to markets.

– Access to land is the first condition. This access needs to be at low cost –or even free of charge– in order to keep a relative advantage. This explains the relatively high share of common land in those farming systems. But other factors are attached to land access and management, such as the technical consistency of pastoral units, that need to be large enough and not scattered and equipped with basic infrastructure (shelter, water points, fences…). Diversity of land types accessible across the year, with seasonal productivity also a key factor to consider. These factors explain the great variety of situations across Europe, from favourable cases where productive and well-structured pastoral units are accessible to farmers (e.g. in pastoral humid mountains) to “difficult” land, poorly productive and/or with low security of tenure from the farmer perspective.

– Access to markets also needs a series of conditions of different kinds. Extensive farming systems have to deal with two major issues: presence of abattoirs, milk collection points, dairies able to connect with consumption basins on the one hand; or alternatively the option to undertake on-farm processing and direct marketing, an option fraught with difficulties in many countries of southern Europe due to inflexible implementation of hygiene regulations (e.g. in Bulgaria, Spain, Macedonia as presented at a EFNCP seminar in 2013 http://see.efncp.org/networking/events/2013/20131002/). The two factors are clearly reinforcing one another in a negative feedback, while the costs of compliance with regulations might lead to closing abattoirs and dairies. Thus the remoteness and marginality of these areas is compounded by the failure of policy (in some cases EU policy, in some cases national policy) to adapt to their needs and values.

HNV farms generally have lower net incomes than non-HNV farms, and often have negative net incomes, sometimes even with CAP support included in the calculation. In such cases, farms are sustained by family farm labour that is valued below the minimum wage. As farms try to maintain economic viability, certain practices of environmental value tend to be abandoned, especially those that are labour intensive. Examples include shepherding of livestock to remote pastures, hay making and the maintenance of dry-stone walls and hedges.

Thus a third condition can be added, being the need for public payments in order to compensate the low physical productivity of such farming systems[2]. Assessing the role of these payments is a complex issue, as it plays in contradictory directions depending on the contexts. Such payments can sustain the economic viability of farming systems, but on the other hand it has been acknowledged that the conditions attached to payments can cause problems for extensive HNV farmers. CAP conditions on land eligibility and cross-compliance are unfitted to the complex landscapes managed and cause administrative constraints that farmers tend to escape by abandoning the most difficult land –if not the activity itself– while intensifying on the most favourable, with negative impacts on biodiversity in both cases. Cross-compliance, including animal identification requirements conceived for industrial systems, is another difficult issue to deal with for a large share of traditional livestock farmers.

These local and regional constraints faced by HNV farmers in their different contexts need to be put in a wider economic picture. Generally speaking HNV farmers compete on a market organised at a European level, in which they are quantitatively marginal, as evoked above. This competition is uneven in terms of physical productivity, while the organoleptic and nutritional quality of the products obtained from HNV pastures is not recognised, for example lower needs of treatment due to fodder rich in tannin (Zimmer and Cordesse, 1996). The niche and local markets cannot be considered as a general option. And assuming that the price for some HNV products is higher –which is not the case in general– the prices of local products tend to converge with mass products that are the reference (e.g. Frayssignes, 2007). As a whole, the hygiene rules and the main research agenda are set in reference to the dominant lowland industrial livestock systems, but are largely unsuited to HNV systems.

As a whole, HNV systems struggle with a dominant market by addressing the specific constraint they meet on the two issues of land and market access. The solutions needed to address them are local and regional and require a strong coordination and political commitment, while the opportunity and threats at the global and European level are generally headwinds, both from an economic and policy perspective. But despite the fact that some success stories take place across Europe and are brought forward, the capacity to address the problem at a local level is not the general rule and depends on the local context, taking into account the combination of relatively favourable conditions in the biophysical, institutional and socio-economic context. On the contrary, most of the national and local authorities in member states tend to promote farming systems based on standard processes rather than on complex management of low-productivity land, that do not require a lot of administrative input for what is perceived as a low return.

III – Policy needs and the range of policy supply: global problems, some local solutions

There is a range of EU policies affecting extensive livestock farming in Mediterranean and mountain areas, including most notably the CAP (Pillars 1 and 2); biodiversity policy; and, less directly, climate policy. Biodiversity policies set EU objectives whose achievement in some cases depends directly on the sustainable continuation of these farming systems across large expanses of land.

[2] However, one should keep in mind that such public payments are also a condition for intensive farming systems, in order to cover their high structural costs. Intensive farming systems in Europe indeed receives more public payments than extensive ones, those payments re-enforcing the structural costs through a rent effect for suppliers (the higher the payment for a farmer, the higher the land rent and the costs of production factors).

For example, Targets 1 and 2 of the EU Biodiversity Strategy require the conservation and restoration of semi-natural pastoral habitats and of their ecosystem services. Unfortunately the EU's environmental policy does not offer mechanisms or financial resources for pursuing these objectives (except on a very limited "pilot" basis through the LIFE funds), and is entirely dependent on the CAP for this, as reflected in Target 3 of the Biodiversity Strategy that aims to increase the use of CAP measures for promoting biodiversity.

The CAP is indeed the main policy driver of farming land use in the EU. However, this policy currently does not take account of most of the local realities faced by HNV farming systems as described above, and this failure is especially apparent in the case of livestock farming systems characteristic of the Mediterranean regions. The roles of Pillars 1 and 2 of the CAP are discussed in more detail below.

Policy design should be based on facts, thus requiring sufficient data and data analysis. In order for policies to take account of extensive grazing systems there is a need for basic information about the extent of these systems, with categorisation into different types according to key characteristics, and about the tendencies affecting these systems. There is a chronic lack of such data at EU level and in many member states. Even basic data on the extent of pastures that are in grazing use are extremely opaque in many countries, with different sources sometimes showing very different statistics. This situation applies to the more extensive types of pasture and especially those with a significant ligneous component, and also especially in the case of common lands. Examples of Mediterranean countries with very unclear data on the extent of pastures in actual use include Albania, Croatia, Greece and Spain (see country chapters in Oppermann *et al*., 2012). In Spain, different statistical sources show a total pasture extent of between 8.5 and 18.5 million hectares. The largest extent is shown by LPIS (Land Parcel Identification System), with notable declines taking place from 2005 (18.958 million ha) to 2013 (18.623 million ha).

Even where the extent of different pasture types may be recorded with reasonable accuracy, there remains the problem of knowing whether these pastures are in use or have been abandoned, perhaps for several years. Land-cover data sets such as Corine, for example, provide no indication of whether pasture is in use. The CAP, through its LPIS and IACS (Integrated Administration and Control System) data systems, has the potential to resolve this, but the tendency of policy is in the opposite direction: to stop recording data such as animal numbers on individual holdings as this is seen as "production linked". As policy makers shift their thinking away from production support, they need to build a new data and administrative control system that records land management actions that are central to ecosystem services, such as grazing and mowing, and not merely land cover types.

Data on tendencies in the farming systems that use semi-natural grazing lands is also very weak. Target 2 of the EU Biodiversity Strategy is of little use without adequate data and monitoring of ecosystems and their services, including such grazing lands, because we will never know if the target has been achieved without such data. Reporting on the condition of pastoral habitats under Article 17 of the habitats Directive is especially weak from Mediterranean member states (Olmeda *et al*., 2013). Oppermann *et al*. (2012) draw attention to signs of significant abandonment of semi-natural pastures in Mediterranean countries such as Albania, Croatia, Macedonia, Montenegro and Spain. But for efficient policy making more concrete data on such trends is required.

CAP Pillar 1

The main policy driving farming patterns in the EU is Pillar 1 of the CAP. This provides income support to farmers, according to a range of rules and conditions (eligibility rules, cross-compliance, new "greening" requirements). Mediterranean extensive grazing systems depend to a large extent on Pillar 1 payments for their survival, and yet the payment system is in many ways biased against these systems. Hence under current policy scenarios, these systems are unlikely to survive.

The main issues are as follows:

- The setting of Pillar 1 income payments bears no relation either to the economic situation (profitability) of the farming system, nor the public goods generated by the system. Generally the least profitable systems producing the most public goods receive the lowest payments, at least in most EU15 member states.
- The "historical" model of Pillar 1 payments is predominant in Mediterranean member states (all of the Mediterranean EU15). Under this model extensive sheep and goat systems receive the lowest support of all the main farming types covered by Pillar 1.
- Eligibility rules are biased against pastures with a high presence of ligneous forage and of landscape features.
- Some member states directly exclude large areas of extensive pastures from eligibility (Bulgaria from 2007, Spain from 2015).
- Cross-compliance rules place a significant burden on extensive grazing systems (e.g. livestock identification requirements, Natura 2000 limitations on grazing).

Although the policy objective of Pilar 1 is to support farm incomes, it takes no account of the very different economic situations of farms and farming systems. Payment levels vary massively, for essentially historical and political reasons, but not with any rational relationship to the economic needs of farmers, nor to the public goods they deliver. Despite the obvious needs, for decades HNV farms have tended to receive lower levels of support from the CAP than non-HNV farms, especially from Pillar 1. These facts are shown by EU studies (EEA, 2010).

The broad debates on CAP reform have highlighted the differences between average Pillar 1 support payments in EU12 and EU15. However, this simplistic and largely political debate tends to conceal the fact that huge differences occur within the EU15, and also within individual EU15 countries and regions.

In the Mediterranean EU15 member states, the current Single Payment System (SPS) is distributed on the "historical" basis, with extremely high levels of support going to farmers who produced (in reference years) certain intensively-farmed crops such as tobacco, tomatoes, irrigated olives, maize and rice. Farmers raising sheep and goats on low-yielding pastures receive a very small payment per hectare, even compared with farmers raising beef cattle. In fact a Romanian or Bulgarian sheep farmer using permanent pastures is eligible for a considerably higher payment per hectare from Pillar 1 (approximately three times higher) than the equivalent sheep farmer in Spain or Portugal.

The reformed CAP may not look very different from this point of view. In Spain for example politicians and farmers' organisations are determined to prevent any significant redistribution of Pillar 1 funds. In France there has been a greater recognition of extensive livestock systems for several years and what is discussed is the modality of the redistribution of Pillar 1, keeping in mind the bonus on a holding's first hectares adopted in France. However, the income needs of extensive livestock farmers still are not fully addressed.

So the bulk of the CAP does not take account of (or reward) environmental services, nor the very real income and social problems of particular farming types that provide a majority of these services. Complementary measures have been available at various times, past and present, such as payments for "extensive" beef cattle (but not sheep or goats) and more recently the Article 69 and 68 options for redirecting a small percentage of Pillar 1 funds to certain farming systems. The latter have been used in several countries (France, Portugal, Spain) for supporting sheep and goat systems.

In fact many of the decisions that cause problems or that provide potential solutions are left to the national and regional levels, and the EU framework does little to help, it does not give a coherent set of priorities or mechanisms for supporting extensive livestock systems.

Pillar 2

The policy rationale of the CAP is that any objectives for agriculture and rural areas other than basic economic support for agriculture must be pursued through Pillar 2, which has much more limited financial resources. We discount from the discussion the environmental aspects of Pillar 1 in the form of cross-compliance and greening, as these are designed to reduce (slightly) the impacts of intensive farming and are practically irrelevant to the challenge of sustaining Mediterranean HNV grazing systems.

The main issues:

- Pillar 2 has a broad tool kit, but how to use it and the prioritisation of objectives is left to member states and regions. There is no EU cohesion on key territorial issues such as extensive grazing systems.
- No clear guidance at EU level on how to use Pillar 2 for pursuing EU policy objectives in relation to ecosystem services, biodiversity, permanent grasslands, fire prevention etc.
- Rural Development Programmes (RDPs) often have weak ex-ante analysis of these issues. Even when key challenges for extensive systems are highlighted in PDR documents, the measures and resources are not necessarily put in place.
- Pillar 2 subsidies for afforestation are an attractive option for extensive livestock farmers, especially as the land afforested is automatically eligible for Pillar 1 payments as well. This is a major disincentive to continuing with farming.
- The co-financing requirement is a disincentive to make use of Pillar 2 for what are seen in some countries as EU environmental aims, rather than purely economic objectives that are seen as national priorities.

The EAFRD (European Agricultural Fund for Rural Development) tool-kit is broad, and increasingly flexible under the proposals for post-2014. If national and regional authorities want to take initiatives to support HNV farming, there are plenty of ways of doing this using EU measures and funds. Several countries and regions continue to make considerable efforts, and there are many examples of good schemes funded by Pillar 2, and of outstanding local projects funded from the CAP and from other sources, such as LIFE and other public and private funds.

However, the main measures available today for supporting HNV farming have existed for many years – the agri-environment measure (AEM) since the 1980s and the Areas facing Natural Constraints (LFA) scheme since the 1970s. It is left entirely to Member States to decide whether to use these measures to support HNV farming, and to what extent. The result is that some countries do a lot, while some others do very little, especially in southern European countries such as Greece, Portugal and Spain (Keenleyside *et al*., forthcoming). This situation does not make for a consistent or coherent strategy to support HNV farming across EU.

The basic need is for relatively simple measures that incentivise the continuation of HNV farming systems on a large scale. Both the AEM and LFA schemes have the potential to be implemented in this way. To note some positive examples, Romania has implemented an ambitious agri-environment programme specifically to support existing HNV livestock systems over large areas of the country. France has set up a pastoral management plan AEM delivering interesting outcomes at site level (Conservatoires d'espaces naturels, 2009). However, generally speaking, implementation of AEM is not adapted to the type and scale of HNV situations in the range of Mediterranean member states.

Implementation of the LFA scheme varies greatly across member states. Generally it is not targeted in favour of holdings with HNV farming characteristics, although this could be done within current EU rules. In France there is some targeting of LFA support towards extensive livestock, with a significant share of Pillar 2 funds. This scheme includes different stocking rates specified for extensive sheep and goat pastoral systems and mountain dairy systems, a higher payment rate for the first 25 ha, and an additional payment for transhumance systems. Such an approach could be of benefit in other Mediterranean countries. An alternative approach in England and Wales has been to replace the system of LFA payments with a special AEM that aims to pursue environmental outcomes on farms within the LFA.

Instead of supporting extensive grazing systems, in some countries large areas of extensive grazing land have been afforested with public subsidy from Pillar 2 funds, a change of use that also entails a considerable loss of biodiversity, landscape and socio-cultural values, as well as leading to severe wild-fire problems in southern Europe.

So far the EU policy framework has not established a clear strategy for HNV farming. The Commission's 2011 Consultation Document on CAP reform explicitly recognised a number of relevant issues including, the large extent of HNV farming systems in the EU, the abandonment risk faced specifically by extensive grasslands, and the fact that extensive pastures and meadows have a worse conservation status than other habitats of European conservation concern (Olmeda *et al.*, 2013). In fact the decline of extensive livestock farming is found to be the greatest threat to Natura 2000 farmland habitats across the EU. But so far this analysis has not been converted into concrete policy action at the EU level.

This weak EU framework gives no indication to member states, including new southern Europe member states (Croatia) and potential new member states (Macedonia, Montenegro), of what they could or should be doing to address the needs of extensive grazing systems. There is no mention in the CAP texts of how EU objectives for ecosystems, biodiversity or climate change (e.g. fire prevention) might be addressed in the design of Rural Development Programmes. Member States are left to work this out for themselves.

A positive aim of the new CAP is to become more outcome-orientated and more strongly linked to priorities. The new EAFRD regulation will require the next round of RDPs to include a clear analysis of needs on the ground in relation to EU priorities for rural development, with appropriate measures and resources in response to these identified needs. If robustly applied by Member States and the Commission, then any programming region with a significant presence of HNV farming should be required to include a satisfactory analysis of the needs of these farming types and a suitable response to these needs through the RDP measures.

IV – Conclusion: subsidiarity is not the only answer, the need for an adapted policy at EU level

Mediterranean extensive livestock systems have distinctive characteristics that differentiate them from most other farming systems in Europe. Compared with mainstream farming in the lowlands of central and northern Europe, Mediterranean extensive livestock systems are predominantly of very high value in terms of biodiversity and a range of ecosystem services, but they face particular socio-economic and regulatory challenges that threaten the continued delivery of these services.

The relevant EU policy goals are found mainly in environmental policy (maintenance of habitats and ecosystems), while the measures and financial resources are all in the CAP. Some aspects of Pillar 1 are biased against the continuation of Mediterranean extensive livestock farming, thus working against environmental goals; there are also potentially useful measures included within Pillar 2, but their use for this purpose varies greatly from one country to another and is notably weak in most Mediterranean member states. Ultimately the policy package implemented on the ground depends increasingly on national and regional political processes and decisions, rather than following EU policy goals.

Mediterranean extensive livestock farming is slipping into decline, not only in the EU15 but also in candidate countries. There is a need for greater recognition of these trends and their environmental consequences, and for more robust data and monitoring systems as the basis for efficient policy design. EU policy should be adapted to the realities of Mediterranean extensive livestock farming, and should ensure that all countries make full use of the available measures for supporting these farming systems.

In principle, the new CAP gives flexibility to each Member State to design and implement a combination of policy schemes susceptible to address this challenge, with the possibility to move funds from Pillar 1 to Pillar 2 and targeting to HNV systems. But in a context of exacerbated competition between agricultural sectors within the European boundaries and limited budget, the absence of a EU vision for extensive livestock and dedicated policies is a failure. The fragile legacy from HNV farming systems is of European interest, there is no strong reason to leave it to the willingness of highly motivated actors at local and regional level only.

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Session 1

Forage services for animal production and product quality

Keynote articles

Potentials and challenges for future sustainable grassland utilisation in animal production

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Abstract. The paper highlights particular benefits and challenges coming along with ruminant production on permanent grasslands and rangelands. A threefold synergy is (i) the utilisation of a nutrient source which is independent of arable land, (ii) the ecological benefits of maintained permanent pastures, and (iii) the production of food with a high nutritional and sensory quality. However, a sustainable use of these pastures requires appropriate management, facing very different challenges depending on the regional conditions. Systemic management schemes based on specific characteristics of the pastures are required for their maintenance and/or development. A further challenge are pasture-bound gastro-intestinal parasites control, which are, however at least partly also an issue of grazing management. The particular nutritional properties of grassland-derived products are scientifically well established, although deeper understanding of specific underlying metabolic mechanisms is still an objective of ongoing manifold research. Implementation of instruments for evaluation of these nutritional values in the market chain is lacking. Scientifically many options for the authentication of grassland-based products are under development, and a major task remains their implementation into practice. Decisive for all successful developments are the economic and political frameworks. A multi-perspective re-consideration of the concepts of efficiency for animal production seems to be required for a fair assessment of the services that production systems based on grasslands and rangelands bring to global food production.

Keywords. Permanent grassland – Forage production – Management – Product quality – Traceability – Animal health.

Potentialités et défis pour une future utilisation durable des prairies en production animale

Résumé. *Cet article met en avant les bénéfices particuliers et les défis auxquels est confrontée la production de ruminants à partir des prairies permanentes et des parcours. Une triple synergie réside dans (i) l'utilisation d'une source de nutriments indépendante des productions des terres arables, (ii) les bénéfices environnementaux du maintien des prairies permanentes, et (iii) la fourniture de produits animaux de haute valeur nutritionnelle et sensorielle. Cependant, une utilisation durable de ces prairies nécessite une conduite appropriée, qui doit faire face à différents défis selon les conditions régionales. Des schémas de conduites systématiques basés sur les caractéristiques spécifiques des prairies sont nécessaires à leur entretien. Un autre défi vient des effets des parasites gastro-intestinaux liés aux prairies, dont la maîtrise dépend en partie de la conduite du pâturage. Les propriétés nutritionnelles particulières des produits animaux issus des prairies sont bien établies scientifiquement, bien qu'une compréhension plus complète des mécanismes métaboliques sous-jacents demeure un objectif de nombreux travaux de recherche. Les moyens techniques pour faire valoir cette valeur nutritionnelle des produits dans les filières économiques sont encore insuffisants. De nombreuses méthodes d'authentification des produits issus des prairies sont en cours de développement, mais une tâche majeure reste de les mettre en œuvre dans la pratique. Le cadre économique et politique est décisif pour tous les développements réussis. Une reconsidération du concept d'efficience de la production animale dans une perspective multiple semble nécessaire pour une évaluation équitable des services que les systèmes de production basés sur les prairies et les parcours apportent à la production alimentaire globale.*

Mots-clés. *Prairie permanente – Production de fourrages – Conduite – Qualité des produits – Traçabilité – Santé animale.*

I – Introduction: European grass- and rangelands and their potential contribution to livestock production, in economic and ecological perspectives

About two thirds of the global agricultural land consists of grasslands and rangelands. In Europe, including the Russian Federation, more than 40% of the total agricultural lands are permanent or temporary meadows and pastures (FAOSTAT, 2013). These areas are the most significant source of feed for domestic herbivores: forages (grazed or conserved) represent approximately 50% of all livestock feedstuffs, globally (Herrero *et al.*, 2013). The permanent pastures are often located in areas, which cannot be used as croplands because of topography, lack of/or oversupply of water, poor soils, or extreme climatic conditions, what defines them as marginal areas. By contrast, temporary meadows are often part of crop rotations and may provide forage with a high density of well digestible nutrients. From both types, a nutrient resource is provided, which can be efficiently converted into human food by ruminant livestock. Due to their digestive physiology, which combines fermentation, chewing and particle sorting in a unique way, ruminants are able to degrade plant fibres efficiently and upgrade nitrogen into amino-acids (Clauss *et al.*, 2010).

A key issue of the evaluation of grassland utilization is the controversial ongoing debate about the contribution of ruminant livestock to counteract or to increase the current environmental problems. Ruminant production on grassland reduces the production pressure on the globally limited arable land (O'Mara, 2012; Taube *et al.*, 2014). However, grassland/rangeland swards largely differ regarding their nutrient density and digestibility (depending on soil and climate conditions, but to a large degree also on management – cf. Boval and Dixon, 2012). This determines their feeding value and the efficiency, including the "eco-efficiency" of ruminant production, if it is calculated as the ratio of resource inputs (nutrients, surfaces, fossil energy and climate-related values) and food nutrient outputs (Herrero *et al.*, 2013; Taube *et al.*, 2014). Because nutrients in swards are not as dense as in grains, this can lead to conclusions, that the intensive grain-based production of pork and poultry products is more efficient and less impacting the climate than any grassland-based ruminant production (Pelletier and Tyedmers, 2010; Herrero *et al.*, 2013). This perspective has to be countered by the fact that a large share of feedstuffs for monogastric animals comprises human edible cereals and oilseeds, thus permanently increasing the pressure towards larger arable land areas, which finally requires ongoing deforestation. It can be further considered that large parts of the global grass- and rangelands can only be maintained with no alternative of utilization other than with ruminants. On this background it is reasonable to calculate the efficiency of livestock production from the inputs of arable land or of human edible protein and calories (Wilkinson, 2011; O'Mara, 2012.). In this respect, ruminant production is highly competitive with that of monogastric livestock, because it relies less on inputs from arable land (O'Mara, 2012), and grassland/rangeland utilisation can be regarded as a core contribution of ruminant livestock to sustainable global resource use. Grassland utilisation with ruminants proved to be the key to reach an efficient conversion rate of human edible feed into animal products (Wilkinson, 2011).

Further, grasslands/rangelands are highly multifunctional and provide important ecological side-effects. These effects are in the first line the habitat function for a high diversity of wild flora and fauna (Mikhailova *et al.*, 2000; Rook and Tallowin, 2003; O'Mara, 2012) and a high potential for carbon sequestration in the soils below grasslands (O'Mara, 2012; Taube *et al.*, 2014). A further important effect of forage-rich diets for livestock is a clear positive impact on the nutritive quality of the resulting products, especially regarding antioxidants, lipid quality and fat soluble vitamins. The quality is clearly related to the botanical biodiversity of the pastures which is associated with a diversity of plant active compounds influencing the animals' metabolism. (Jayanegara *et al.*, 2011; Buccioni *et al.*, 2012; Willems *et al.*, 2014). Summarizing, the use of grasslands for ruminant grazing under proper management affords four main synergistic effects: (i) provision of food which is based on local resources and not in competition to edible arable products, (ii) high-quality products,

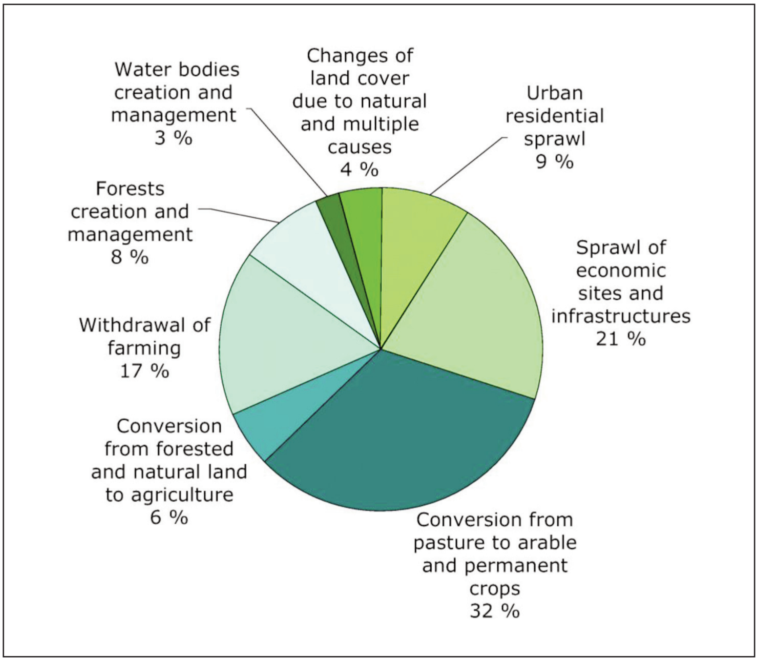

Fig. 1. Causes of loss of grasslands in Europe. From EEA (2010).

(iii) a reservoir of biodiversity, and (iv) a potential carbon sink. These four elements have to be considered together in any assessment of the eco-efficiency of grassland-based livestock systems.

Grassland/rangeland areas are worldwide under high pressure, which appears however in very different forms, depending on the regions. While in many countries overgrazing, i.e. a too high density of livestock per hectare, causes severe degradation, erosion and loss of the natural grasslands (Robinson *et al.*, 2003; Taube *et al.*, 2014), in Europe, particularly in the mountain regions and in southern and eastern European countries, the problem is more often underutilization and abandonment of pastures due to societal and economic changes, followed by encroachment and successive woody vegetations (Hadjigeorgiou *et al.*, 2005; Mikhailova *et al.*, 2000). By contrast, in northern European regions, wherever the conversion into arable land is possible, ploughing up is the main pressure on the permanent pastures (Taube *et al.*, 2014). More than 50% of grassland losses in Europe are due to the reasons mentioned (Fig. 1), which are all rooted in agricultural management decisions. The challenge these cases have in common, is the efficient and long-term sustainable use of the grasslands/rangelands. This means for every region that management options have to be developed, which increase the nutritive value of the grazed forage (Boval and Dixon, 2012; O'Mara, 2012; Herrero *et al.*, 2013), in order to (depending on the region and policy): (i) make the animal production more competitive in economic and ecological scales, (ii) increase the achievable income, and thus increase the stakeholders' motivation to use and maintain the permanent pastures, (iii) adapt animal numbers per hectare to the carrying capacity of the grassland/rangeland and thus implementing management options that avoid degradation, (iv) improve the health of grazing animals, particularly with respect to pasture-born parasites, and (v) introduce active policies (temporary or permanently) that pay to fill the gap between productive and ecological functions. Further, there will necessary be trade-offs between nutritive and ecological values (Baur *et al.*, 2007) as well as between main nutrients and functional plant metabolites that enhance product quality (Leiber *et al.*, 2006; Jayanegara *et al.*, 2011). Management options, which help to reconcile these different aspects, will be highly required for the future maintenance and development of grassland/rangeland-based livestock systems. Additionally, market concepts that provide a higher price for the nutritional quality and ecological function of grassland-derived products are highly needed. These market developments have to be based on a specific product authentication, requiring further research and development efforts.

Summing up, the maintenance and efficient utilisation of European grassland resources requires further efforts on the levels of research, close-to-practice management development and political measures. Important needs and potential in research and practice developments will be specified within this paper.

II – Potential and constraints of permanent pastures (grass- and rangelands) for provision of forage

Species composition of permanent grasslands and rangelands varies in large proportion according to pedo-climatic conditions and management practices. Every sward is a unique mixture of species differing in their functional traits (Violle *et al.*, 2007), and thus responding differently to climatic conditions and utilization. Based on functional traits (e.g. specific leaf area and leaf dry-matter content), plant community ecologists classify species in functional types. These types correspond to plant growth strategies according to fertility level and defoliation rate (Cruz *et al.*, 2002; Louault *et al.*, 2005). Competitive species adapted to fertile soils and frequent (e.g. *Lolium perenne*) or less frequent defoliation (e.g. *Dactylis glomerata*) are characterized by high specific leaf areas and low leaf dry-matter content, favouring fast regrowth after defoliation. In contrast, conservative species adapted to infertile soils (e.g. *Festuca rubra*) show low specific leaf area and high leaf dry-matter content. Theoretically, based on such classifications, each plant species can be associated with a gradient of production and digestibility values (which usually refer to spring growth). At paddock scale, a sward can also be described by its functional composition, which can be translated into technical characteristics, such as precocity, suitability for being grazed late in the season, etc. (Duru *et al.*, 2010; Launay *et al.*, 2011).

A recent study in France (Michaud *et al.*, 2011) characterized a set of 190 permanent pastures representative of most pedo-climatic conditions from Atlantic to Alpine areas (excluding Mediterranean areas). The high variability observed in forage production (between 4.2 and 8.1 t DM/ha obtained with 4 cuts for most of the paddocks) and digestibility (between 0.70 and 0.83 g/g at the beginning of spring) was to some extent related to the functional composition of the grasslands, in terms of botanical families and functional types of grasses (Baumont *et al.*, 2012). The most productive grasslands in spring and during the whole year (r = 0.81 between both) were those richest in competitive grasses. In contrast, a negative relationship was observed between forage yield and the proportion of conservative grasses in the grasslands. Forage quality, both at the beginning and the end of spring, was positively related to the proportion of legumes species in the grasslands, as legume proportion increased crude protein content, but also digestibility in studies for sown multi-species swards (Huyghe *et al*,. 2008). A higher stability of forage quality in spring was related to high proportions of forbs and conservative grasses. Knowledge of the temporal patterns of forage availability and quality can help to define appropriate grassland management to cope with the nutritional demand of the animals (Duru *et al.*, 2010). For example, productive grasslands rich in competitive grasses are adapted for harvesting and need early utilisation to maintain forage quality. Grasslands with high proportion of legumes and thus high protein content will be adapted for grazing by high producing animals. Thus, for each paddock, a range of possible utilizations can be defined, as a result of its grass functional composition. This is particularly true in mountain conditions, where the altitude gradient increases the diversity. Typical mountain pastures rich in conservative grasses have to be exploited in an extensive manner, and can provide grass later in season and due to their botanical diversity other forage services linked to product quality and animal health.

The methods to characterize grasslands cannot, in most cases, be applied to rangelands, for two reasons: first, rangeland vegetation often includes shrubs and trees, and second, rangelands are often grazed after grass growth peak, in such management conditions that the animals are able to select a diet which has little to do with the average composition of the sward. The presence of shrubs and trees creates patches of shade which modify water and light availability for the underlying herbaceous species; thus, the abundance and quality of the underlying grass species are different (Zarovali *et al.*, 2007). While research has been focussed on characterizing the nutritive value of green forage, rangelands are often used in summer or winter, when at least part of the sward is senescent. When animals graze, they compose a diet by selecting plant species and plant parts as a function of the relative quality and palatability of the items available, but also from their previous feeding experience and of the grazing conditions determined by management (Baumont *et al.*, 2000; Provenza *et al.*, 2003). Thus, both the available forage on the pasture and the ingested diet of the grazing animals, are difficult to predict.

The methods effectively used to characterize forage production on rangelands are based on three major assumptions: (1) numeric precision would be vain, since it would be impossible to document the immense diversity of situations encountered, (2) the most pertinent information is the amount and quality of intake, and not the amount and quality of the whole sward, (3) the rangeland cannot be characterized independently from the grazing management applied. Based on such assumptions, a typology was established in the 1990s for French peri-Mediterranean regions (IDELE, 1999). Based on a typology of rangeland vegetation which takes into accounts both the type and abundance of herbaceous and shrub cover, it proposes a range of possible utilizations. An utilization is characterized by the season, stocking density, total or partial consumption of the herbaceous layer, nutritional requirements of the animals, supplementation-if any- and number of daily rations grazed, expressed in “days x sheep”. Thus, the latter information includes an evaluation of the amount and quality (through nutritional requirements of the grazing animals and supplementation) of the forage ingested on the rangeland. Such information has been successfully used for the design of decision support tools (see Martin *et al.*, 2014 ibid). A major challenge in the future will consist in linking the complementary methods of grassland and rangeland evaluation, which might prove that rangelands can be considered as a decent forage resource, even for productive farming systems.

III – Contribution of grasslands to dairy product quality

The sensory and nutritional characteristics of dairy products are governed first by a number of factors linked to the processing of milk. The chemical and microbiological characteristics of the raw milk used also play a major role, in particular in the case of products in which the raw material modifications during processing are restricted. The characteristics of raw milk used are dependent on factors linked to animal characteristics and management that have increasingly been the focus of consumers’ concern. Among these factors, animals’ diets are sensitive because some of them, like pasture, carry a positive image that can be attractive to consumers and most importantly because they may confer special nutritional and sensory properties to the dairy products.

It is now clearly established that the fatty acid and antioxidant content and composition of the feedstuffs fed to ruminants are the main drivers of the plasticity of milk in these nutritionally relevant components. In particular, grazed grass has a high content of fat rich in C18:3n-3 and high amounts of tocopherol and carotene while, on the opposite, maize silage and cereals are rich in C18:2n-6 and contain only little carotene and tocopherol. As a consequence, in comparison to milks derived from diets based on maize silage or cereals, pasture derived milks have a lower content in saturated fatty acids (some having a clear negative impact on human health, i.e. C16:0) and a higher content in unsaturated fatty acids including the major c9C18:1 monounsaturated fatty acid and minor trans and polyunsaturated fatty acids like C18:3n-3 and c9t11CLA considered as positive for human health (Chilliard *et al.*, 2007; Shingfield *et al.*, 2013). Pasture derived milks are also richer in antioxidants like carotenes, retinol, tocopherol and some phenolic compounds capable to protect the unsaturated fat against oxidation (Noziere *et al.*, 2006; Besle *et al.*, 2010). In mixed diets, the enrichment of unsaturated fatty acids and antioxidants in milk is proportional to the percentage of pasture in the diet (Coppa *et al.*, 2013). As the grass content in fat and carotenes decreases while grass matures, the specific positive features of pasture derived milk are higher when pasture is grazed at a vegetative stage. Milk derived from grass preserved in the form of hay or silage has an intermediate pattern because most of the nutritionally relevant compounds in grass are partly lost or oxidized during harvesting: some compounds i.e. C18:3n-3 are close to that of pasture derived milks and most of the other like the major c9C18:1 and C16:0 fatty acids are close to that of maize silage or concentrate derived milks (Chilliard *et al.*, 2007).

From the sensory point of view, many experiments (reviewed by Martin *et al.* 2005) have shown that feeding dairy cattle with pasture grass in comparison to winter diets, in particular those including high amounts of concentrate or maize silage, leads to more yellow butter and cheese because of their higher content in pigments, i.e. β-carotene. Cheeses have also a softer texture due of the lower melting point of the fat, richer in long chain unsaturated fatty acids. The raw milk cheeses issuing from pasture are also generally characterized by their stronger flavor associated to specific volatile compounds arising from the catabolism during ripening of unsaturated fatty acids, carbohydrates and proteins. This effect of pasture on cheese flavor is more difficult to interpret. Nevertheless, as it is partly lost when the milk is previously pasteurized, it cannot be ruled out that the native microbial population of milk and/or the milk components modified by heat treatment like endogenous lipases or proteases may vary according to animals' diets and finally explain the influence of pasture on cheese flavour (Martin *et al.*, 2005). The effects of diets on the sensory properties of cheeses depend also on the cheese type: they seem to be of greater magnitude in the case of large hard cheeses requiring a long ripening time than in the case of small soft cheeses ripened quickly. Lastly, the sensory features of pasture derived raw milk is also stronger maybe due to the production in the rumen of volatile compounds like skatole or dimethyl-disulfide that are transferred to milk when cows graze a vegetative grass particularly rich in easily fermentable nitrogen (Coppa *et al.*, 2011).

Within the grass based diets, the influence of the preservation mode concerns mainly the dairy products' yellow colour and carotene content, which are higher when grass is preserved as silage, by comparison to hay (Nozière *et al.*, 2006). Significant differences in the sensory and nutritional characteristics of milk and derived products are also observed according to the botanical composition of the grasslands. In particular, the highly biodiverse Mediterranean or mountain permanent grasslands containing a wide variety of plant species rich in secondary metabolites reduce the biohydrogenation of fatty acids in the rumen and result in milks and cheeses with a higher content of polyunsaturated fatty acids and plant secondary metabolites like terpenes or phenolic compounds (Leiber *et al.*, 2005; Besle *et al.*, 2010). In addition, it is clearly established that the botanical composition of the grass influences cheese texture, flavour and appearance (Martin *et al.*, 2005). Nevertheless, this influence is particularly difficult to explain as it varies widely according to the local context and cheese types considered.

IV – Contribution of grasslands to meat quality

It is well known that the quality of meat is strongly affected by the animal feeding. In particular, many studies have demonstrated that extensive feeding systems based on green pastures increase the intramuscular unsaturated and n-3 fatty acid proportion (for a review see Wood *et al.*, 2008) and improve the oxidative stability of meat as compared to animals given concentrates in stalls (for a review see Descalzo *et al.*, 2008). However, more recent studies have aimed at increasing the knowledge of how different pastures and different grazing managements can affect these aspects of meat quality.

Several pasture plant species, in both alpine and Mediterranean environment, contain phenolic compounds. These components are able to affect the ruminal ecosystem, thus reducing the biohydrogenation of unsaturated fatty acids (Vasta *et al.*, 2010). Willems *et al.* (2014) have demonstrated that, in alpine environment, different pasture species can lead to differences in the intramuscular and adipose tissue fatty acid composition. In particular, phenolic compounds present in some plants, can prevent ruminal biohydrogenation thus increasing the accumulation of alpha-linolenic and linoleic acid in the tissues of animals grazing these plants. The occurrence of secondary compounds (in particular tannins and saponins) in grasslands is recently being exploited as a natural strategy for gastro-intestinal parasite control (see § 6). Therefore recent studies have aimed at evaluating the possible impact of such strategies on the quality of meat. For instance Brogna *et al.* (2014) found that the inclusion of tannins and saponins –in a concentrate-based diet– as remedy for parasite control – did not affect the main meat quality parameters of lamb, including fatty acid composition and oxidative stability. It would be of interest to evaluate the impact of similar remedy treatments in animals treated with plants secondary compounds naturally contained in grasslands/rangelands. Phenolic compounds are natural antioxidants and are commonly believed to contribute towards an improved antioxidant status of the tissues from pasture-fed animals. However, only few studies have investigated on their bioavailability. López-Andrés *et al.* (2013) have demonstrated that in animals grazing a ryegrass pasture, polyphenols are not detectable in tissues and therefore are not the main contributors to the antioxidant status of pasture-fed animals.

Mediterranean pastures are available during a limited part of the year. Reducing the grazing pressure with a correct grassland management could allow to preserve these pastures. Luciano *et al.* (2012) and Vasta *et al.* (2012) offered to three different groups of growing lambs a sward to graze for eight hours (from 9 am to 5 pm) or four hours either in the morning (from 9 am to 1 pm) or in the afternoon (from 1 pm to 5 pm). They have demonstrated that limiting the daily access to pasture from eight to four hours did not affect carcass weight and composition. Intramuscular fatty acids were affected by the time of grazing with higher levels of polyunsaturated fatty acids and lower levels of saturated fatty acids in the meat of animals given access to pasture in the afternoon as compared to those grazing for eight hours or for four hours in the morning. These results could likely be explained by the diurnal variation of the chemical composition in the plants. It was also found that the restriction of grazing did not compromise the storage stability of meat. In outline, the results of these studies highlighted the need for further research to identify and study the main factors to consider in implementing restricted grazing management which maximum profit without compromising animal health and welfare.

For dairy as well as for ruminant meat products further research is required to achieve a systematic knowledge basis about the factors influencing the specific quality of grassland-derived products. It appears particularly important to study systematically the effects of a wide range of dietary polyphenols, especially if present at high concentrations in other commonly used forages. This would be needed for the targeted production of specific foods, which would safely meet standards and achieve higher prices. Such standards have, however, still to be defined. The basis for their definition and control would be authentication systems as outlined below.

V – Authentication of grassland-derived products

The above presented results on dairy and meat products evidence specific features of grassland-derived dairy products and support the idea that a synergy between sustainable utilisation of the grassland/rangeland resources and positive side-effects on product quality emerges in such production systems. Hence, a clear differentiation adding value to these products appears to be possible at least during summer, when the grasslands are available.

Several factors have contributed to research interest in the area of products authentication, such as: the increasing consumer demand for guarantee about mode of production because of several food crises; the evidence that pasture-feeding can impart beneficial effects on meat and milk from a nutritional perspective; the interest in production practices which are more environmental friendly and more respectful towards animal welfare; the interest for producers to obtain market recognition and premium prices and to avoid piracy of their brands. To meet these demands, research has been developed to identify reliable authentication methods for meat and dairy products to be used in parallel with documentary traceability. Plant biomarkers, coming directly from the diet, have been widely proposed as valuable tools (Prache, 2007; Engel *et al.*, 2007). In particular, terpenes have been used successfully in meat (Priolo *et al.*, 2004) and dairy products (Tornambé *et al.*, 2006; Revello Chion *et al.*, 2010; Coppa *et al.*, 2011) as markers of animal diet, and particularly of pasture-feeding. More recently, polyphenols have proven to be quite valuable to authenticate pasture-derived milk and cheeses, especially if animals graze biodiverse pastures (Besle *et al.*, 2010). However, concentrations of terpenes and polyphenols differ widely according to pasture botanical composition and phenological stage (Cornu *et al.*, 2001; Sangwan *et al.*, 2001; Reynaud *et al.*, 2007). Moreover, the majority of phenolic compounds found in milk remain unidentified and identification of terpenes can vary largely according to the analytical method used (Pillonel *et al.*, 2002). As a result, the analytical methods are limiting at present the routine use of these compounds for the authentication of meat and dairy products.

Carotenoid pigments have also been used successfully to distinguish pasture-derived from concentrate-derived ovine meat (Priolo *et al.*, 2002; Prache *et al.*, 2003a and b), bovine meat (Serrano *et al.*, 2006; Röehrle *et al.*, 2011), and dairy products (Slots *et al.*, 2009; Stergiadis *et al.*, 2012). However, also herbage carotenoid content decreases as herbage phenology develops or when herbage is conserved (Calderon *et al.*, 2006; Nozière *et al.*, 2006). As a consequence, carotenoids become less reliable to authenticate pasture-derived milk and meat when pastures are in an advanced stage of maturity, or in case of stall diets which incorporate green herbage or well-conserved forages (Slots *et al.*, 2009; Prache *et al.*, 2009; Stergiadis *et al.*, 2012). Dose-dependent response studies have shown that lamb fat carotenoid concentration was linearly related to carotenoid intake level (Dian *et al.*, 2007), while the relationship was rather curvilinear for milk carotenoid content (Calderon *et al.*, 2006).

The stable isotopes ratios of oxygen, hydrogen, and sulphur are generally used for geographical origin assessment because they depend on latitude and on proximity of the sea (Manca *et al.*, 2001; Renou *et al.*, 2004; Ehtesham *et al.*, 2013). The stable isotopes ratios of carbon and nitrogen in meat and milk have been especially used to authenticate the diet. Tipically, carbon stable isotopes allow the control of whether or not maize has been used in the animal diet (De Smet *et al.*, 2004; Bahar *et al.*, 2009). A recent study demonstrated that nitrogen stable isotopes ratio allowed to authenticate meat produced from legume-rich diets (Devincenzi *et al.*, 2014), because legumes use nitrogen from the air as a nitrogen source. Fatty acid specific carbon stable isotopes offer the potential to link authentication with aspects of the animals' lipid metabolism leading to effects on the products fatty acid composition (Richter *et al.*, 2012a and 2012b).

The fatty acid (FA) composition of milk and meat also gives precise information about animal feeding diet (Aurousseau *et al.*, 2004; Engel *et al.*, 2007; Coppa *et al.*, 2013). Differences in milk and meat FA profile when using contrasting diets have been observed by several authors both in controlled conditions (i.e. reviews of Chilliard *et al.*, 2007, and Shingfield *et al.*, 2013; Aurousseau *et al.*, 2004) and on farm (Ferlay *et al.*, 2008; Stergiadis *et al.*, 2012; Borreani *et al.*, 2013). However, diet authentication based on FA was less accurate when samples derived from mixed diets were considered (Martin *et al.*, 2014).

Recently, global approaches based on meat, milk and cheese infrared (IR) spectra analysis were proposed as rapid, cheap and chemical-free methods to authenticate animal feeding diet. Near IR spectroscopy (NIRS) and medium IR spectroscopy (MIRS) on milk and cheese was found to be reliable to authenticate the main forage fed to cows (Coppa *et al.*, 2012; Valenti *et al.*, 2013;

Andueza *et al.*, 2013), at least when the dietary proportion of the forage exceeded 50%. However, similarly to FA, the IR methods lost reliability with mixed diets (Coppa *et al.*, 2012). In lamb meat, NIRS of perirenal fat enabled accurate discrimination between pasture-fed lambs and concentrate-fed lambs, the wavelengths regions implicated in the discrimination being probably due to differences in light absorption by carotenoid, haeminic pigments and fatty acids (Dian *et al.*, 2008).

The IR methods have a huge potential in routine application for meat and dairy products authentication, because they are reliable, rapid and chemical-free. In case of doubtful results when using IR data, a more detailed analysis using the specific compounds mentioned above may be performed. Intermediate feeding situations, for example in case of mixed diets or diet switches, may be less easily recognized and may require a combination of tracing methods. In particular, the persistence and the latency of appearance of diet tracers and the corresponding spectral changes in meat and milk are currently under active investigation (de Oliveira *et al.*, 2012a and b). These limits should be taken into account in establishing commitments in meat and dairy products specifications.

VI – Animal Health Issues – focus on gastro-intestinal nematodes

Grazing can have several positive effects on ruminants' health, in general terms (Künzi *et al.*, 1988) or related to udder health (Goldberg *et al.*, 1992). Factors may comprise species-appropriate behaviour including feed choice (Provenza *et al.*, 2003; Villalba *et al.*, 2010), but also the high concentrations of plant active compounds including phenols, essential oils, vitamins and unsaturated fatty acids. However, grazing also comprises several challenges towards animal health.

Apart from possible physiological problems (e.g. acidosis, rumen bloat, milk fever, intoxications), pasture born helminth infections (i.e.. gastro-intestinal nematodes (GIN), liver flukes or lungworms) probably represent the most important production and health problem of grazing ruminants (Perry and Randolph, 1999). The need to control pasture born parasites came along together with the intensification of ruminant production systems with high stocking rates and rotational systems that substantially increased pasture contamination and as a consequence favoured infection and reinfection of the hosts. In 1960 the first class of chemical drugs (i.e. benzimidazoles) were developed and allowed for an effective control of parasites. Although several additional classes of anthelmintics were introduced into the market in the forthcoming years, the excessive use of these compounds led to a rapid occurrence of resistant helminth populations. Today anthelmintic resistance is one of the most pressing problems of pasture based ruminant production (Waller, 2006) and is counteracted by the development of alternative strategies to control the parasites. Amongst those strategies, a pasture management considering the epidemiology of helminths has proven to be particularly successful in cattle (Waller, 2006). Compared to sheep and goats, these animals are able to show a more effective immune response to some helminths, particularly to GIN. Also mixed or alternate grazing with cattle and sheep/goats has shown to be a promising strategy to limit GIN infections in both host species by essentially diluting the infection. The background of the latter strategy is the relative specificity of GIN species to either cattle or sheep/goats.

Another promising strategy to control helminths is the use of plant secondary metabolites (PSM), particularly tannins (see also § 4). There is a substantial body of evidence for anthelmintic effects of tannin-containing legume forages such as sainfoin, sericea lespedeza and some lotus species (Hoste *et al.*, 2012). The observed effects can clearly be attributed to the presence of tannins and include a reduction of the worm fecundity, a reduced ability of incoming larvae to establish within the host and the reduction of the adult worm burden within the host. The latter effect, however, is subject to substantial variability including animal response. Other PSMs to control helminths have rather been used in the form of plant extracts and in some cases have proven being highly effective (Athanasiadou *et al.*, 2007). Generally, however, plant extracts to control helminths seem to be subject to a substantial degree of variability, which originates from a multitude of sources (e.g. site of plant growth, time of harvest, conditions of conservation, a.s.o.). Research for both PSM containing fodder plants and plant extracts is ongoing and remains to be a field with a lot of potential for the control of helminths.

Helminth infections of the gastro-intestinal tract induce extra-costs for the host animal. Colditz (2008) specified these costs amongst others as increased metabolic costs, turnover costs of cells and proteins of the immune system, damage of host tissues and reduced nutrient intake due to anorexia. Coop and Kyriazakis (1999) suggested a partitioning framework in the priority of the allocation of available resources to various body functions. The authors suggest that animals will give highest priority to its maintenance functions (body protein: repair, replacement and reaction to infection in affected tissues). If the animals are immunologically matured, the second highest priority is given to growth and reproductive functions. Therefore Coop and Kyriazakis (1999) conclude that improved nutrition will have beneficial effects on the host-parasite interaction especially in periods of high nutrient demand such as rapid growth. Today it is generally accepted that host resistance to GIN is sensitive to protein scarcity rather than to energy scarcity (Houdijk, 2012) and that GIN infection and its consequences can be alleviated by an improved protein supply. It therefore makes sense not only for general nutritional goals, to increase protein supply of ruminants, but also for parasitological reasons.

Overall, research in the field of alternative control of pasture born helminths needs to be further intensified, in order to handle the negative consequences of these parasites on ruminants' health and productivity. This should be done by using different control strategies in parallel in order to make use of potential synergic effects which may arise from their combination.

VII – Conclusion: Future challenges to sustain and develop the multifunctional role of permanent grasslands in European agriculture

The different perspectives of this paper show that there is a large potential for synergies being achieved by the smart utilisation of the European pastures. The targets which are associated, and can be reached simultaneously, are: (i) producing animal feed source, which is (partly) independent from arable land resources and thus not in competition with food crops, (ii) producing food with a particularly high nutritional value due to increased concentrations of functional fatty acids, antioxidants and vitamins, and (iii) maintaining ecosystems of a high ecological value in terms of biodiversity, carbon sequestration and landscape protection.

Challenges are largely connected to ecological and economical sustainability. One important field of solutions for both is the proper management of pasture aiming at the optimal match of carrying capacity and stocking management (species, densities and rotations, adapted to regional and seasonal characteristics), as indicated in § 2 of this paper. Good integration of research, development and extension, acknowledging the high value of farmers' practical knowledge in this field, could be a basis for concrete developments in pasture management. A future challenge for research could be a deeper understanding of the interactions between animal requirements and spatial grazing and selection behaviour, also with respect to forages rich in plant secondary metabolites. A second important aspect for promotion of the sustainable utilisation of pastures is to bring the positive achievements of pasture-based production efficiently to the market. Particularly the specific nutritional values are –although scientifically proven many times– not considered in the price building, neither between dairies and farmers, nor when the products are sold to the customers. Part of this problem lies in legal frameworks about health claims on products. But part is also due to lacking instruments for authentication of food origin and their properties. This paper showed that the technology will soon be available – implementation is the necessary next step.

However, a very basic problem hindering a development towards better utilisation of the pasture resource is the economic framework in a concrete and in a conceptual sense. Regardless of all possible and necessary improvements in the nutritional value and conversion efficiency of natural grasslands/rangelands there will always be large areas which are lower in nutrient density and feed-to-food conversion efficiency than intensively managed temporary grasslands or even grains from arable lands. This argument is used in concepts of ecological efficiency to disregard grassland-based production systems as ecologically inefficient (e.g. Pelletier and Tyedmers, 2010; Herrero *et al.*, 2013). This will also be an economic reality as long as the feedstuffs derived from arable land are cheap and competitive. However, it has to be countered by the fact that many grasslands and rangelands represent a non-arable land contribution to food production. Especially those areas which carry low quality feed are often without any other alternative for utilisation. Efficiency thus has to be calculated not only as product units per animal or hectare or kg of feed, but rather by considering the inputs of arable land (Wilkinson, 2011; O'Mara, 2012) and all further factors related to intensive arable crop production. Multi-perspective definitions of efficiency appear as one highly necessary precondition for the development of political, legal and economic frameworks within which a sustainable grassland and rangeland economy can develop. The ecological efficiency of these systems is an aspect of societal needs and responsibilities. Therefore, societal refunding of ecoservices provided by grassland-based agriculture still appears to be an important issue for local and European policy, which is currently addressed by the "Greening" policy of the European Commission (EC, 2013). The practicability of this measure has to be proven in future. Research, development and extension activities as outlined in this paper may support the implementation of this subsidy instrument on local scales.

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A meta-analysis of climate change effects on forage quality in grasslands: perspectives for mountain and Mediterranean areas

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Abstract. Atmospheric carbon dioxide (CO_2), global mean temperature and inter-annual variability in temperature and rainfall are expected to be significantly higher by the end of the 21st century. In order to review the effects of these factors on forage quality, we carried out a meta-analysis based on climate manipulation experiments. A first original output is the absence of effect of elevated CO_2 on structural carbohydrates (NDF, ADF, lignin), and digestibility. Elevated CO_2 decreased by an average of 9% forage nitrogen (N) content, but the concentration of N in the harvested biomass could be maintained as the result of increased legume abundance. There were no consistent effects of warming on N, water-soluble carbohydrates, NDF, ADF and digestibility. We highlighted the continuum in the effect of water availability from drought to irrigation, with a curvilinear increase of forage N response as water availability decreased. Digestibility increased on average by 10% with drought, but with strong experimental variations. Special emphasis is placed on the discussion of the specificities of mountain and Mediterranean grasslands. Forage N content increased by an average of 9% as a response to warming in mountain areas compared with a 2% decrease in temperate plains. In Mediterranean areas, forage N content was only reduced by 1% as the result of elevated CO_2. In conclusion, we did not observe any dramatic change in forage quality induced by each climate change factor, but further experiments should test for the effects of combined factors including extreme climatic events.

Keywords. Elevated CO_2 – Warming – Precipitation change – Nitrogen – Non-structural carbohydrates – Fibres – Digestibility.

Une méta-analyse des effets du changement climatique sur la valeur des fourrages : perspectives pour les zones de montagne et Méditerranéennes

Résumé. *Tous les modèles climatiques prédisent une augmentation de la teneur en CO_2 atmosphérique, des températures moyennes et une plus forte variabilité des températures et des précipitations d'ici la fin du 21ème siècle. Nous avons réalisé une méta-analyse à partir des expérimentations de manipulation climatique en champ pour comprendre les effets de ces changements sur la valeur des fourrages. Un premier résultat original est l'absence d'effet de l'augmentation de la teneur en CO_2 atmosphérique sur la teneur en fibres et la digestibilité des fourrages. L'augmentation du CO_2 a réduit en moyenne de 9% la teneur en azote (N) des fourrages, mais celle-ci peut cependant être maintenue par l'augmentation de la part des légumineuses dans les couverts. Nous n'observons pas d'effet de l'augmentation des températures sur l'N, les sucres solubles, les fibres et la digestibilité des fourrages. Nous mettons en évidence le continuum de l'effet d'une sécheresse ou de l'irrigation sur la réponse de l'N des fourrages qui augmente de manière curvilinéaire avec la diminution de la disponibilité en eau. La digestibilité des fourrages a augmenté de 10% en réponse à la sécheresse, mais cette valeur moyenne masque des disparités importantes entre essais. Nous discutons ensuite les spécificités des zones de montagne et Méditerranéennes. L'augmentation des températures s'est traduite par une augmentation de 9% de la teneur en N des fourrages en zone de montagne, alors que celle-ci baisse de 2% en plaine tempérée. En zone Méditerranéenne, la teneur en N des fourrages ne baisse que de*

1% en réponse à l'augmentation de la teneur en CO_2. Prises séparément, les variables du changement climatique n'entraînent donc pas de baisse notoire de la qualité des fourrages, mais leurs effets combinés doivent maintenant être analysés, ainsi que ceux d'événements extrêmes.

Mots-clés. *CO_2 atmosphérique – Température – Précipitations – Azote – Sucres – Fibres – Digestibilité.*

I – Introduction

Global atmospheric change consists of (i) an increase of the main greenhouse gases: CO_2, methane and nitrous oxide and (ii) transient changes in temperature, precipitation and other climatic elements over the next decades to centuries. For the preparation of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2013a) global projections of the earth's climate have been developed using general circulation models for a set of new emission scenarios, the so called Representative Concentration Pathways (RCPs). The latter are referred to as concentration pathways in order to emphasize that they are not definitive socioeconomic scenarios, but rather internally consistent sets of time-dependent projections of climate forcing that could potentially be realized with more than one underlying socioeconomic scenario (Collins *et al*., 2013).

The increase in atmospheric CO_2 concentration is the most reliable aspect of global atmospheric change. The increase of atmospheric CO_2 concentration has been from 338 ppm to 398 ppm between 1980 and 2014. According to the four widely varying RCPs, atmospheric CO_2 concentration by 2100 could reach 421 ppm (RCP2.6, low), 538 (RCP4.5, medium-low), 670 ppm (RCP6.0, medium-high) or 936 (RCP8.5, high) (IPCC, 2013b). With respect to RCP4.5 and taking the scenario uncertainty into account, the earth's annual mean surface air temperature is expected to increase relative to 1986-2005 by +1.1 to +2.6°C (Collins *et al*., 2013). Maximum warming is expected to occur in the high latitudes of the northern hemisphere. In Europe, warming is projected to be strongest in the Northwest (NW), where it may reach +3 to +7°C in winter, while the hotspot for warming in summer is projected in the Iberian Peninsula with +3 to +4°C (IPCC, 2013c). Leliévre *et al*. (2010) reported that in southern France the boundaries of Mediterranean climate moved to the North and NW at the rate of 30-40 km per decade since 1980. In winter, however, temperature increase in the Mediterranean region is projected to be relatively mild (+1 to +2°C) by the majority of models. Increased inter-annual variability may be another significant aspect of climate change, and this is of high ecological relevance. Using a regional climate model, Schär *et al*. (2004) predict for central Europe that year-to-year temperature variability will increase by up to 100% by 2071-2100. This would lead to more frequent heat waves and droughts during the growing season. All climate models suggest that average precipitation will increase although reductions are likely in some regions. For 2100 and the RCP4.5 an increase in precipitation by +10 to +20% both in winter and summer is projected for Northern Europe (IPCC, 2013c). For the Mediterranean region a slight reduction of precipitation of 0 to -10% in winter and -10 to -20% in summer is projected. The magnitude of regional precipitation change varies considerably amongst models, and in many areas is less than the standard deviation of model-estimated natural variability.

The objective of this paper is to review the current knowledge on the effects of the impact of atmospheric change –elevated CO_2, increased temperature, and drought– on a wide range of forage quality parameters. The basis of this review is a meta-analysis based on climate manipulation experiments covering a wide range of climatic conditions and all types of grasslands (permanent grasslands, temporary grasslands, mixtures). Special emphasis is placed on the discussion of the specificities of mountain and Mediterranean grasslands.

II – Impact of climate change on plant ecophysiology and livestock digestion

Forage quality depends on nutrient concentration, which determines digestibility, partitioning of metabolized products in the digestive tract and forage intake; it thus strongly affects animal performance. Forage quality is estimated by chemical or biological analyses. Chemical analyses include ash and nitrogen (N) content, total non-structural carbohydrate content (water soluble carbohydrates: WSC and starch), and structural fibres (neutral detergent fibre: NDF, acid detergent fibre: ADF, lignin: ADL). Biological analyses are mainly based on the estimation of the dry matter digestibility either using ruminal fluid *in vitro* (Telly and Terry, 1963) or enzymes (Aufrère and Demarquilly, 1989).

Climate change impacts livestock digestion in two ways, i) its effects on the physical and chemical characteristics of forages, and ii) its direct effects on digestive processes. Ecophysiological changes in plants in response to a heat stress depend on warming level and drought intensity. Extreme climatic events lead to tissue senescence that strongly decrease forage quality. Under moderate heat stress, plant maturation is faster, water content of plant tissues decreases while WSC increase. Maturation of plants increases stem-to-leaf ratio and cell wall content, including lignin which interferes with the digestion of cell wall polysaccharides by acting as a physical barrier to microbial enzymes (Moore and Jung, 2001). High temperatures amplify the lignification process by increasing cell lignification rather than the proportion of cells becoming lignified (Wilson *et al.*, 1991). Consequently, heat stress usually decreases DM digestibility (Lu, 1989). However, under elevated CO_2, an increase of WSC content and a corresponding decline in cell wall content can increase DM digestibility (Picon-Cochard *et al.*, 2004), which reveals complex interactions between climatic factors.

It has been well documented that high temperatures decrease voluntary intake by ruminants due to thermoregulation since most of heat production is due to rumen fermentations (Beatty *et al.*, 2008). O'Brien *et al.* (2010) showed that heat stress consequently reduced the performance of growing cattle. Animals can adapt their foraging behaviour, e.g. reduce feeding bout duration, and increase night feeding. In addition, increasing nutrient density (because dietary protein degradability may become critical), and limiting high-fibre diets (to decrease heat production) can help maintaining normal rumen function (West, 2003). Some direct impacts of heat stress on digestion have also been reported such as a slower passage rate and a longer retention time of digesta in the gastrointestinal tract (Silanikove, 1992). Slower passage rates may partly result from changes in reticular motility (Miaron and Christopherson, 1992). Reduced daily intake, associated with a decrease in volatile fatty acid concentration in the rumen and prolonged retention of feed in the gastrointestinal tract, could increase forage digestibility (Schneider *et al.*, 1988; Miaron and Christopherson, 1992). Bernabucci *et al.* (2009) recently revealed that variations of diet digestibility in ewes chronically exposed to heat stress could also result from adaptation of rumen function to hot environments with less cellulolytic and amylolytic bacteria.

III – A meta-analysis based on climate manipulation experiments

For conducting the meta-analysis, we created a database (references in Table 1) of climate change effect (elevated atmospheric CO_2 concentration, warming, drought or irrigation, and their interactions) on forage quality variables using the Web of Science in November 2013. Search terms were 'climate change' and 'forage quality' or 'nitrogen' or 'carbohydrate' or 'fibre' or 'phosphorus' or 'nutrients' or 'lignin' or 'digestibility' or 'NDF' or 'ADF' or 'ADL'. A total of 81 papers were selected, but only 50 were used after excluding reviews and original papers with unavailable data (e.g. ANOVA results were given rather than mean values) or infrequent quality variable (e.g. tannins, macro-nutrients that were analyzed in less than six papers). Additional 21 papers were used to

Table 1. **Main characteristics of climate manipulation experiments used in the meta-analysis**

Ecosystem†	Vegetation type	Quality variables	Treatments	Ref.
Semi-arid plains				
Native rangeland	GC_3, GC_4, F	N	CO_2	[1]
Mixed-grass prairie	GC_3, GC_4	N	CO_2, T	[2]
Mixed-grass prairie	GC_3, GC_4	N/P	CO_2, T	[3]
Shortgrass steppe	G, F, Sedges	N	D	[4]
Subtropical plains				
Tallgrass prairie	GC_3, GC_4, F	N, C/N	T	[5]
Phalaris aquatic, Trifolium subterraneum ↑	GC_3, L	N, Dig, TNC	CO_2, T	[6]
Arachis glabrata ƚ	L	NDF, ADF, ADL, Dig	CO_2, T	[7]
Holcus lanatus, Pennisetum clandestinum	GC_3, GC_4	N, C/N, ADL	CO_2	[8]
Tallgrass prairie	GC_3, F	N	T	[9]
Temperate plains				
Deschampsia flexuosa	GC_3	C/N	CO_2, T, D	[10]
Temperate grassland	GC_3, GC_4, F, L	N, NDF, ADF, WSC, Dig	CO_2	[11]
Phleum pratense ʆ	GC_3	N, P, WSC, starch, TNC, NDF, ADF, ADL, Dig	T	[12]
Lolium arundinaceum	GC_3	N, C/N, NDF, ADL	CO_2, D, T	[13]
Cichorium intybus, M. sativa,T. pratense	F, L	N	D	[14]
Grassland species	GC_3, F	N	CO_2	[15]
Lolium perenne	GC_3	N	CO_2	[16]
Lolium perenne	GC_3	N	CO_2	[17]
Medicago sativa	L	TNC, NDF, ADF, ADL, Dig	D	[18]
Lolium perenne	GC_3	WSC	CO_2	[19]
Trifolium repens	L	N, Dig	CO_2	[20]
Medicago sativa	L	N, NDF, ADL, Dig	D, W	[21]
Lolium perenne	GC_3	Starch, TNC	CO_2	[22]
Grassland species	GC_3, GC_4, F, L	N, ADL	CO_2	[23]
Semi-natural heathland	GC_3, F	C/N	CO_2, T, D, and all interactions	[24]
Festuca arundinacea	GC_3	N, ADL	CO_2	[25]
Temperate grassland	GC_3, GC_4, F, L	N	CO_2	[26]
Phleum pratense ʆ	GC_3	WSC, starch	CO_2, T	[27]
Pascopyrum smithii, Bouteloua gracilis ƚ	GC_3, GC_4	N, TNC	CO_2, T, CO_2xT	[28]
Plantago lanceolata, T. officinale, E. repens ƚ	GC_3, F	N, C/N	T	[29]
Trifolium ambiguum, M. sativa, T. pretense	L	N, NDF, ADL, Dig	W	[30]
Perennial grass species	GC_3	N, NDF, ADL	W	[31]
Legume species	L	N, NDF, ADF	W	[32]
Grass and legume species	GC_3, L, F	N, NDF, Dig	D	[33]
Grass species ↑	GC_3	N	CO_2	[34]
Alopecurus pratensis	GC_3	N, C/N	D	[35]
Holcus lanatus	GC_3	N, C/N, WSC	D	[36]
Lolium perenne	GC_3	N	CO_2	[37]
Sub-arctic/arctic climate				
Bog species	GC_3, F	N, P	T	[38]
Semiarid steppe	GC_3	N	W	[39]
Deciduous dwarf shrubs	Woody	N	T	[40]
T. pratense, T. repens	L	N, NDF, ADL, Dig	CO_2	[41]
Tundra	Cyp	N	T, W	[42]
Tundra	Cyp	N, C/N	T	[43]

Mountain climate				
Agrostis capillaris, Festuca viviparia, Poa alpine	GC_3	N, P	CO_2	[44]
A.capillaris, F.vivi., P.alpina	GC_3	WSC, starch, TNC	CO_2	[45]
Festuca paniculata	GC_3	N, WSC	TxD	[46]
Perennial grassland	GC_3, F, L	N	T, TxD, TxDxCO_2	[47]
Mixed grass prairie	GC_3, GC_4	N	CO_2, T	[48]
Glacier forefield species	GC_3, F	N, C/N, WSC	CO_2	[49]
D. glomerata, L. perenne	GC_3	N, NDF, Dig	W	[50]
Perennial grassland species	GC_3	N, NDF, Dig	W	[51]
Shortgrass steppe	GC_3, GC_4	N	CO_2	[52]
Meadow and shrubland	F, Sedges	N	T	[53]
Perennial grassland species	F, L, Cyp	N, WSC	CO_2	[54]
Mixed-grass prairie ʆ	GC_3, GC_4, F	N	CO_2	[55]
Shortgrass steppe	GC_4	N, Dig	D	[56]
Shortgrass steppe	GC_3, GC_4	N, WSC, NDF, ADL, Dig	CO_2	[57]
Shortgrass steppe	GC_3, GC_4	N	CO_2	[58]
Perennial grasses	GC_4	N, C/N	CO_2	[59]
Perennial grassland	GC_3, F, L	N, NDF, TNC, Dig	CO_2	[60]
Gentiana straminea, Potentilla anserine	F	P	T	[61]
Meadow	GC_3, Cyp	ADF, ADL, Dig	T	[62]
Mediterranean climate				
Dactylis glomerata, Bromus erectus ł	GC_3	N, TNC	CO_2	[63]
Semiarid grassland species ʆ	GC_3, F, L	N, C/N, WSC	CO_2	[64]
Annual grassland	GC_3, F	N, ADL	CO_2, T, W	[65]
Annual grassland species	GC_3, F	N	CO_2	[66]
Annual grassland	GC_3, F	N	CO_2	[67]
Grassland and forest trees	F, L, Woody	N, TNC	CO_2	[68]
Forest and shrubland	Woody	N, C/N	D	[69]
Cynodon dactylon	GC_4	N, P	W	[70]
Various climates				
US grasslands	GC_3, GC_4	N, Dig	T, D	[71]

† Based on information provided by the authors and on Holdridge classification of biomes; ↑ experiment in tunnels; ⊥ greenhouse; ƒ growth chambers; G: grasses (C_3 or C_4 photosynthetic types); F: non-N fixing dicots; L: N-fixing dicots; Cyp: *Cyperaceae*; ADF: acid detergent fibre; ADL: acid detergent lignin; NDF: neutral detergent fibre; Dig: digestibility; WSC: water soluble carbohydrates; TNC: total non-structural carbohydrates; CO_2: atmospheric CO_2 enrichment; T: warming; D: rainfall/irrigation reduction; W: irrigation

[1] Dijkstra *et al*. (2008), [2] Dijkstra *et al*. (2010), [3] Dijkstra *et al*. (2012), [4] Evans and Burke (2013), [5] An *et al*. (2005), [6] Lilley *et al*. (2001), [7] Newman et al. (2005), [8] Ross *et al*. (2002), [9] Verburg *et al*. (2009), [10] Albert *et al*. (2011), [11] Allard *et al*. (2003), [12] Bertrand *et al*. (2008), [13] Brosi *et al*. (2011), [14] Brown *et al*. (2005), [15] Crous *et al*. (2010), [16] Daepp *et al*. (2000), [17] Daepp *et al*. (2001), [18] Deetz *et al*. (1996), [19] Fischer *et al*. (1997), [20] Frehner *et al*. (1997), [21] Halim *et al*. (1989), [22] Hunt *et al*. (2005), [23] Knops *et al*. (2007), [24] Larsen *et al*. (2011), [25] Newman *et al*. (2003), [26] Newton *et al*. (2010), [27] Piva *et al*. (2013), [28] Read and Morgan (1996), [29] Rodgers *et al*. (2012), [30] Seguin *et al*. (2002), [31] Sheaffer *et al*. (1992), [32] Sheaffer and Seguin (2009), [33] Skinner *et al*. (2004), [34] Soussana *et al*. (2005), [35] Walter *et al*. (2012a), [36] Walter *et al*. (2012b), [37] Zanetti *et al*. (1997), [38] Aerts *et al*. (2009), [39] Gong *et al*. (2011), [40] Hansen *et al*. (2006), [41] Muntifering *et al*. (2006), [42] Sharp *et al*. (2013), [43] Welker *et al*. (2005), [44] Baxter *et al*. (1994), [45] Baxter *et al*. (1995), [46] Benot *et al*. (2013), [47] Cantarel *et al*. (2013), [48] Carrillo *et al*. (2012), [49] Inauen *et al*. (2012), [50] Jensen *et al*. (2003), [51] Jensen *et al*. (2010), [52] King *et al*. (2004), [53] Klein *et al*. 2007, [54] Körner *et al*. (1997), [55] LeCain *et al*. (2012), [56] Milchunas *et al*. (2004), [57] Milchunas *et al*. (2005), [58] Morgan *et al*. (2001), [59] Newingham *et al*. (2013), [60] Picon-Cochard *et al*. (2004), [61] Rui *et al*. (2012), [62] Xu *et al*. (2002), [63] Castells *et al*. (2002), [64] Grunzweig and Körner (2001), [65] Henry *et al*. (2005), [66] Hungate *et al*. (1996), [67] Hungate *et al*. (1997), [68] Körner and Miglietta (1994), [69] Sardans *et al*. (2013), [70] Utrillas *et al*. (1995), [71] Craine *et al*. (2010). The full list of references is available from the authors.

complete the database, based on a second round of search with terms 'warming' or 'drought' or 'water deficit' or 'water stress' and 'forage' or 'grassland' and 'nutritive value' or 'chemical composition' or 'digestibility'. A total of 71 papers were thus finally analyzed. Short-term climate manipulation experiments apply single or combined climate change factors in a controlled way and thus allow testing scenarios. Outdoor experiments with natural ecosystem were preferred, but some experiments performed in semi-controlled conditions were also selected. We included some data on shrubs and tree foliage since they are occasionally browsed especially in Mediterranean areas, and an altitudinal gradient experiment (Xu *et al*., 2002). Atmospheric CO_2 concentration was increased on average by 283 ± 102 ppm (mean ± SD, n = 340 observations from 41 experiments in the database) compared with ambient CO_2 366 ± 20 ppm; air or canopy temperature was increased by an average of 3.7 ± 4.6 °C (n = 205 observations, 25 experiments) during the growing season compared with ambient temperature 12.3 ± 5.4 °C, which broadly corresponds to the medium-high RCP scenario (IPCC, 2013b). Precipitation were reduced by 49 ± 34 % in drought experiments (n = 83 observations, 14 experiments) and water supply was increased by 78 ± 68 % in irrigation trials (n = 111 observations, 9 experiments). Few experiments combined several factors (n = 113 observations, 12 experiments). The effect of climate change was sometimes analyzed according to season, N fertilization, and grazing or defoliation regimes. Forage quality was measured on organs (leaf lamina, sheaths and stems), plant species, mixtures or plant communities. Species were therefore grouped according to functional group: C_3 grasses (GC_3), C_4 grasses (GC_4), Legumes (L), Forbs: non N-fixing dicots (F), *Cyperaceae* (C), or woody (shrubs).

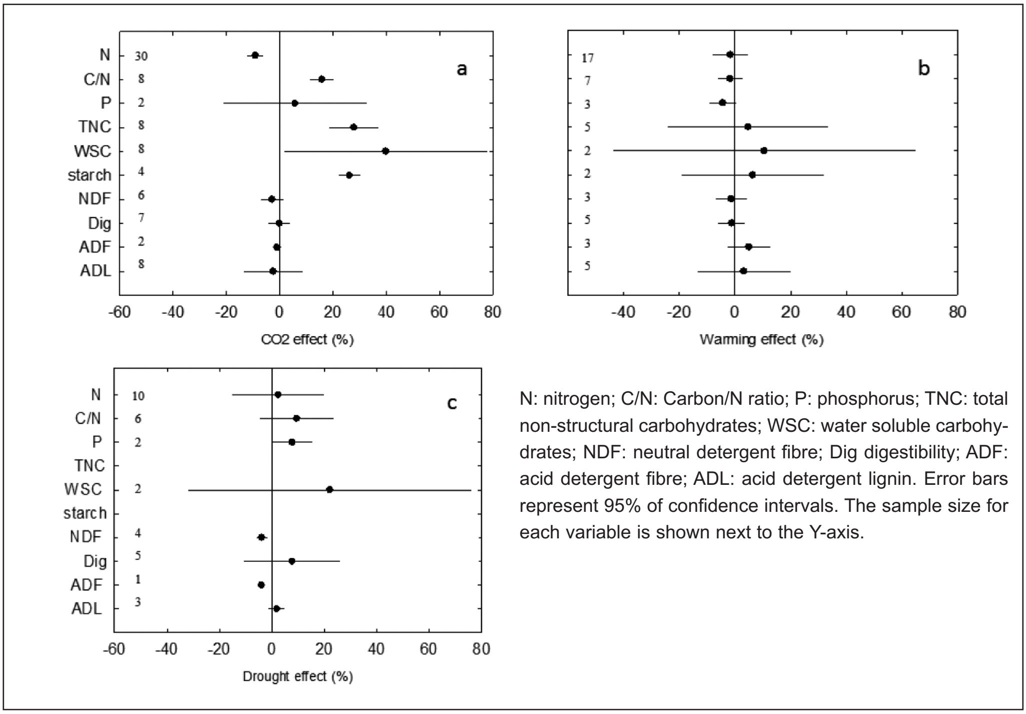
IV – General trends

1. Elevated CO_2 effect

Elevated CO_2 decreased by an average of 9% forage nitrogen content and increased by about 30% the non-structural carbohydrates (total, soluble, starch) of forage tissues (Fig. 1a). Also water soluble carbohydrates (WSC) increased, but with very high variability that could result from the instability of soluble carbohydrates within plant tissues (source/sink relationships are affected by elevated CO_2), but also from time of harvest, organs or analytical method. These responses confirm the conclusions of several meta-analyses or reviews (Soussana *et al*., 2002; Lüscher *et al*., 2004; Hopkins and Del Prado, 2007; Soussana and Lüscher, 2007; Wang *et al*., 2012; Xu *et al*., 2013), but an original output from our meta-analysis is the absence of effect of elevated CO_2 on structural carbohydrates (NDF, ADF, lignin), and digestibility.

Effects of elevated CO_2 on digestibility were measured in seven experiments (Table 1; Fig. 1a) but only three (Allard *et al*., 2003; Picon-Cochard *et al*., 2004; Milchunas *et al*., 2005) simultaneously measured nitrogen, and structural and non-structural carbohydrates (average ratios of elevated CO_2 / ambient CO_2 were: non-structural carbohydrates = 1.271; N = 0.929; NDF = 0.985; ADF = 0.984; digestibility = 0.999). The results are thus close to the general trend (Fig.1a). In a shortgrass steppe, Milchunas *et al*. (2005) however reported a decline of digestibility, which is consistent with the slight decrease of non-structural carbohydrate and nitrogen contents while fibre content increased. Differences between experiments could result from variations in species composition (Allard *et al*., 2003), proportion of tissues with contrasting digestibility, and environmental factors (e.g. soil nutrients). As a consequence of the increase in atmospheric CO_2 concentration, we can hypothesize changes in forage protein-energy balance that are likely to modify microbial synthesis in the rumen and affect digestibility (Soussana *et al*., 2002). Increase in the non-structural carbohydrate content of forages could be an advantage for fast acidification of forages while making silage, so that no or less additive would be necessary.

For all quality variables, we observed the same response between functional groups (Fig. 2). Within grasses, only N and C/N ratio responded slightly differently between C_3 and C_4 grasses, with a



N: nitrogen; C/N: Carbon/N ratio; P: phosphorus; TNC: total non-structural carbohydrates; WSC: water soluble carbohydrates; NDF: neutral detergent fibre; Dig digestibility; ADF: acid detergent fibre; ADL: acid detergent lignin. Error bars represent 95% of confidence intervals. The sample size for each variable is shown next to the Y-axis.

Fig. 1. The mean effect size of a) elevated CO_2, b) warming and c) drought on the main forage quality variables.

lower N ratio for C_3 (-13%) than for C_4 (-5%), and thus a higher C/N ratio for C_3 grasses. This is consistent with the conclusions of Wang *et al*. (2012) who compared C_3 and C_4 species response, including woody species and crops, to elevated CO_2. This more neutral effect of elevated CO_2 on the N content of C_4 grasses, results from the photosynthesis and biomass accumulation of C_4 species being less affected by elevated CO_2 than those of C_3 species.

Shifts in species composition in response to elevated CO_2 could however strongly impact overall forage digestibility in grazed pastures (Morgan *et al.,* 2004; Milchunas *et al.,* 2005). The considerably lower concentration of N under elevated CO_2, observed for *Lolium perenne* leaves in pure stands of the Swiss FACE experiment, was found to a much lesser extent for *L. perenne* grown in mixture with *Trifolium repens* (Zanetti *et al*., 1997; Hartwig *et al*., 2000). Highly important, in the mixture the proportion of N-rich *T. repens* increased at the expense of the N-poorer *L. perenne* from 21% at ambient CO_2 to 33% at elevated CO_2 (Hebeisen *et al*., 1997; Daepp, 2000). In more complex mixtures containing other grasses, legumes and non-leguminous dicot species, the proportion of legumes in the community also increased significantly under elevated CO_2 (Lüscher *et al*., 1996; Campbell *et al*., 2000), especially when the community was frequently cut (Teyssonneyre *et al*., 2002). As a result, the concentration of N in the harvested biomass of the mixture showed no significant reduction under elevated CO_2 (Lüscher *et al*., 2004). These results demonstrate that the response of plant communities cannot be predicted from the response of individual species grown in pure swards, and that CO_2 induced changes in the proportion of species with differing forage quality may be more important than CO_2 induced changes in the quality of individual species.

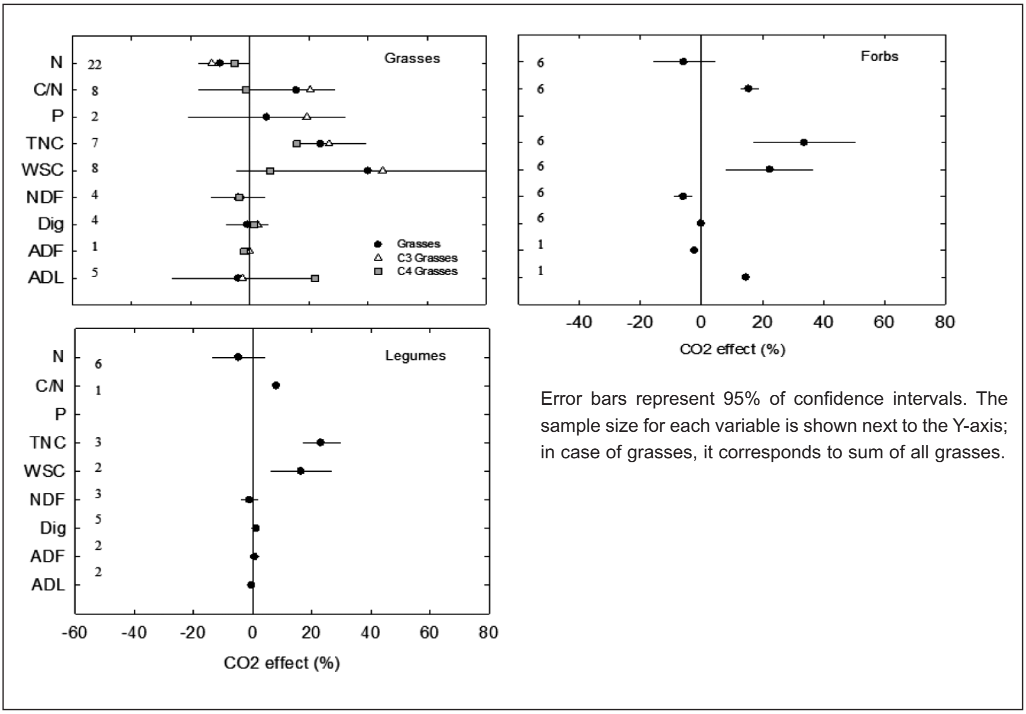


Fig. 2. The mean effect sizes of elevated CO_2 on the main forage quality variables in grasses, forbs and legumes.

2. Warming effect

The meta-analysis did not reveal any significant effects of warming on N, NDF, ADF, WSC and digestibility (Fig.1b). Similar patterns were found for grasses, forbs and legumes although few data were available for forbs, legumes (Fig.3) and C_4 grasses. This contrasts with results from two meta-analyses (Dieleman *et al*., 2012; Bai *et al*., 2013) and a survey on *Medicago sativa* (Walgenbach *et al*., 1981) concluding that warming slightly increased plant N content. Higher mineralization in warmer soils can indeed increase soil N availability and consequently plant N uptake. However, reduced soil moisture can also cause highly stressful conditions that are likely to mitigate the effects of an increase in soil N availability on plant uptake; this could explain contrasting trends in the effect of warming on forage N content.

According to Buxton and Fales (1994) temperature is the main factor that influences the nutritive value of forages. In general, a rise in temperature increases plant growth, reduces leaf: stem ratios and increases NDF, ADF and lignin contents. Consequently, digestibility is usually reduced. When changes in temperature occurred over the growing season, the effects of temperature, ontogeny and maturity are confounded. In our meta-analysis, we compared the chemical composition of the same organs or plants under ambient or elevated temperature. The effect of warming has been shown to modify fibres and digestibility differently in leaves and stems (Wilson *et al*., 1991). Here, the absence of clear effects of warming on plant chemical composition and digestibility could result from the fact that measurements carried out on different organs were mixed in the meta-analysis. It also suggests that the effects of warming on forage quality could mostly be driven by the evolution of plant phenology.

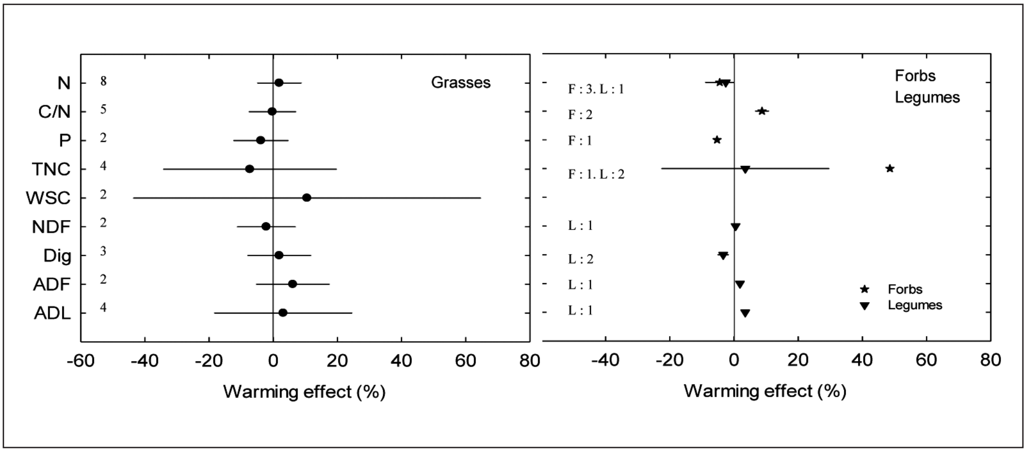


Fig. 3. The mean effect sizes of warming on the main forage quality variables in grasses, forbs and legumes. Error bars represent 95% of confidence interval. Sample size for each variable is shown next to the Y-axis.

Indirect effects of warming could also arise from shifts in sward botanical composition. The amplitude of these indirect effects is assumed to vary according to climatic conditions and plant communities (Izaurralde *et al*., 2011; Rodgers *et al*., 2012). Simulations in the Aubrac area of Central France predicted a shift towards exploitative grasses of higher digestibility as the result of a 1.2°C warming (Picon-Cochard *et al*., 2013). Cantarel *et al*. (2013) observed that an average 3.5°C warming during 4 years decreased grass proportion by 10% at the expense of legumes (mainly *Vicia* sp.), increasing forage N content in this upland permanent grassland.

3. Drought effect

Overall, experiments investigating the effect of drought on forage quality are rarer than those manipulating atmospheric CO_2 or temperature. In the meta-analysis, ten studies analyzed the effects of drought on forage nitrogen concentration (six for C/N) with never more than five experiments for other parameters (Fig. 1c). Drought led to an average 5% decrease in plant cell-wall (NDF) content. Digestibility increased on average by 10%, with strong variations between experiments (Halim *et al*., 1989; Deetz *et al*., 1996; Skinner *et al*., 2004; Milchunas *et al*., 2004; Craine *et al*., 2010). The lack of clear drought effect could be the consequence of the small amplitude of NDF variations, a small increase in lignin content sometimes counteracting the decrease of NDF. We highlighted a continuum in the effect of variations in precipitation from reduction (drought) to irrigation on plant N response, i.e. the ratio of N content between drought (or irrigation) and control values, with a curvilinear increase of forage N response as water availability decreased (Fig. 4). Variability of N and C/N forage contents was greater compared with experiments in which atmospheric CO_2 or temperature were manipulated (Fig. 1). Yet data from the literature on the effect of periods of low precipitation on plant N concentration are conflicting, with some authors reporting a reduction (Hayes, 1985; Craine *et al*., 2010) and others an increase (Murphy *et al*., 2002). A reason for this could be the shifts in community structure that were observed as a response of grassland ecosystems to drought. Increases in dominant perennial forbs and decreases in dominant grasses have for instance been reported with warming and summer drought in the UK (Sternberg *et al*., 1999). Legumes, such as white clover, decreased under drought conditions while other species such as the deep-rooted chicory tended to yield well (Skinner *et al*., 2004). Variations in forage N content can thus be expected since legumes are richer in N than other functional groups. Some legumes such as sainfoin or alfalfa are known to be drought tolerant and their persistence could maintain or even increase forage N content. Finally, it is noteworthy that legume quality can increase under drought conditions due to a higher leaf-to-stem ratio, delayed maturity, and higher quality of both the leaf and stem fractions (Peterson *et al*., 1992).

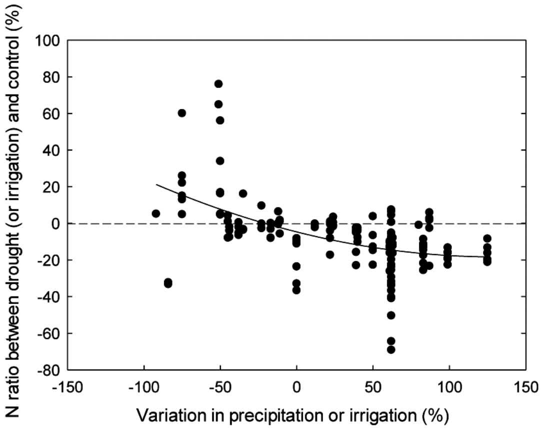


Fig. 4. Effect of variations in precipitation from reduction (drought, i.e. negative values on the X-axis) to irrigation (positive values) on plant N response, i.e. the ratio of N forage content between drought (or irrigation) and control. Values at 0 on the X-axis are drought experiments in which average precipitation was kept constant but increased in variability (Walter *et al*., 2012a,b).

V – Specificities of mountain and Mediterranean areas – further research needs

1. Mountain areas

The meta-analysis allowed us comparing the outputs from 19 climate manipulation experiments under mountain climate conditions, with those from 28 papers from temperate plains (Table 1). Mountain was defined based on the altitude that was above 800 meters. Within temperate plains, we considered lowland sites under either oceanic or continental influence, with mean annual temperature above 6°C separating the latter from sub-arctic climate in Holdridge classification. Applying some particular climate change factors in a controlled way and analyzing their direct effects on forage quality did not allow identifying specific trends for the effects of elevated atmospheric CO_2 in mountain areas (Fig. 5). Overall, N concentration was reduced by 10% (± 5%) *vs* 11% (± 4%) in temperate plains. Water soluble carbohydrates were increased by 54% in mountain areas (*vs* 27% for temperate plain) but with huge experimental variations that prevent concluding on any significant difference. Only Picon-Cochard *et al*. (2004) and Milchunas *et al*. (2005) analyzed the effect of elevated CO_2 on the NDF content of upland swards; it was on average similar to that in current CO_2 conditions (Fig. 5b). A recent experiment revealed a slight but significant 3% decrease in NDF herbage content as the result of elevated CO_2 (+ 140 ppm), while N forage content decreased by 13%; consistently digestibility remained unchanged (Niderkorn *et al*., 2014). Perhaps more significant are the theorized shifts in vegetation composition predicted in future CO_2-enriched environments, with some evidence in mountain areas (Teyssonneyre *et al*., 2002; Stampfli and Zeiter, 2004). Rising atmospheric CO_2 concentration has the potential to cause significant alterations in grassland structure and function, with some outcomes leading to grasslands that are more productive but of lower forage quality for domestic livestock (Campbell *et al*., 2000).

The effects of increasing average air temperature (six experiments) or reducing precipitations (three experiments) were even less analyzed in mountain areas. We identified some contrasting trends on the direct effects of increasing air temperature since forage N content increased by an average of 9% (± 7%) under mountain climate conditions compared with a 2% decrease (± 9%) in temperate plains. This increase in forage N concentration in mountain areas is consistent with the results from two meta-analyses (Dieleman *et al*., 2012; Bai *et al*., 2013). According to what we discussed in section 3, it suggests non-limiting soil water conditions in most mountains areas (at least in those where climate manipulation experiments have been conducted so far). Consistently, productivity in subalpine grasslands in the Pyrenees was reported to be more temperature-limited than water-limited (Sebastià, 2007). Shifts in plant community structure as the result of warming could have further positive effects on forage quality, e.g. the increase of legume abundance in perennial grasslands in the French Massif-Central (Cantarel *et al*., 2013), or of exploitative grasses in the Aubrac region (Picon-Cochard *et al*., 2013). Effects of an extreme summer event (i.e. a 2-week heat wave at +6°C combined with a 3-month summer drought) differed from those of moderate warming (+2°C). Niderkorn *et al*. (2014) found that both sward biomass and quality dropped during the extreme event, but in the autumn the N content of re-growing tissues increased by 35% while NDF decreased by 7%; this led to a significant 8% increase of forage *in vitro* digestibility, which contrasts with what is reported in Figure 5b.

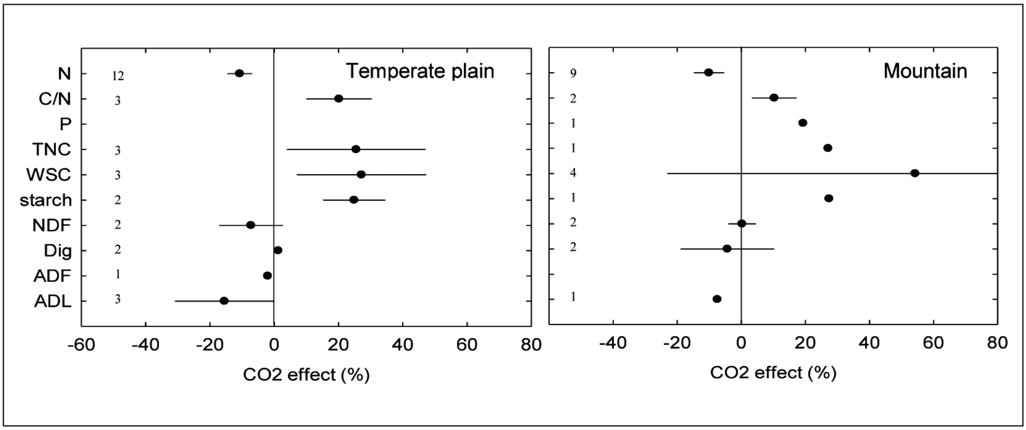


Fig. 5. The mean effect sizes of elevated CO_2 on the main forage quality variables in mountains (> 800 m a.s.l.) and temperate plains (oceanic or continental with annual temperature > 6°C). Error bars represent 95% of confidence intervals. The sample size for each variable is shown next to the Y-axis.

Only three experiments investigated the effect of reducing water availability on forage quality in mountain grasslands. Consistent with the general trend reported in Figure 4, the N content of forages increased with water shortage whether it was applied alone or in combination with other factors (Milchunas *et al*., 2004; Benot *et al*., 2013; Cantarel *et al*., 2013). Water soluble carbohydrates increased in subalpine grasslands as the consequence of an increase in air temperature and of summer drought (Benot *et al*., 2013). In vitro digestibility of forages also increased in a shortgrass steppe as the result of water shortage (Milchunas *et al*., 2004).

More generally, warming and changes in water availability can modify the boundaries of productivity defined seasons and seasonal herbage surplus or shortage. A positive effect of warming in mountain areas would be the decrease in the length of the winter period. Shorter winters reduce animal feed stock needs and allow an earlier start of sward growth which may allow a more intensive exploitation (additional cuts or mowing at higher altitude) of resources when spring and summer droughts are not too severe (Nettier *et al.*, 2010). A high year-to-year variability in temperature and rainfall could however threaten the capability of high-altitude grasslands to provide high quality forages during summer. In the Pyrenees, shifts in botanical composition could have negative effects on forage quality since some highly palatable grasses, such as *Festuca nigrescens,* were negatively affected by climate change, while less palatable forbs (e.g. *Potentilla neumanniana, Euphorbia cyparissias*) became abundant (Sebastià, 2007). Interactions between climate and management could be relevant in this context. Both grazing and changes in cutting regimes (e.g. early cuts) could buffer the negative effects of climate change on forage quality, so that it is likely that pasture management offers promising options for adapting livestock systems to climate change.

2. Mediterranean areas

The meta-analysis led us to analyze the data from only eight experiments, the effect of elevated CO_2 being the most frequently tested (Table 1). Nitrogen concentration was recorded in all the experiments. On average, forage N content was only reduced by 1% (± 9%) *vs* -11% (± 4%) for temperate plains. This could either result from shifts in vegetation communities or from a concentration of N in plant tissues under drought conditions (Fig. 4). Both WSC and TNC increased as the result of elevated CO_2, which is consistent with overall trends reported in Figure 1a. No measurement of digestibility was made in any of these climate manipulation experiments. In Mediterranean areas, the increment of plant biological activity can be slowed down by soil water scarcity, but due to the lack of data we mainly base our discussion on measurements of the quality of forages adapted to Mediterranean areas.

Mediterranean grasslands quality is often limited by the lack of legumes. P-fertilization and liming on native pastures are effective methods to increase legumes in grasslands thus promoting N fixation (Cocks and Gintzburger, 1993). Annual self-reseeding legumes (e.g., subclover and medics) have been extensively used for pasture improvement in the Mediterranean basin for over forty years; in resources-poor drylands, they represent a valuable source of protein that mitigates the negative effects of drought and warming of forage production (Porqueddu, 2001). Possibilities to exploit the genetic resources of perennial legumes that are able to escape summer drought and regrow at the season break e.g. *Sulla coronaria*, *Onobrychis viciifolia* (Sulas, 2005; Re *et al*., 2014) offer opportunities to stabilize both production and forage quality. Several breeding program, especially in Australia and New-Zealand, focused on the production of deep-rooted and drought tolerant perennial legumes (e.g., Caucasian clover, stoloniferous red clover, tallish clover, etc.), which have a high feeding value that declines slowly with maturity. Recent research indicates that *Psoralea bituminosa* L. Stirton also has potential as a highly-nutritive forage legume for Mediterranean disadvantaged areas (Reaside *et al*., 2013).

In perennial grasses, some Mediterranean varieties of tall fescue, cocksfoot and phalaris are adapted for climate with annual rainfall >500 mm and accumulated summer water deficit <700 mm (Leliévre *et al*., 2008). Summer dormancy and dehydration tolerance are considered as the main drought tolerance traits (Norton and Volaire, 2012). Porqueddu and Carneiro (unpubl. data) conducted a multi-site comparison that revealed the higher digestibility of seven cocksfoot cultivars (except for subsp. hispanica Kasbah) compared with six tall fescue cultivars. Wide intra-specific variability was observed for N, NDF, ADF and ADL content, and digestibility. This experiment showed that most perennial grass varieties that are able to persist over long summer drought combine early autumn regrowth with high crude protein content (e.g., 23.5% for the Sardinian ecotype Ottava). In winter and spring, crude protein content is halved and fibre content generally decreases, which tends to buffer digestibility. Little work has been done on the selection of reed canarygrass and perennial ryegrass. According to Gutman *et al*. (2001), more information on the effects of defoliation and grazing on biomass partitioning in perennial grasses is needed to improve the forage quality and production efficiency in Mediterranean grasslands.

Pasture mixtures available in southern Europe consist in a small number of annual legumes (subclover, medics, etc.) sometimes including low proportions of annual grasses (e.g. annual ryegrass, Italian ryegrass). In areas with higher rainfall, perennial grasses, such as cocksfoot and reed canarygrass, are used in mixtures. It is also frequent to find complex mixtures including up to 15-20 species (Porqueddu and Gonzales, 2006). Compared with pure stands, grass-legume mixtures provide higher yields with better seasonal distribution and limit the spreading of unsown species. The feeding value of the different grass-legume mixtures has been discussed by Maltoni *et al*. (2007). Mixtures have less seasonal variations in quality compared with pure stands. According to Norton and Volaire (2012), it may thus be possible to develop a stable pasture mixture comprising summer dormant and summer active species/varieties so that any moisture available throughout the year can be utilized by one of the mixture component. Our meta-analysis did not reveal any variations in the response of grasses, forbs and legumes to elevated CO_2, warming and drought. Climate change is thus not expected to directly affect the chemical composition of grasses and legumes, but could shift their relative abundance in mixtures according to the previously discussed adaptations of functional types.

VI – Conclusion

In this review, we analyzed the single effects of elevated CO_2, warming or precipitation change on the main forage characteristics. While many studies have investigated changes in nitrogen content, less information is available for non-structural carbohydrates. Fibres and *in vitro* digestibility were recorded in a very limited number of studies, and were on average similar to those in current climatic conditions. Overall, we thus did not observe any dramatic change in forage quality induced by climate change factors, apart from those that may result from shifts in grassland botanical composition. The combined effects of climate change factors and the effect of extreme events were seldom investigated. Our meta-analysis outputs (e.g. contrasting response of N to each factor in Fig. 1), literature reviews (Dieleman *et al*., 2012) and some pioneer experiments testing combinations of climatic factors (Read and Morgan, 1996; Larsen *et al*., 2011; Cantarel *et al*., 2013) suggest that their combined effects on forage quality cannot be easily predicted from single factor responses. Further experiments should thus be carried out focusing on these combined effects. In addition, response to extreme events can differ from those obtained under moderate warming and drought (Benot *et al*., 2013; Niderkorn *et al*., 2014), and should thus be further tested. Very few data are also available for Mediterranean areas, which prevented any comparison apart from the response of N forage content to elevated CO_2. The field manipulation experiments we used in the meta-analysis have a strong predictive power, and allow a precise monitoring of all system variables. However, they may exacerbate the effects of natural climatic changes on plant ecosystem processes (Leuzinger *et al*., 2011), which might in turn affect forage quality. Management options could buffer the effects of climate change on forage quality. However, they were only investigated in a limited number of studies with mown grasslands (e.g. Zanetti *et al*., 1997; Daepp *et al*. 2000; Picon-Cochard *et al*., 2004). Long-term experiments that follow vegetation dynamics as a response to climate variability (LTER in the US, SOERE in France, etc.) are closer to natural pedoclimatic conditions, take account of climate variability (gradual natural trends, extreme events), and allow testing for the effects of grazing management. It is thus likely that predicting forage quality from grasslands in a changing climate will require both approaches to be pursued in a coordinated way.

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Session 1

Forage services for animal production and product quality

Oral presentations articles

Intake of plants containing secondary compounds by sheep grazing rangelands in the province of Boulemane (Morocco)

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Abstract. Understanding the feeding choices of ruminants grazing pastures containing plant secondary compounds (PSC) can help designing pastoral management strategies which stimulate the consumption of rangeland vegetation, while preserving its biodiversity and regeneration potential. In this objective, a survey was carried out with 35 breeders then 11 shepherds in the province of Boulemane in eastern Morocco. The sheep farming systems investigated were based on the exploitation of natural vegetation of the steppes and hills whereby alfa and sagebrush are predominant. The aims of the study were: (1) to determine the preferences of sheep in terms of plant species ingested, (2) to identify the main factors influencing these behaviours and (3) to relate these observations to the chemical composition of the parts ingested in particular the plant secondary compounds (phenols and tannins). Despite the relatively varied species present on the rangelands, only around 8-10 species were considered by shepherds as being relevant as forage resources. The relative preferences of sheep between these species varied according to shepherds and sites. Farmers implemented seasonal management strategies, based on the relative palatability and availability of the plant species on the rangeland. Further analyses will determine the possible relation between plant composition, grazing and supplementation management, and sheep preferences.

Keywords. Rangelands – Feeding behaviour – Secondary compounds – Grazing management – Local ecological knowledge.

Ingestion de plantes contenant des composés secondaires par des brebis pâturant sur parcours dans la province de Boulemane (Maroc)

Résumé. *Comprendre les déterminants des choix alimentaires dans des pâtures riches en composés secondaires peut aider à mettre en place des modes de conduite qui stimulent l'ingestion tout en maintenant la biodiversité et la capacité de régénération des végétations. Dans cette optique, une enquête fut conduite auprès de 35 éleveurs puis de 11 bergers dans la province de Boulemane dans l'est du Maroc. Les systèmes d'élevage ovins ciblés étaient basés sur l'utilisation des parcours de steppe et de colline, à faciès d'alfa et d'armoise principalement. Les objectifs de l'étude étaient les suivants: (1) déterminer les préférences des ovins en termes d'espèces végétales ingérées, (2) identifier les principaux facteurs qui influencent ces comportements et (3) corréler ces observations à la composition chimique des parties ingérées et en particulier à la teneur en composés secondaires (polyphénols et tannins). Malgré la diversité d'espèces présentes sur les parcours, seulement 8-10 espèces étaient perçues comme ressources fourragères par les bergers. Les préférences perçues variaient selon les bergers et les parcours. Les éleveurs adaptaient leur stratégie de conduite selon la saison, en fonction de l'appétence relative et de la disponibilité des plantes sur les parcours. Des analyses complémentaires devraient permettre de comprendre les liens entre composition chimique des plantes, ingestion, complémentation et préférences des ovins.*

Mots-clés. *Parcours – Comportement alimentaire – Composes secondaires – Conduite du pâturage – Savoirs de bergers.*

I – Introduction

Rangelands are important sources of forages for the rearing of small ruminants particularly in the arid regions (Allen-Diaz *et al.,* 1996). They provide cheap forage but also support ecological services (carbon sequestration, biodiversity preservation, water quality (Havstad *et al.,* 2007). In the Mediterranean region, rangelands are often degraded, either by under-utilization causing shrub encroachment and increased fire risk (southern Europe) or by over-utilization resulting in the disappearance of perennial species and the development of low-palatable, invasive species and bare ground, with consequent erosion, soil end fertility losses (Northern Africa). In Mediterranean rangelands, many typical browse species and a number of forb species contain considerable amounts of condensed tannins or other PSCs (Jouven *et al*., 2010).

Plant secondary compounds (PSCs) are substances produced by the plants to resist herbivory and as such generally limit grazing by causing aversion in terms of astringencies and even toxicity when ingested (Jensen *et al.,* 2013). At pasture, the profile of plant species and plant parts ingested by ruminants is affected by many factors among which the presence of PSCs (Provenza and Ropp, 2001). Diet composition in PSC-rich pastures might be determined by the types and amounts of PSCs in the plant parts and the association of nutrients and toxins in the whole diet, with possible compensations due to nutrient-toxin and toxin-toxin interactions (Provenza *et al*., 2003).

Understanding the feeding choices of ruminants grazing PSC-containing pastures can help designing pastoral management strategies which stimulate the consumption of rangeland vegetation, while preserving its biodiversity and regeneration potential. The aim of this work was to assess, based on farmer's knowledge, the consumption of PSC-containing plants by sheep grazing Mediterranean rangelands and the possible interactions with the feeding management. This paper presents the preliminary results of this study.

II – Materials and methods

The area investigated was the natural rangelands in the province of Boulemane (in the Middle Atlas of Morocco) on three sites (Boulemane, El Ksabi and Guigou). Interviews were carried out with 35 local farmers in order to describe the local farming systems and identify a few experienced shepherds which would accept to discuss about sheep feeding behaviour and management practices. Extensive interviews were carried out with 11 shepherds, following the method of Meuret (1997). They were done out on the rangeland, while the shepherd guided the flock, and included, at the end, the identification of a number of local plant species based on photographic clichés. The objective of these interviews was to collect information on the local ecological knowledge of shepherds in terms of plant species ingested, preferences, aversions, grazing patterns, seasonality and circumstantial grazing if any. In order to assess plant nutritional and anti-nutritional compounds, vegetation samples of plant parts ingested by sheep were collected on the rangelands, dried at 40°C then analysed with near infra-red spectroscopy (NIRS) for chemical composition; laboratory analyses (Landau *et al*., 2004) were performed to determine polyphenol and tannin contents (PSCs).

III – Results and discussion

1. The farming systems in the three sites surveyed

At Boulemane (average altitude of 1900 m) sheep farming dominates, and the animals are grazed on steppes and hillsides. El Ksabi (average altitude of 1100 m) is located between Boulemane city and Missour and is an area of oasis with olive orchards and cereals fields. The third locality surveyed was around the town of Guigou (average altitude of 1500 m) and is characterised by woody hills. Sheep graze dry rangelands all year round in Guigou. In Boulemane, due to cold and snowy winters and in Eksabi, due to forage scarcity, flocks are moved to other areas (for ex. near Guigou) for winter grazing.

For all the sites surveyed, flock size was quite uniform at around 200 heads with *Timahdite* being the main ovine breed, chosen for its adaptation to cold during winter months. Herd composition was mainly sheep in Boulemane and Guigou whilst in El Ksabi almost half of the herd was goats due to the relatively warmer and drier conditions in the area and the presence of bushes similar to *Ziziphus lotus (L.)* Lam which is consumed mainly by goats. All the farmers complained about lack of water both for livestock drinking and biomass development. Shepherds main preoccupation was to use the resources available to maintain a sizeable flock for as long as possible without recurring to supplementation.

2. Diversity of forage species on the rangeland and sheep preferences

From the interviews of the shepherds, it was found that shepherds considered only a limited number of species (the most abundant) as being relevant for grazing. In Boulemane, the main species cited by shepherds were *Stipa* sp. (local name: halfa), *Thymus ciliatus* (azoukini), *Poa* sp. (tawarra), *Santolina rosmarinifolia* (shiha), *Eruca vesicaria* (haarein), *Rosmarinus officinalis* (azir), *Ranunculus* sp (lafoudfoulous) and *Adonis aestivalis* (shook). In El Ksabi, shepherds identified *Stipa tenasissima (*halfa*)* as the main forage species and *Perganum harmala* (harmal), *Artemisia herba-alba* (shiha) and *Thymus ciliatus* (azoukini) as the other significant forages found on the rangelands. In Guigou, *Quercus rotundifolia* (karoush), which was considered by shepherds as the main source of forage in winter. The other species considered as important by shepherds were *Poa* sp. (tawarra), *Thymelea* sp. (talzazat*), Scorzonera pygmaea* (tinegmit*), Genista quadriflora* (casdir*) and Nonaea mucronata* (agarbaz*).*

The relative preferences of sheep between these species varied according to shepherds encountered and sites: thus in Boulemane and Guigou, the most preferred species were those bearing flowers such as *Eruca vesicaria* and *Scorzonera pygmaea* whilst in El Ksabi, the biodiversity of the rangelands appeared to be poorer and so the species preferred was *Stipa* sp. However, these preferences change with the season due mainly to the availability. For example, in summer, *Perganum harmala* which is generally disregarded by sheep, is well grazed probably due to the scarcity of other species and also because when wilted it is less "smelly" which is a peculiarity of that species and could be the cause of the avoidance observed in sheep. Interestingly, some species which are quoted in the literature (Berkat *et al*., 2004) as edible forage species for the area, such as *Dactylis glomerata*, *Hieracium pseudopilosella Medicago suffruticosa* and *Globularia alypum* were not cited or noted in the rangelands surveyed. Tentative explanations may be: a) there is a rarefication of these species or more plausibly b) they are not predominant in the limited zone which was covered in the study. Strikingly, during the course of the conversations with some shepherds, species which are reported as toxic in literature (Lamnaouer and Abdennebi, 1994) such as *Astragalus* sp. and *Androcymbium gramineum* when shown on printed pictures were reported not only as harmless but even as preferred species which sheep look for. This may either indicate confusion by shepherds due to the similarity of the photos shown with other species or the ability of sheep to overcome the toxic effects.

3. Chemical composition and PSC content of the species identified

In terms of nutritive value of the plants species collected from the rangelands in the area of study, there were wide variations in the parameters measured depending on species, stage of growth and plant parts analysed. Thus, the crude protein content (%DM) for example ranged from 4.0% to 24% in *Poa* sp., from 9.7% in green *Festuca* sp. to 17.2% in wilted *Festuca* sp. or from 4.0%

in the twigs to 16% in the leaves in *Santolina rosmarinifolia.* In general, as expected, leaves showed higher crude protein and lower fibre content than twigs or stem.

In terms of PSCs, the polyphenols ranged from 0.72% in *Thymus ciliatus* leaves to more than 4.05% in *Quercus rotundifolia* leaf and twig mixture. PSC concentration varied depending on the part analysed, thus we found 3.6% of polyphenols in the seeds of *Perganum harmala* but only 1.13% in the leaves. The condensed tannins (CT) levels ranged from 0.09% in *Stipa* sp. inflorescence to 1.0% in *Quercus rotundifolia.* They were positively correlated to the level of polyphenols. In this study, the levels of PSCs may have had a very limited effect on the preferences as voiced by the shepherds. In fact, in the case of *Perganum harmala*, the seeds which contain almost 3 times more polyphenols than the leaves are preferably ingested by the sheep. Such observations may be accounted for by the relatively low levels of both polyphenols and CTs in all the species analysed. These levels are below the generally accepted threshold of 2.5% which is considered by many authors as being the level at which toxic effects occur (Frutos *et al*., 2004, Waghorn *et al.,* 2003) although there is no hard and fast rule due to complex interactions amongst the different types of PSCs and nutrients (Provenza *et al.,* 2003).

IV – Conclusion

According to the sayings of shepherds, sheep keeping on the rangelands in the study area has changed very little in the past decades. The poorer forage availability experienced in recent years in Boulemane and El Ksabi was associated with water scarcity rather than with grazing practices. Tannins though ubiquitous are not found at very high levels in the plants of the steppe and do not seem to interfere with sheep feeding behaviour. Plant tannins content apparently had no noticeable bearing on the decision making of shepherds.

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Genetic affinity, ß –ODAP, homoarginine and asparagine contents of Turkish grass pea landraces

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Abstract. In 12 Turkish provinces grass pea has been cultivated for a long time. Throughout these provinces 52 grass pea landraces seeds were collected from 52 different districts. Genetic affinity levels among and inside the genotypes were determined by ISSR method. The data obtained from genetic analysis were processed by using NTSYSpc and a dendrogram has been generated. Similarity coefficients among the genotypes ranged from 0.43 to 0.82. ß-3-(-N-oxalyl)-L-2, 3-diamino propionik asit (ß –ODAP), homoarginine and asparagine analysis were done in grass pea seeds also, by using capillary electrophoresis. The data of this work reflects that ß –ODAP, homoarginine and asparagine contents of grass pea local landraces vary in a wide range from very low to high levels. A positive correlation between homoarginine and ß –ODAP quantities in seeds of 52 *Lathyrus* local landraces was proven in this work. Also, a correlation between asparagine and ß –ODAP levels was observed in some accessions. Because of grass pea genotypes with higher yield and low ß –ODAP content are relevant for future genetic and breeding studies, all of these accessions should be preserved as a genetic material.

Key words. Grass pea – Turkey - Genetic affinity – ß –ODAP – Homoarginine – Asparagine.

Affinité génétique, teneurs en ß-ODAP, homoarginine et asparagine des variétés locales de gesse de Turquie

Résumé. *Dans 12 provinces de Turquie, la gesse est cultivée depuis longue date. Dans ces provinces, des semences de gesse de 52 variétés locales ont été cueillies dans 52 districts différents. Les niveaux d'affinité génétique inter et intra-génotypes ont été déterminés par la méthode ISSR. Les données obtenues à partir de l'analyse génétique ont été traitées par NTSYSpc et un dendrogramme a été créé. Les coefficients de similarité entre les génotypes allaient de 0,43 à 0,82. Des analyses de -3-(-N-oxalyl)-L-2,3-diaminopropionic acid (ß-ODAP), homoarginine et asparagine ont été effectuées également sur les semences de gesse, par électrophorèse capillaire. Les données de ce travail reflètent que les teneurs en ß-ODAP, homoarginine et asparagine des variétés locales de gesse varient dans un large intervalle, depuis des niveaux très faibles jusqu'à des niveaux élevés. Une corrélation positive entre les quantités d'homoarginine et de ß-ODAP dans les semences des 52 variétés locales de* Lathyrus *a été trouvée dans ce travail. Une corrélation entre les niveaux d'asparagine et de ß-ODAP a également été observée dans certaines accessions. Étant donné que les génotypes de gesse présentant un meilleur rendement et une faible teneur en ß-ODAP sont importants pour de futures études de génétique et d'amélioration, toutes ces accessions devraient être conservées comme matériel génétique.*

Mots-clés. *Gesse – Turquie – Affinité génétique – ß-ODAP – Homoarginine – Asparagine.*

I – Introduction

Grass pea (*Lathyrus sativus* L.) has an amazing capability to survive under harsh environmental conditions (Campbell, 1997). Grass pea seeds have high nutritional value, with 26-30% protein content (Hanbury *et al.*, 2000). However widespread and abundant production and usage of *L. sativus* seeds as a food legume in human and animal diet has been prevented due to the presence of a free amino acid with neurotoxic effects: ß- N-*oxalyl*-*L*-α,ß-diaminopropionic acid (ß –ODAP) is suggested to be the causative agent for a paralysis of the lower limbs, known as "neurolathyrism". In addition to ODAP, *L. sativus* contains other free amino acids, such as homoarginine, which also play an important role in physiological and biochemical processes. There are controversial reports about the effects of homoarginine. Homoarginine has been proposed to modulate the toxicity of ß –ODAP (Shamin *et al.*, 2002).

Results have been successful in many studies in order to determine the phylogenetic relationships between and within *Lathyrus* populations using the ISSR primers. The aim of this paper was to provide information on the ß –ODAP, homoarginine and asparagine contents and genetic affinity of grass pea populations cultivated in Turkey.

II – Materials and methods

From various regions of Turkey, 51 grass pea and one *Lathyrus clymenum* local landraces were collected and cultivated in the experimental fields of Ondokuz Mayis University. One released cultivar was also included in the research. The seeds harvested in the year of 2011 were analysed for ß –ODAP, homoarginine and asparagine by a new, validated and simple capillary electrophoretic method. Calibration graphs were prepared by using standard mixtures. ODAP and amino acids were extracted from dry powdered grass pea seeds (0.50 g) by ethanol-water (30:70, v/v, 50.0 mL) mixture (Onar *et al.*, 2014). DNA analysis was performed in 5 plant stools by using appropriate primers and the method of ISSR to examine the genetic proximity.

III – Results and discussion

The most abundant of the three measured amino acids was homoarginine (Fig. 1). The concentration of homoarginine ranged from 2.14 mg/g to 1.27 mg/g (w/w). This amino acid was followed by ß –ODAP and the concentration ranged from 1.04 mg/g to 8.68 mg/g (w/w). For asparagine, the minimum concentration was 0.06 mg/g (w/w) while the maximum was 4.74 mg/g (w/w) of seed. Polignano *et al.* (2005) reported ß –ODAP grass pea seed concentrations as 0.24-0.64% in 47 progenies. Fikre *et al.* (2008) indicated that homoarginine was up to 0.8%, ß –ODAP was between 0.02% and 0.54% while asparagine content was between 0.01% and O.06% in 9 genotypes.

Comparison of these results with the data of this work reveals that homoarginine, ß –ODAP and asparagine concentrations of 52 *Lathyrus* local landraces seeds spread from low to high levels. Linear regression model of ANOVA revealed a positive significant correlation between ß –ODAP and homoarginine concentrations of seeds (Fig. 1). This is very important because homoarginine can modulate the toxicity of ß –ODAP (Shamin *et al.*, 2002).

This finding is in agreement with literature information of Piergiovanni and Damascelli (2011). Although there is a significant positive correlation between ß –ODAP and asparagine concentrations for some genotypes as can be seen in Fig. 1.

The ß –ODAP content of grass pea is known to vary widely, both among genotypes and environments (Campbell, 1997). We compared the data of ß –ODAP with the data published by Basaran *et al.* (2011) that belongs to the same *Lathyrus* local landraces (used the same analysis method). A statistical difference between ß –ODAP contents of 2011 harvest and collected samples in 2007 was found at 95% confidence level. The ß –ODAP data of this work reflect the differences due to the environment, because grass pea seeds of this study were obtained by cultivation of samples collected by Basaran *et al.* (2011).

The concentrations of the isolated DNA samples ranged between 17.3 nanogram/milliliter (ng/mL) and 267.5 ng/mL. In the used primers, the band sizes in each genotype were obtained ranging

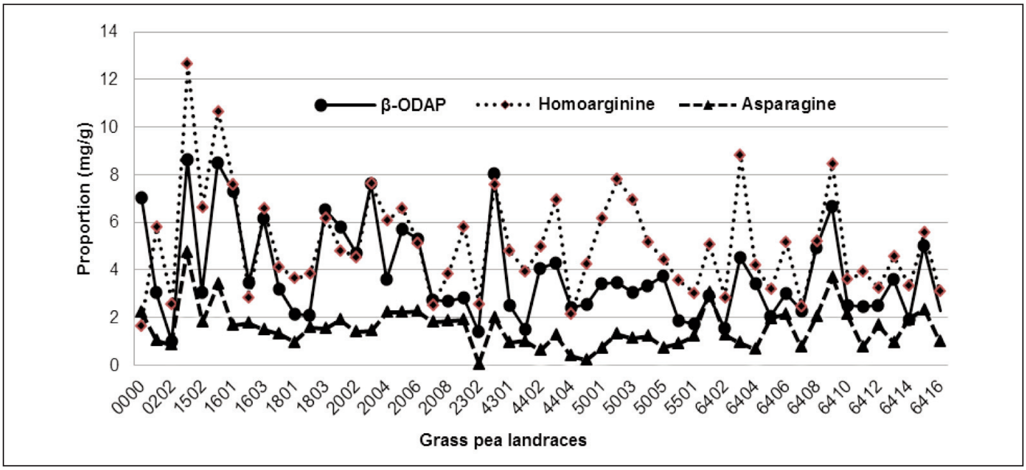

Fig. 1. Proportions of ß –ODAP, homoarginine and asparagine in seed extracts of 52 grass pea populations.

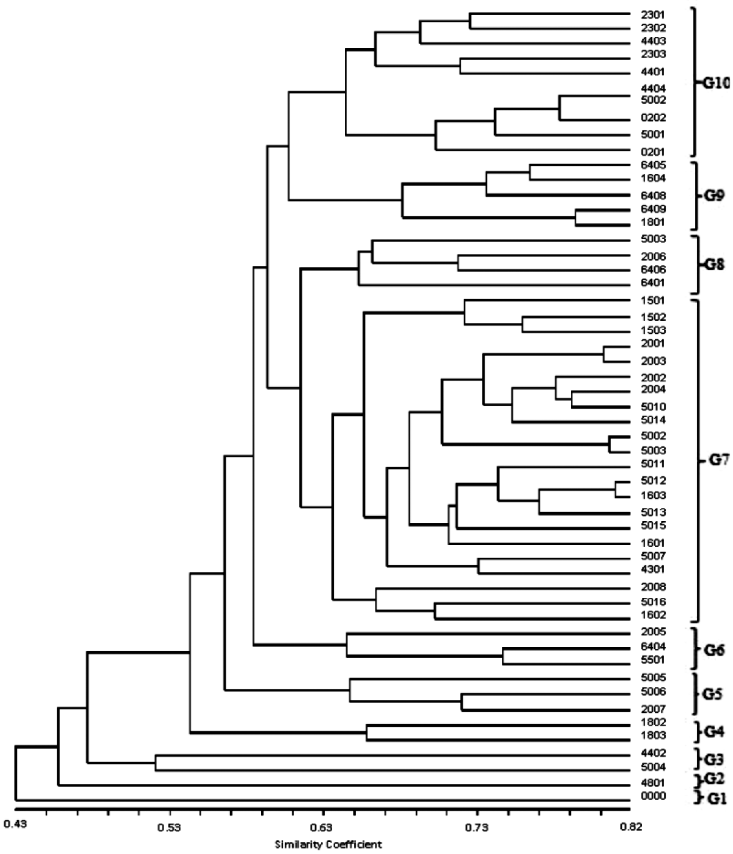

Fig. 2. Genetically similarity dendrogram created with ISSR markers for grass pea genotypes.

between 0.23 kilo base (kb) and 1.28 kb. The DNA samples from grass pea genotypes were analysed through the program of NTSYSpc 2.0 after screening and scoring via ISSR primers. The lowest genetic relationship was determined between the genotype numbered 4402 and cultivar Gurbuz with the value of 0.244. The maximum genetic relationship was determined between the genotype numbered 4404 and the genotype numbered 5002 with the value of 0.825. Furthermore, the analyses except cultivar Gurbuz showed that genetically the furthest genotypes were found to be the genotypes numbered 1802 and 5004 with the similarity coefficient of 0.313. The average values of genetic distances among all genotypes identified as 0.592. Ten main groups were formed in dendrogram (Fig. 2). The genotypes collected from similar ecological conditions have been found to combine as the basis of the subgroup of genotypes. Probably there has been seed exchange among the local farmers.

IV – Conclusions

The *Lathyrus* local landraces were collected from traditional farmers in various regions of Turkey. The data of this work reflects that ß –ODAP, homoarginine, asparagine contents and genetic affinity of grass pea local landraces vary in a wide range from very low to high levels. Although all of these accessions should be preserved as a genetic material, the grass pea genotypes with higher yield and low ß –ODAP content are relevant for future genetic and breeding studies.

A positive correlation between homoarginine and ß –ODAP quantities in seeds of 52 *Lathyrus* local landraces was proven in this work. This is very important because homoarginine can modulate the toxicity of ß –ODAP (Shamin *et al.*, 2002). The results obtained from this work and the other study conducted with the same landraces showed that environment highly affected ß –ODAP content of *Lathyrus* seeds.

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Livestock winter feeding in prehistory: role of browse leaves, annual twigs of woody plants, senescent grasses, *Hedera helix* and *Viscum album*

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Abstract. Browse plants, *Viscum album*, *Hedera helix* and annual twigs were probably the principal winter feeding of livestock in prehistory. We investigated the nutritional value of leaves and annual twigs of 13 principal broad-leaved woody species together with *Viscum album* and *Hedera helix*, some of them recorded by archaeologists as exploited for livestock foddering and others rarely used. We collected their annual twigs and senescent grass biomass in February in the Czech Republic. Concentration of nitrogen, phosphorus, fibre fractions NDF, ADF and lignin were analysed in all samples. *Carpinus*, *Fagus* and *Quercus* had low nutritive value whereas *Ulmus*, *Fraxinus*, *Tilia* and *Acer* with the highest nutritive value. Winter twigs had lower nutritive value than their leaves, meadow hay or senescent steppe grasses. *Hedera* and *Viscum* in winter had substantially higher nutritive value than twigs of woody plants. Livestock winter feeding by woody species could have important consequences on livestock breeding and on forests in Europe during last 10000 years.

Keywords. Cattle – Forest vegetation – Neolithic – Year-round grazing.

***L'alimentation de bétail pendant l'hiver dans la préhistoire : le rôle en tant que fourrage des feuilles, des branches annuelles des arbres, et des graminées sénescentes,* Hedera helix *et* Viscum album**

Résumé. *Dans la préhistoire, les arbres,* Viscum album, Hedera helix *et des branches annuelles ont été probablement le fourrage principal pour le bétail pendant l'hiver. Nous avons étudié la valeur nutritive des feuilles et des branches annuelles de 13 espèces des ligneux y compris* Viscum album *et* Hedera helix*, certaines d'entre-elles ayant été identifiées par les archéologues comme exploitées pour l'alimentation du bétail et d'autres non-exploitées. Nous avons collecté leurs branches annuelles et des graminées sénescentes en février dans la République tchèque. Les concentrations en azote, en phosphore, les teneurs en fibres NDF, ADF et en lignine ont été analysées dans les échantillons.* Carpinus*,* Fagus *et* Quercus *ont eu une valeur nutritive faible, alors que celle-ci était élevée pour* Ulmus*,* Fraxinus*,* Tilia *et* Acer*. Les branches annuelles on eu une valeur nutritive plus basse que celle de leurs feuilles, du foin ou de la biomasse sénescente sur les prairies.* Hedera *et* Viscum *ont eu en hiver une valeur nutritive plus élevée que celles des branches des arbres. L'alimentation du bétail pendant l'hiver par des espèces ligneuses a pu avoir des conséquences importantes sur l'élevage et la survie du bétail et sur le développement des forêts en Europe pendant les derniers 10000 ans.*

Mots-clés. *Bovins – Végétation des forêts – Néolithique – Pâturage annuel.*

I – Introduction

It is generally accepted that the livestock of prehistoric farmers in Central and Northern Europe grazed on pastures, fallows, stubbles and in forests during the vegetation season. During the winter time livestock was probably fed by leaves of main broad-leaved woody species, harvested and dried during the vegetation season (Rasmussen, 1993). Livestock was probably also partly fed by winter collected twigs (Haas *et al.,* 1998). Leaf-foddering should thus have played the main role in winter feeding of livestock in Europe since the beginning of farming and animal husbandry till fabrication of first scythes which enabled cutting of grasslands and hay making (Hejcman *et al.,* 2013). Therefore, hay making step by step replaced foddering by browse species, although browse leaf fodder was used as a supplement to winter hay feeding in some regions up to the present (Slotte, 2001). The theory of leaf foddering in the Neolithic is based on archaeological evidence of woody species recorded in coprolites of goats, sheep and cattle discovered in Switzerland, Germany and in France (e.g. Rasmussen, 1993; Delhon *et al.,* 2008).However storage of dried browse leaves for winter use could be insufficient, hence year-round livestock grazing without any or with a very limited amount of supplementary feeding could be thus most probably the dominant means of livestock grazing system in Central Europe since the Neolithic up to the 18th century. This rises a question which plants could be grazed or browsed by livestock during winter in a forest and how such type of forage could satisfy requirements of livestock for nutrients. Thus the objective of this work was to determine the nutritive value of winter collected annual twigs of the main woody species (*Acer platanoides*, *Betula pendula*, *Carpinus betulus*, *Corylus avellana*, *Fagus sylvatica*, *Fraxinus excelsior*, *Populus tremula*, *Quercus robur*, *Salix caprea*, *Tilia cordata* and *Ulmus glabra*), leaves of mistletoe (*Viscum album*) and ivy (*Hedera helix*), and to compare them with senescent winter steppe grassland biomass and meadow hay.

II – Materials and methods

We collected leaf biomass and annual twigs with buds of 13 woody species common in Central Europe at least since the Neolithic (5600 BC). Samples were taken from at least three individuals of each species at four sites in February 2013. Selected sites were broad-leaved forests and their margins in the Czech Republic: We collected in total 52 (13 species x four site replicates) annual twigs and winter leaf biomass samples which were then oven-dried at 60 °C for 48 hours and ground to powder.

In twig and leaf samples, the concentration of nitrogen (N) and phosphorus (P) and the content of neutral- (NDF) and acid- detergent fibre (ADF) and acid detergent lignin (ADL) were determined by standard analytical methods and according to AOAC (1984) in an accredited laboratory.

Data tested by the Kolmogorov-Smirnov test of normality, met assumptions for the use of parametric tests. One-way ANOVA followed by post-hoc comparison using the Tukey's multiple range tests in Statistica 9.0 program (StatSoft, Tulsa, USA) were used to identify significant differences in concentrations of nutrients and NDF, ADF and ADL contents among species.

III – Results and discussion

There were significant differences in the concentration of all investigated nutrients in annual twigs and winter biomass among browse plant species. *Viscum* was the plant with highest concentration of N, P and the lowest NDF and very low ADL content. Very similar nutrient pattern was found in *Hedera*. On the other hand, concentration of N was the lowest in *Fraxinus* and *Populus*, P was lowest in *Quercus, Carpinus* and *Fagus.* Content of NDF was rather high in *Carpinus* and *Fagus*, similarly as the indigestible ADL together with *Betula* (Table 1).

Winter green leaves such as *Hedera* and *Viscum* belong to the best forage which might have been available in forests during the winter. Their nutritive value, according to the highest N and lowest NDF and lignin concentrations, was higher than the nutritive value of all winter collected annual twigs of woody species. Their high nutritive value is comparable only with winter leaves of *Rubus fruticosus* (Verheyden-Tixier *et al.,* 2008) which was also among plant species recorded in Neolithic coprolites of sheep/goat in the Grande Rivoire rock shelter in France (Martin, 2011). According to macro-remains of *Viscum* found at archaeological localities (Kühn *et al.*, 2013), we deduce that the ancient farmers collected *Hedera* and *Viscum* during the wintertime intentionally and used them for the feeding of animals, because they are the richest source of N and P in winter. *Viscum* was collected, although the amount of its biomass was relatively small in forests in comparison to the biomass of woody species and its collection was laborious. Therefore, we suggest that *Viscum* was probably used as a supplement for feeding of privileged animals such as lactating and pregnant cows or goats with the highest N and P requirements, researched by farmers intentionally. Nowadays the high nutritive value of *Viscum* is also well known to hunters in Austria or in the Czech Republic who still use the biomass of *Viscum* to attract deer to particular places during the winter. Similarly to *Viscum*, *Hedera* has higher nutritive value than annual twigs of woody species and this is why it was probably selectively grazed by livestock in winter. In the experiment by Van Uytvanck *et al.* (2009), for example, *Hedera* completely disappeared from forest managed for several years by year-round cattle grazing. Therefore a decrease in the pollen production of *Hedera* in different periods (e.g. Bottema, 2001) could be considered as an indicator of human activities in forests connected with livestock breeding.

Table 1. Concentration (means ± standard error of mean) of nitrogen (N), phosphorus (P), neutral detergent fibre (NDF) and acid detergent lignin (ADL) in annual twigs of browse plants. Calculated by one-way ANOVA, differences among species for all chemical properties were significant (P<0.01). Using the Tukey post-hoc comparison test, species with the same letter were not significantly different

Species	N (g kg^{-1})	P (g kg^{-1})	NDF (g kg^{-1})	ADL (g kg^{-1})
Acer platanoides	15.6 ± 1.4 ^{ab}	1.8 ± 0.2 ^{ab}	577 ± 14^{cd}	225 ± 14 ^{def}
Betula pendula	13.9 ± 0.4 ^{a}	1.6 ± 0.1 ^{ab}	600 ± 24^{cd}	266 ± 24 ^{f}
Carpinus betulus	14.7 ± 0.8 ^{a}	1.3 ± 0.1 ^{a}	642 ± 27^{d}	206 ± 10 ^{bcdef}
Corylus avellana	17.9 ± 2.1 ^{ab}	1.8 ± 0.2 ^{ab}	551 ± 58 ^{bcd}	255 ± 20 ^{f}
Fagus sylvatica	14.4 ± 1.1 ^{a}	1.3 ± 0.1 ^{a}	632 ± 31^{d}	261 ± 17 ^{f}
Fraxinus excelsior	12.4 ± 0.7 ^{a}	1.5 ± 0.1 ^{ab}	587 ± 31^{cd}	144 ± 15 ^{ab}
Hedera helix	16.9 ± 1.0 ^{ab}	1.4 ± 0.05 ^{a}	392 ± 9 ^{a}	112 ± 5 ^{a}
Populus tremula	12.5 ± 0.7 ^{a}	1.5 ± 0.2 ^{ab}	577 ± 38^{cd}	226 ± 20 ^{def}
Quercus robur	14.0 ± 0.3 ^{a}	1.2 ± 0.1 ^{a}	582 ± 29^{cd}	238 ± 8 ^{ef}
Salix capraea	15.9 ± 0.6 ^{ab}	2.1 ± 0.2 ^{ab}	488 ± 10 ^{abc}	207 ± 18 ^{bcdef}
Tilia cordata	15.2 ± 1.2 ^{ab}	1.9 ± 0.2 ^{ab}	596 ± 23^{cd}	215 ± 9 ^{cdef}
Ulmus glabra	14.6 ± 0.6 ^{a}	1.5 ± 0.05 ^{ab}	456 ± 6 ^{abc}	213 ± 6 ^{bcdef}
Viscum album	21.1 ± 2.3 ^{b}	2.4 ± 0.4 ^{b}	431 ± 13 ^{ab}	150 ± 7 ^{abc}
Meadow hay	20.0 – 28.7	2.7 – 3.7	500-680	40
Steppe grass winter biomass	17.9	2	724	89
Optimum range for cattle	19.2 – 25.6	2.3 – 3.7	330-450	max. 80

Nutritive value of all winter collected annual twigs of woody species was substantially lower than the nutritive value of meadow hay (Table 1) and also spring collected leaf-fodder of broad-leaved woody species (Verheyden-Tixier *et al.,* 2008; Hejcmanová *et al.,* 2013). Low nutritive value of twigs was given by insufficient concentrations of N and P and too high concentrations of NDF and lignin. The next characteristic aspect of twigs was relatively small differences in the concentration of P among individual species in comparison to their leaves in which differences were substantially higher. Twigs of *Fagus* and *Carpinus* had absolutely the worst nutritive value because of their highest lignin content which is in accordance with their leaves (Hejcmanová *et al.,* 2013). Leaf-fodder of *Ulmus* and *Tilia* were the best of all woody species in Central Europe and this is also consistent with the nutritive value of their twigs which was also comparable to *Salix*. Senescent grassland biomass collected in winter on steppe grassland was of better nutritive value than twigs of woody species because of higher concentrations of N and P. This suggests that livestock first of all grazed senescent grassland biomass and then, if no other alternatives were available, started to browse trees.

IV – Conclusions

We suggest that winter collected *Hedera* and *Viscum* could have been searched by prehistoric farmers for supplementary feeding of privileged animals because of their high nutritive value. Prehistoric farmers could also feed livestock directly in forests by driving herds to intentionally cut trees or their branches with *Hedera* or *Viscum.* Winter collected annual twigs of all woody species had very low nutritive value, much lower than the meadow hay, leaf-fodder or senescent steppe grassland biomass. After grazing of senescent grassland biomass, annual twigs of woody species were probably browsed by livestock. Insufficient winter nutrition could be one of causes of the low body size of cattle recorded since the Neolithic up to the 18th century. Year-round livestock grazing practiced by ancient farmers seems to be the key driver for the formation of open forests.

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The DNA based characterization of the diet from digested samples: a reliability study in ruminants

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Abstract. Characterizing the diet of ruminants at pasture in diversified grasslands is a difficult step that could be realized by using the DNA-based methods recently developed for assessing the composition of environmental samples (i.e. metabarcoding approach). In this study, we performed two experiments to assess the performance of this method. The diet was inferred from rumen and faecal samples after DNA extraction, subsequent amplification of a short fragment of chloroplast DNA with universal primers used for plant DNA identification (*trn*L approach), and sequencing of the PCR products using HighSeq Illumina system. The first experiment compared the results obtained from replicated extractions and PCRs performed on faecal samples from cattle with a diversified diet, and showed a high reproducibility of the method. The second experiment was designed to assess the semi-quantitative aspects of this approach. Five diets were allocated to five sheep fed *ad libitum* according to a 5 × 5 Latin square design. The diets were mixtures of green fodder differing by their white clover: ryegrass ratios (i.e., 0:100, 25:75, 50:50, 75:25 and 100:0). The analysis of rumen contents allowed a reliable estimation of the proportion of each species ingested, while the information was much less accurate from faecal samples. Technical and analytical solutions are currently tested in order to improve the quantitative information obtained from faecal samples.

Keywords. Ruminants – Diet analysis – DNA metabarcoding – Chloroplast *trn*L intron – Sequencing.

Caractérisation du régime alimentaire des ruminants à partir de l'analyse des produits de la digestion par DNA metabarcoding

Résumé. *La caractérisation du régime alimentaire des ruminants au pâturage au sein de prairies diversifiées est un verrou méthodologique qui pourrait en partie être levé à l'aide de méthodes basées sur l'analyse de l'ADN présent dans des échantillons environnementaux (métabarcoding). Pour évaluer la fiabilité de cette technique, nous avons mené deux expérimentations au cours desquelles l'ADN issu d'échantillons de contenu du rumen et de fèces a été extrait. Un fragment court d'ADN chloroplastique a été amplifié en utilisant des amorces universelles (approche trnL) et les produits PCR ont été séquencés en utilisant un système HighSeq Illumina. La première expérimentation a consisté à comparer les résultats obtenus à partir d'extractions et de PCRs répétées sur des fèces de bovins alimentés avec un régime diversifié et a permis de valider la reproductibilité de la méthode. La deuxième expérimentation a été conçue pour évaluer les aspects semi-quantitatifs de cette approche. Cinq moutons ont été alimentés* ad libitum *selon un carré latin 5 × 5 avec cinq mélanges binaires de ray-grass anglais et de trèfle blanc en proportions variables (0:100, 25:75, 50:50, 75:25 et 100:0). Les analyses de contenu du rumen ont permis de quantifier de manière fiable les proportions ingérées de chaque espèce, tandis que l'information issue de l'analyse des fèces était beaucoup moins précise. Des solutions techniques et analytiques sont actuellement examinées pour améliorer la quantification à partir des échantillons fécaux.*

Mots-clés. Ruminants – Analyse du régime alimentaire – ADN metabarcoding – Intron chloroplastique *trn*L – Séquençage.

I – Introduction

Characterizing the diet of grazing ruminants in complex environment is an important methodological gap for the research on the animal-plants relationships in diversified grasslands (permanent or multispecies temporary grasslands). The current methods are based on the direct observation of the foraging behaviour (Holechek *et al.*, 1982), the microhistological techniques (Alipayo *et al.*, 1992), the extraction and the analysis of long chain alkanes presents in plant cuticular wax (Dove and Mayes, 1996), or the spectral methods (NIRS, near infrared reflectance spectroscopy) (Keli *et al.*, 2008). These methods are time-consuming, not very accurate, or not well adapted to diversified swards.

The recent development of a molecular technique allowing the identification of plant species in complex or degraded matrices (DNA metabarcoding) could allow a methodological innovation in this field (Pegard *et al.*, 2009). This technique is based on the analysis of very short residual fragments of plant DNA in digestive residues using a couple of universal primers targeting a variable area of intron of gene chloroplastic *trn*L (UAA) of the plants (Valentini *et al.*, 2009). DNA metabarcoding has recently been tested to assess qualitatively the composition of the diet of cattle in grasslands with contrasted botanic diversity (Farruggia *et al.*, 2012). Twice as many taxons were found in the faeces from animals grazing on species rich grassland compared to faeces from animals grazing on species poor grassland.

The objective of this work was to test the reproducibility and the potential of the DNA metabarcoding technique to characterize quantitatively the diet of ruminants fed multispecies forages.

II – Materials and methods

Experiment 1: Faecal samples were taken on five dairy cows grazing a species-rich grassland. From each of the five samples, three subsamples were prepared on which the DNA was extracted with the DNeasy Blood and Tissue Kit (QIAgen) following the manufacturer's instructions. Each DNA extracts were amplified in triplicate with the *trn*L gh primers (g primer, GGGCAATCCTGAGCCAA; h primer, CCATTGAGTCTCTGCACCTATC; Taberlet *et al*., 2007). Paired-end sequencing (100 nucleotides on each extremity of the DNA fragments) from all the PCR products (n = 45) was carried out at the French National Sequencing Centre (CEA Genoscope) on a high-throughput sequencing technology (Illumina HiSeq 2000 system).

Experiment 2: To test the semi-quantitative approach of the *trn*L approach for estimating the diet of herbivores, an experiment on sheep was conducted. During the period of May–July 2011, pure plots of white clover (*Trifolium repens*) and ryegrass (*Lolium perenne*) were used to test five binary mixtures differing by their clover:ryegrass ratios of 0:100, 25:75, 50:50, 75:25 and 100:0. The five diets were allocated to five 1-year-old male Texel sheep fed *ad libitum* according to a 5 × 5 Latin square design. For each sheep and each diet, one rumen sample and one faecal sample were collected on two successive days (n = 50). The collection started 13 days after the beginning of the diet in order to prevent an effect from the previous diet. The DNA analysis was performed following the procedure used in Experiment 1. The sequences produced were assigned to a species using programs from the OBITools software package (avalaible at http://metabarcoding.org/obitools). The relative number of sequences obtained for each plant species in the PCR products was compared to the actual relative proportion of these species in the diet.

III – Results and discussion

In Experiment 1, each replicate has been first characterized by a set of sequences called MOTUS (Molecular taxonomic unit) without species identification. A principal component analysis (PCA) was carried out on these MOTUS to test the reproducibility of the method (Fig. 1). The three axis explained 53%, 14% and 11% of the total variance, respectively. Axis 1 and 2 highlighted one deviant PCR product. Axis 2 and 3 of the PCA showed a good discrimination of the MOTUS on the basis of cows but not on the basis of extractions and PCR. Hierarchical ANOVA performed on the factorial coordinates of the PCA confirmed that there was no effect of extraction or PCRs. The observed deviant PCR product could result from the production of errors or the amplification of very minor species in the first cycles of the PCR, leading to a non-representative final product (Coissac *et al*., 2012). Taking these results together, it can be recommended to perform one extraction per sample and three PCRs per extraction, which makes it possible to eliminate the deviant PCRs detected by the PCA. The same analysis has been made after assignment of taxa to generated sequences. The reproducibility of the results was better because this step also took into account the possibility of errors on the assigned sequences when comparing at the reference index.

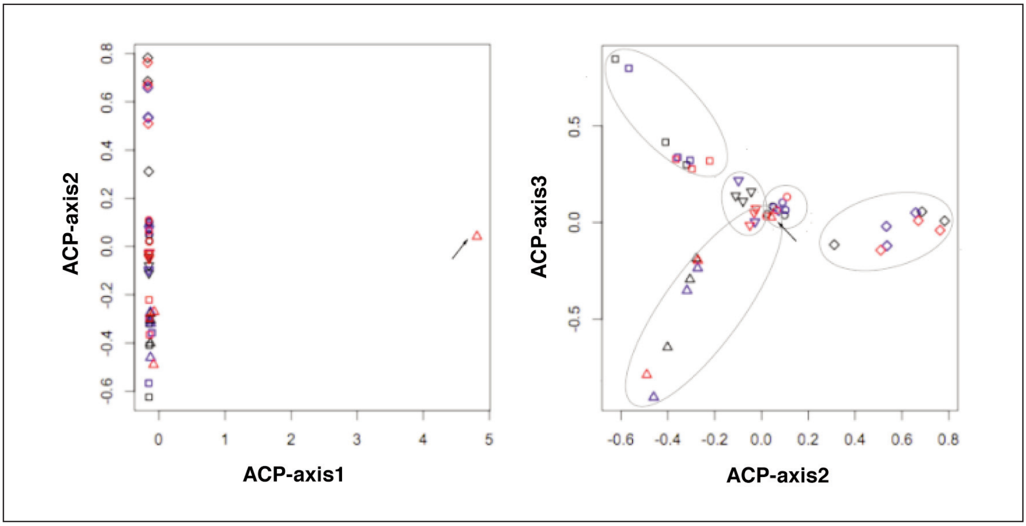

Fig. 1. Principal Component Analysis based on the sequences (MOTUS, Molecular Taxonomic Units) generated with *trn*L approach. Each type of marker represents a cow, each colour corresponds to one extraction and each point is a PCR. Each ellipse corresponds to one of the five cows.

In Experiment 2, the results obtained from rumen contents showed a very good determination of the proportions of ryegrass and white clover in the diet (Fig. 2). The Pearson correlation coefficient between the actual fraction of ryegrass in the diet and the proportion estimated using the DNA metabarcoding approach was highly significant ($r = 0.87$, $P<0.001$).

The semi-quantification was less accurate when the DNA metabarcoding analyses were carried out on faeces, since the proportions of ryegrass in the diet were underestimated (Fig. 2). This could be explained by a lower recovery of the ryegrass DNA in faeces in comparison with rumen contents due to a differential in the post-rumen digestibility. A bias could occur due to the method of DNA extraction used, which tends to support the recovery of the intracellular DNA.

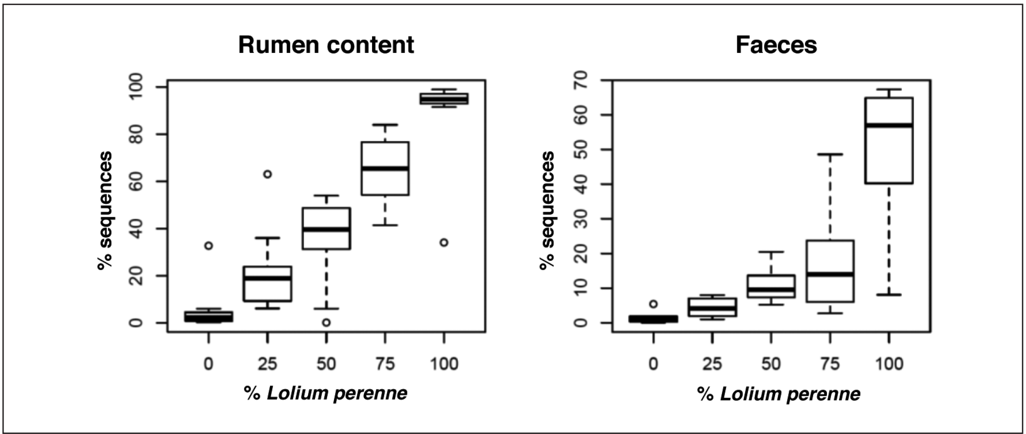

Fig. 2. Percentages of ryegrass (*Lolium perenne*) sequences found in the PCR products generated from rumen contents and faeces from sheep fed ryegrass-white clover mixtures in various proportions.

IV – Conclusions

Overall, the DNA metabarcoding appears reproducible to characterize the diet of ruminants, although deviant PCRs can be observed. One extraction per sample and three PCRs per extraction can be recommended. Very promising results were obtained from rumen contents which validates the possibility of determining the proportions of species by DNA metabarcoding for simple mixtures. The comprehension of the biases observed between plant species and the kind of digestive residues (rumen or faeces) should make it possible to improve the use of this methodology, in particular by improving the method of DNA extraction.

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Dairy cattle on Norwegian alpine rangelands – grazing preferences and milk quality

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Abstract. The results from the study 'Effects of vegetation and grazing preferences on the quality of alpine dairy products' will be presented. The main objective of the project was to investigate the connections between alpine rangeland vegetation, landscape use and grazing preferences of free ranging dairy cattle and the milk quality with regard to fatty acid composition and content of various secondary plant metabolites. Two herds in two different geographical summer farming areas were studied during three grazing seasons (2007-2009). Area use and grazing preferences were studied by using high frequency GPS data in combination with detailed vegetation mapping, field studies of animal behaviour, microhistological analysis of faeces, analyses of rangeland vegetation composition and records of grazed plant species. The results showed that when available, the dairy cattle preferred open areas with a vegetation rich in species, dominated by grass and herb species. Different plant groups influenced the chemical composition of the milk differently. The study concludes that milk from alpine rangelands differ from "normal" summer and winter milk in Norway by having a healthier fatty acid composition and a higher content of various secondary plant metabolites, which may be a potential for development of labelled products. Also, preventing regrowth of alpine rangelands seems to be important, not only to maintain high biodiversity but also to secure good product quality.

Keywords. Alpine rangelands – Biodiversity – Grazing preferences – Milk quality – GPS.

Des vaches laitières sur les pâturages alpins norvégiens – préférences au pâturage et qualité du lait

Résumé. *Les résultats présentés concernent une étude sur «les effets de la végétation et des préférences au pâturage sur la qualité des produits laitiers alpins». L`objectif était d'examiner la relation entre les pâturages alpins, l`utilisation des parcelles, les préférences alimentaires des bovins et la qualité du lait, concernant sa composition en acide gras et en métabolites végétaux secondaires. Deux troupeaux dans deux régions de pâturage estival différentes ont été étudiés pendent trois saisons (2007-2009). L'utilisation des parcelles et les préférences alimentaires ont été étudiées par un suivi GPS haute fréquence en combinaison avec une analyse détaillée de la végétation, des études du comportement animal sur le terrain, des analyses micro histologiques des fèces, des analyses de la composition des plantes et un suivi des plantes broutées. Les résultats montrent que les bovins laitiers préfèrent, si possible, les espaces ouverts et une végétation riche, dominée par les graminées et les herbes. Les différents types de végétation influencent la composition chimique du lait. L'étude conclut que le lait des pâturages alpins est différent du lait 'normal' estival et hivernal en Norvège, ayant une composition en acides gras plus saine et un contenu plus élevé en métabolites végétaux secondaires, offrant ainsi un potentiel de développement de produits labellisés. Il semble important de préserver les pâturages alpins du reboisement pour maintenir une grande biodiversité et garantir la qualité des produits.*

Mots-clés. *Pâturages alpins – Biodiversité – Préférences de pâturage – Qualité du lait – GPS.*

I – Introduction

Agriculture is still one of the most important businesses for settlement in alpine regions in Norway. In such areas, the traditional production system for milk production was summer farming on alpine rangelands. However, agricultural practices changed during the last century and milk production in alpine areas decreased considerably. In Norway, about 1200 mountainous summer farms are still in use. The grazing animals at these summer farms maintain landscape qualities, grazing resources and high biodiversity, which are important common goods and a contribution to local resource exploitation. If these traditional and extensive production systems shall survive, however, it is necessary to bring in a new economy, which makes it possible to compete with bulk products from intensive production systems. One strategy, which has proved to help alpine farmers in e.g. France and Italy, is diversification of dairy products, based on scientific evidence, which may give products from extensive product systems in alpine regions a better price in the market (Lombardi *et al.,* 2008). Milk from species rich pastures in alpine regions often exhibits a healthier fatty acid composition than milk produced on species poor pastures and pastures in the lowlands (Collomb *et al.,* 2002a). There is still generally little knowledge about the quality of Norwegian alpine milk products and how this quality is related to the grazing preferences of free ranging cattle and species composition of the grazing plants. The main objectives in this study was thus to investigate: 1. Area use, grazing patterns and grazing preferences of free ranging dairy cattle in two alpine rangelands; 2. Fatty acid composition and the content of various antioxidants and terpenes in the milk from the dairy cattle in the study areas; 3. Possible connections between alpine rangelands, grazed plants groups and milk quality.

II – Materials and methods

1. Study sites and herds

The study sites were two summer farms situated in two different alpine regions in south-central Norway, Valdres and Hallingdal, with dairy cattle grazing alpine ranges. The sites are referred to as site 1 (in Valdres) and 2 (in Hallingdal). Site 1 (60°57´N; 8°49´E) is situated approximately 910 m a.s.l., in the northern boreal vegetation zone. Site 2 (60°32´N; 8°11´E) is located approximately 1040 m a.s.l. in the transition between the northern boreal and low alpine vegetation zone. The animals in both herds are of the breed Norwegian Red. At site 1, the herd consisted of 12-14 dairy cows and 7-9 heifers while the herd at site 2 consisted of 18-20 dairy cows and 1-3 heifers. The herds grazed on alpine rangeland 9-11 hours per day, after the morning milking and until they returned to the milking barn in the afternoon. After the afternoon milking, the cattle were let out in fenced cultivated pastures at the summer farms where they spent the night resting and grazing until the morning milking. Supplemental feeding consisted of 4-6 kg grain based concentrates per cow per day at both sites.

2. GPS collars, field studies and vegetation maps

Global positioning system (GPS) units were utilised for tracking the grazing cattle. Five dairy cows in the herds wore collars with GPS units while they were out grazing between morning and afternoon milking, during two study periods (in July and August) in 2007-2009. The GPS units were logging the geographical position and time every 5 seconds. The data from all days were integrated in a Geographical Information System (GIS); thus, the movement of the cows could be analysed and presented on maps. In 2008, parallel field studies of animal behaviour were done during the periods when the cattle wore GPS collars. By using parameters derived from the GPS data alone, models of behaviour were developed and validated by observation data, and the GPS data could finally be classified into walking, grazing and resting. Vegetation maps, based on aerial photo interpretation and field work, were made from both study areas. Digital aerial near-infrared colour photos (CIR) with a pixel resolution of 0.20 m x 0.20 m on ground level were used for interpretation. Natural and semi-natural vegetation types available for grazing were interpreted according to a classification system based on Sickel *et al.* (2004). The vegetation maps were used together with GPS data in GIS analysis.

3. Milk sampling procedures and analysis

In all study years (2007-2009), milk samples (morning milk) were taken from 9-10 cows in each herd, once in July and once in August at both study sites for analysis of fatty acid composition, carotenoids, vitamin E and terpenes. Analysis of tocopherol and carotenoids were performed at a commercial laboratory using HPLC with fluorescence and diode array detectors, respectively. Methylated fatty acids were analysed at the same laboratory using GC with flame ionization detector. Terpenes were sampled using a head space method and subsequently analysed using GC-MS at the University of Copenhagen, Department of Food Science.

4. Diet variables

Faeces samples were collected and prepared for microhistological analyses following the procedures of Garcia-Gonzalez (1984). A set of individual diet variables was made from the results of the microhistological analyses of faeces samples taken from the GPS cows. The species and plant families detected were grouped in five functional groups: woody species, grasses, sedges, herbs and Pteridophytes, and the proportions of grazed plant groups were calculated. The faeces samples were taken day 1-5 in the week, and the milk samples were taken on day 7 in the same week. Grazed plant species were also recorded by plot analysis on grazed patches. A grazed patch was defined as a patch where a cow was observed grazing continuously for 1 minute or more. Five grazed patches from each locality within a vegetation type were marked with wooden sticks and analysed by putting down a frame sized 0.5 m x 0.5 m around the stick. All species within the plot were recorded and scored with respect to whether they were grazed on or not. The proportions of grazed plant groups (woody species, grasses, sedges, herbs and Pteridophytes) within each grazed vegetation type were calculated. For every GPS cow, a set of diet variables were calculated by multiplying the proportions of grazed plant groups within the vegetation type with the proportion of time spent grazing in the vegetation type the week before milk sampling, summing up for all grazed vegetation types and calculating the overall proportions of eaten plant groups from that week.

5. Statistical analysis

For the analysis used to develop GPS models, the data were stored in a PostGIS 1.5 enabled PostgreSQL 9.1.8 database. To do the analyses, the dataset were pulled into R 2.14.1. The scripts used in the analyses are available at http://github.com/sickel/cowplot at commit f4353c8. To investigate potential relationships between diet and the chemical composition of the milk, generalised linear mixed modelling was performed using the milk data as response variables and different measures of cow diet as explanatory variables. The analyses were performed in R.

III – Results and discussion

It was possible to classify grazing behaviour correctly from the high frequency GPS data with as much as 92 percent accuracy. Grazing was the main activity and the cows preferred to graze in open areas with a vegetation rich in species, dominated by grass and herb species. Previous studies have shown that cattle select grasslands for grazing (Sickel *et al.*, 2004) probably due to a combination of high plant density and nutrient content (Dumont *et al.,* 2007). The study also reveals that to maintain the biodiversity and grazing value of these semi-natural species rich habitats it may be necessary to supply grazing with clearing of bushes and trees. Furthermore, the analytical results which characterize the milk from summer farms in this project, and which can be said to give rise to unique milk products are low contents of the unfavourable fatty acids C14:0 and C16:0, high levels of the favourable fatty acids C18:3 n-6 and CLA, a low ratio omega-6:omega-3 and a relatively high number of terpenes. These findings are in accordance with Martin *et al.* (2005). The results of the statistical modelling indicate that the different plant groups on the rangelands were significantly related to specific chemical components in the milk. The omega 3 fatty acid C18:3 and β-carotene were both positively related to herbs. This is in accordance with the studies of Collomb *et al.* (2002b) who found that PUFAs were positively correlated with herb species from the families *Asteraceae, Apiaceae, Rosaceae* and *Fabaceae*. Our results corroborate these findings as some of the most frequently eaten herb species at our study sites also belonged to three of these families. The levels of C18:2 n-6 decreased with increasing levels of woody species, grasses and sedges in the diet. Woody species and sedges occur with higher proportions in the diet at site 1 where C18:2 n-6 was found to occur with lower levels than at site 2 where herbs have higher proportions in the diet. As Collomb *et al.* (2002b) found herbs to be positively correlated with PUFAs this might also explain this negative relation of C18:2 n-6 with other plant groups. The ratio omega-6:omega-3 decreased as the intake of grass increased in the diet. This may be explained by decreasing levels of C18:2 n-6 with increased levels of grasses in the diet as discussed above. Lot of grass in the diet may also imply grazing on open grass and herb rich field layer, which also lead to a higher intake of herbs. Herbs increase the levels of C18:3 n-3 as discussed above. A low ratio omega-6:omega-3 may thus be explained by either less C18:2 n-6 or more C18:3 n-6, or a combination of both. Oleic acid, C18:1 c9, was positively related to woody species and Pteridophytes and the saturated fatty acid C14:0 was on the contrary negatively related to these variables. It is difficult to say whether there is a direct influence of woody species and Pteridophytes on the levels of these fatty acids in the milk or if there are underlying factors e.g. energy shortage, which are the real explanations of these observed relationships.

Acknowledgments

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Effects of pasture type on carcass and meat characteristics of kid goats

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Abstract. The aim of this experiment was to study the effect of the feeding system in two mountain areas from the Tunisian Northwest (Bahra and Ain Draham) on the carcass and meat characteristics of goats. In the region of Ain Draham, characterized by mountainous terrain and soil unsuitable for crops, goats grazed natural forests with dominance of woody species. While in the region of Bahra, grazing pasture is based on herbaceous and goats were supplemented with concentrate and hay. At the age of five months, ten goats from each region were slaughtered. Body weight at slaughter (SBW) of kids was affected by the pasture type (17.7 and 21.8 kg for Ain Draham and Bahra, respectively). Also, higher carcass weight and higher dressing percentage were recorded for goats from Bahra. Similarly, the skin, head and feet weights were higher for this group; these organs are strongly correlated to the SBW which was higher for Bahra region. However, chemical composition of goats' meat (dry matter, proteins and lipids) was similar for goats from both regions. In conclusion, the concentrate supplementation to the herbaceous pasture resulted in higher SBW and carcass weight without effect on meat composition.

Keywords. Pasture – Tunisian goats – Carcass – Meat.

Effets du type de pâturage sur les caractéristiques de la carcasse et de la viande des chevreaux

Résumé. *Le but de cette expérience était d'étudier l'effet du système d'alimentation dans deux zones du nord-ouest tunisien (Bahra et Ain Draham) sur les caractéristiques de la carcasse et de la viande de chevreaux. Dans la région d'Ain Draham, caractérisée par un terrain et un sol impropre aux cultures, les chevreaux pâturent les forêts naturelles dominées par les espèces ligneuses. Alors que dans la région de Bahra, le pâturage est basé sur les herbacées avec complémentation par l'aliment concentré et du foin. À l'âge de 5 mois, dix chevreaux de chaque région ont été abattus. Le poids vif à l'abattage des chevreaux a été affecté par le type de pâturage (17,7 et 21,8 kg respectivement pour Ain Draham et Bahra). En outre, le poids de la carcasse et le rendement commercial des chevreaux de Bahra ont été plus élevés que ceux d'Ain Draham. De même, les poids de la peau, de la tête et des pieds étaient plus élevés pour les chevreaux de Bahra; le poids de ces organes étant fortement corrélé au poids vif à l'abattage qui était plus élevé pour la région Bahra. Cependant, la composition chimique de la viande (matière sèche, protéines et lipides) était similaire pour les chèvres des deux régions. En conclusion, le pâturage des herbacées complémenté par l'aliment concentré a augmenté le poids vif à l'abattage et le poids de la carcasse des chevreaux sans aucun effet sur la composition de la viande.*

Mots-clés. *Type de pâturage – Chevreaux – Carcasse – Composition de la viande.*

I – Introduction

The demand for goat meat exceeds supplies in many parts of the world (Singh *et al*., 2006) and especially in the Mediterranean countries where goat meat is an important part of breeders' incomes. Goat meat is considered to be relatively lean with a low percentage of fat (Webb *et al*., 2005). Information on the origin of animals and their production system has become important criteria for consumers' choices. Therefore, the producer may sort to employ production systems that provide acceptable carcass and meat quality (Warren *et al*., 2008) and maintain healthy products for consumers.

Therefore, the aim of this experiment was to study the effect of the feeding system in two mountain areas from the Tunisian Northwest (Bahra and Ain Draham) on the carcass and meat characteristics of kid goats.

II – Material and methods

1. Animals and rearing system

The study was carried out during summer (June-August) in two mountain areas from the Tunisian Northwest (Bahra and Ain Draham). Ain Draham is a mountainous region dominated by natural forests. The feeding system in this region is based mainly on grazing forest plants. While, in Bahra region, the feeding system is based on herbaceous pasture supplemented with concentrate (barley) and oats hay. At the age of five months, ten male goats from each region (local breed) were slaughtered.

2. Measurements and analysis

Body weight at slaughter (SBW) was recorded. Skin, feet, head, red cut-down (liver, kidneys, spleen, and heart); omental fat, all fractions of the digestive tract and the hot carcass (HCW) were weighed. Samples of *Longissimus dorsi* were dried (50°C), ground (1 mm screen), and stored for subsequent analyses. DM was determined by drying at 80°C until constant weight. Mineral content was determined by ashing at 600°C for 8 h. Nitrogen was determined by Kjeldahl method (CP = N × 6.25). Meat lipids were determined by Soxhlet extraction.

3. Statistical analysis

A one-way analysis of variance for the feeding system effects on the slaughter parameters, non carcass components and chemical composition of meat using GLM procedure in SAS (1989) was applied. Then, the test Duncan was used to compare these effects ($\alpha = 0.05$).

III – Results and discussion

1. Rearing system

The region of Ain Draham (northwest of Tunisia) is characterized by rugged, mountainous terrain and soil occupied by natural forests and unsuitable for crops. The herbaceous layer is almost absent throughout the year (Gasmi-Boubaker, 2005) especially during summer when this experiment was conducted. The feeding system in this region is based mainly on grazing forest plants. The main species are trees (Pinaceae and Fagaceae) and shrubs (*Erica arborea, Myrtus communis, Pistacia lentiscus*). While, in Bahra region, the feeding system is based on herbaceous pasture (ryegrass, trefoil, alfalfa) and goats were supplemented with concentrate and hay; this feeding system would result in higher nutrient supply than Ain Draham one.

2. Slaughter parameters

Slaughter body weight (SBW) of kids averaged 17.7 and 21.8 kg for Ain Draham and Bahra, respectively, with significant differences between the regions (P = 0.001). The poor feeding system based exclusively on forest plants in Ain Draham originates this low SBW compared to that of Bahra where animals were supplemented with concentrated and hay. Statistical analysis of the HWC and the commercial dressing percentage revealed significant differences (P<0.01) between the two areas in favour to the region of Bahra (Table 1). This difference is related to the fact that these parameters are strongly correlated to the SBW itself affected by the feeding system (Atti and Khaldi, 1987; Sañudo *et al*., 1993; Mahouachi and Atti, 2005).

Table 1. Slaughter Body weight (SBW) (kg), carcass weight (kg) and dressing percent

Group	Bahra	Ain Draham	SEM	P-values
SBW (kg)	21.8	17.7	1.29	***
HCW (kg)	9.1	6.3	2.47	***
CDP (%)	41.6	35.2	10.96	***

CDP, commercial dressing percentage; HWC, hot carcass weight; SBW, slaughter body weight.

3. Non-carcass components

The pasture type tends to affect the red cut-down (Table 2). This is due to the fact that red cut-down organs are not affected by SBW (Kamalzadeh *et al*., 1998; Atti *et al*., 2004). The skin, head and feet weights were significantly affected (P<0.01) by the pasture type; as indicated above, these weights are strongly correlated to the SBW which was higher for Bahra region. Curiously, the omental fat was significantly similar among both feeding systems although the higher value for Bahra system. It was shown that animals fed high energy level had more omental fat in absolute and relative values (Atti *et al*., 2004).

Table 2. Effect of the pasture type on non- carcass components

Group	Bahra	Ain Draham	SEM	P-values
Red cut-down (g)	387	330	20.1	NS
Skin (g)	1551	1013	85.4	***
Head (g)	1425	1114	54.6	***
Feet (g)	665	488	25.6	***
Omental fat (g)	78	55	10.9	NS

4. Chemical composition of goats' meat

The pasture type did not affect (P>0.05) the chemical composition of goats' meat (Table 3) from Bahra and Ain draham. Meat of goats from the same breed (Atti *et al*., 2004), reared in feedlot and receiving different concentrate protein content (100, 130 or 160 g/kg DM), presented more fat (11.6%) but less protein (84%) than those reported in the current study.

Table 3. Effect of the pasture type on the chemical composition of goats' meat

	Bahra	Ain Draham	SEM	P-values
RDM (%)	27.1	26.3	1.49	NS
Ash (%)	3.6	3.2	0.42	NS
Protein (% DM)	88.5	88.0	8.40	NS
Fat (% DM)	9.6	9.3	3.10	NS

IV – Conclusion

The concentrate supplementation to the herbaceous pasture resulted in higher Slaughter Body weight and carcass weight without effect on meat composition.

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Visible spectroscopy on carcass fat to distinguish pasture-fed, concentrate-fed and concentrate-finished pasture-fed lambs

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Abstract. The ability to authenticate the method of production of food products has become a major challenge for scientists and monitoring bodies. This study compared two methods based on the use of visible reflectance spectrum of fat tissues to discriminate pasture-fed (n = 76), concentrate-fed (n = 79) and concentrate-finished (for 28 days) pasture-fed (n = 69) lamb carcasses. The reflectance spectrum of perirenal and subcutaneous caudal fat was measured at slaughter and at 24 h *post mortem*. Method 1 used an index calculated from the reflectance spectrum data at wavelengths between 450 and 510 nm, whereas method 2 was performed at wavelengths between 400 and 700 nm. Method 2 yielded higher overall proportion of correctly classified lambs than method 1 (92.9% *vs.* 64.7%, P<0.0001), regardless of the measurement time and site. The proportion of lambs which were correctly classified using method 2 was 95.6% and 95.9% for measurements made on perirenal fat at slaughter and at 24 h *post mortem*. This study indicates the importance of the zones of light absorption by carotenoid and haeminic pigments in the discrimination between lambs from three different feeding systems.

Keywords. Authentication – Pasture-feeding – Concentrate-feeding – Concentrate-finishing – Spectroscopy – Sheep – Lamb.

L'analyse du spectre de réflectance du tissu adipeux permet de discriminer trois modalités d'engraissement des agneaux : à l'herbe, en bergerie, ou avec une finition en bergerie après pâturage

Résumé. *La possibilité d'authentifier le mode de production des animaux à partir de leurs produits est devenue un enjeu majeur pour les scientifiques et les organismes de contrôle. Cette étude a comparé deux méthodes basées sur l'analyse du spectre de réflectance dans le visible du tissu adipeux pour discriminer les agneaux d'herbe, les agneaux de bergerie et les agneaux d'herbe finis en bergerie pendant 28 jours. Les spectres de réflectance du gras périrénal et du gras sous-cutané caudal ont été mesurés à l'abattage et à 24 h* post mortem*. La méthode 1 a utilisé un indice calculé à partir de la zone du spectre de réflectance comprise entre 450 et 510 nm, alors que la méthode 2 a utilisé l'ensemble du spectre de réflectance entre 400 et 700 nm. La proportion d'agneaux correctement classés a été plus élevée avec la méthode 2 qu'avec la méthode 1 (92,9%* vs. *64,7%, P<0.0001), indépendamment du moment et du site de la mesure. La proportion d'agneaux correctement classés par la méthode 2 était de 95,6% et 95,9% pour les mesures effectuées sur le gras périrénal à l'abattage et à 24 h* post mortem*. Cette étude montre l'importance des zones d'absorption de la lumière par les pigments caroténoïdes et héminiques dans la discrimination entre les trois types d'agneaux.*

Mots-clés. *Authentification – Agneau d'herbe – Agneaux de bergerie – Finition – Spectroscopie – Ovins – Agneau.*

I – Introduction

Consumers show growing interest in the method of production of their food and growing preference for food products of pasture-based systems of production (Prache and Thériez, 1999). It is therefore important to be able to authenticate food products from particular production systems.

The measurement of the reflectance spectrum of the fat has proven to be of practical interest since it is non-invasive, takes little time and can easily be implemented in the meat industry with a portable spectrophotometer. Prache and Thériez (1999) proposed a mathematical analysis of the reflectance spectrum of the fat at wavelengths between 450 and 510 nm (which corresponds to the zone of light absorption by carotenoids) to quantify the intensity of the signature of these pigments and discriminate pasture-fed from stall-fed lamb carcasses. Dian *et al.* (2007) increased the reliability of the discrimination between pasture-fed and stall-fed lambs by using the full data set of the reflectance spectrum at wavelengths between 400 and 700 nm. However, because of grass shortage during the summer period, pasture-fed lambs are often stall-finished with low-carotenoid diets. The purpose of this study was therefore to further test the reliability of these two spectral methods for discriminating lamb carcasses from less contrasted production systems (pasture-feeding, concentrate-feeding and concentrate-finishing after pasture-feeding).

II – Materials and methods

This study was carried out over 5 years (2008-2012) at two experimental farms of INRA (Unité Expérimentale des Monts d'Auvergne and Unité Expérimentale des Ruminants de Theix). A total of 224 Romane breed male lambs were used: 76 were fed pasture for at least 60 days (P), 79 were stall-fed concentrate and straw (S) and 69 were fed pasture for at least 60 days followed by an abrupt switch to concentrate and straw indoors (PS) for 28 days. The P and PS lambs grazed pastures that were maintained at a leafy stage and offered *ad libitum*. The P lambs were fed pasture until slaughter. The PS lambs were expected to gain on average 7.0 kg LW gain (LWG) during the finishing period indoors. Stall-fed lambs were fed *ad libitum* a commercial concentrate, containing no green vegetative matter and straw until slaughter. These last feedstuffs were given also to PS lambs during the stall finishing period. The lambs were slaughtered when they had reached a target body condition score of 3 (on a scale of 0 to 5), which was manually assessed by a skilled technician.

The reflectance (R) spectrum of perirenal and subcutaneous caudal fat was measured on all lambs, using a MINOLTA CM-2002 spectrophotometer (D65 illuminant, observer angle 10°). For each tissue, 5 measurements were made at slaughter and at 24 h *post mortem*. In method 1, the fat reflectance spectrum data were used at wavelengths between 450 and 510 nm to calculate an index quantifying light absorption by carotenoid pigments stored in the fat. The R spectrum was translated to give a reflectance value at 510 nm of zero (TR). On the translated spectrum, the integral value ($I_{450\text{-}510}$) was calculated as follows: $I_{450\text{-}510}$ = [(TR 450/2) + TR 460 + TR 470 + TR 480 + TR 490 +TR 500 + (TR 510/2)] × 10.

The integral value was averaged and then linear discriminant analysis was performed, followed by a cross-validation procedure, to classify the fat samples according to feeding treatment, using Minitab software v. 13 (Minitab Inc., Paris).

In method 2, the full R dataset at wavelengths between 400 and 700 nm was used. The R data were averaged, then transformed (log (1/R)) and exported into Win ISI II version 1.6 software (Infrasoft International, Port Matilda, PA, USA) for multivariate analysis. The raw R spectra of each tissue representing the three feeding treatments were submitted to discriminant analysis using a partial least squares discriminant analysis (PLS-DA) approach. A principal component analysis (PCA) performed beforehand was used to rank the reflectance spectra from each feeding treatment according to the Mahalanobis distance (*H*) to the average R spectrum, in order to detect sample outliers (H>3). No outliers were found. The models were tested via a cross-validation procedure, in which 56 randomly chosen samples were temporally removed from the initial data set to be used for validation (i.e. a quarter of all data samples). The PLS-DA model was developed based on the other samples (calibration samples) and used to classify the validation samples. This procedure was repeated four times, i.e. until all data set samples had been used through the validation procedure. The cross-validation error of the models was calculated.

The proportion of correctly classified samples was analyzed using the CATMOD procedure of the SAS (1999) software package using a four-factor model (feeding treatment: P *vs.* S *vs.* PS; discrimination method used in the fat: method 1 *vs.* method 2; site of measurement: perirenal *vs.* subcutaneous caudal fat; and time of measurement: at slaughter *vs.* at 24 h *post mortem*).

III – Results and discussion

The proportion of correctly classified samples using linear discriminant analysis performed on $I_{450\text{-}510}$ (method 1) was 67.1%, 84.8% and 60.9% for P, S and PS lambs, respectively (70.9% on average), when the measurement was made on perirenal fat at slaughter, and 68.4%, 84.8% and 66.7% for P, S and PS lambs, respectively (73.3% on average), when the measurement was made on perirenal fat 24 h *post mortem* (Fig. 1). This method correctly classified 55.3%, 68.4% and 23.1% of the P, S and PS lambs, respectively (i48.9% on average), when the measurement was made on subcutaneous caudal fat at slaughter, and 76.3%, 69.6% and 50.7% of the P, S and PS lambs, respectively (65.5% on average), when the measurement was made on subcutaneous caudal fat 24 h *post mortem*.

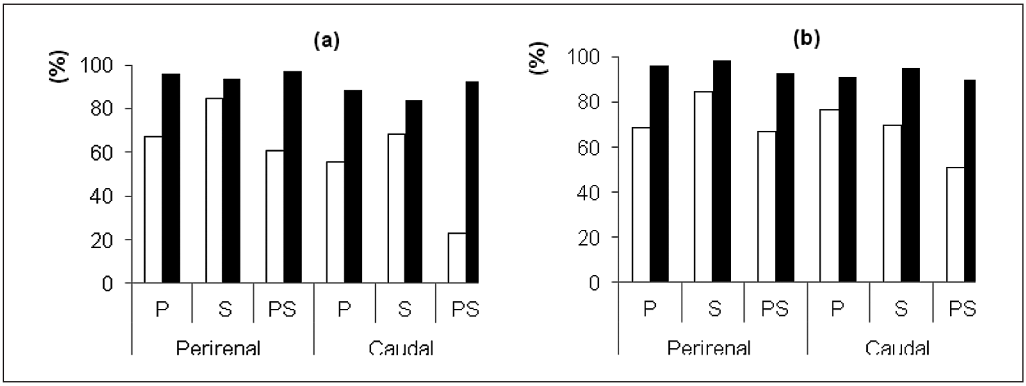

Fig. 1. Proportion of correctly classified lambs using method 1 (integral value $I_{450\text{-}510}$, white symbols) and method 2 (full reflectance spectrum data sets at wavelengths between 400 and 700 nm, black symbols) on perirenal and subcutaneous caudal fat measured at slaughter (a) and at 24 h *post mortem* (b). P: Pasture-fed lambs; S: Stall-fed lambs; PS: Stall-finished pasture-fed lambs.

The method 2 allowed for the correct classification of 96.1%, 93.7% and 97.1% of the P, S and PS lambs, respectively (95.6% on average), when the measurement was made on perirenal fat at slaughter, and 96.1%, 98.7% and 92.8% of the P, S and PS lambs, respectively (95.9% on average), when the measurement was made on perirenal fat 24 h *post mortem* (Fig. 1). This method correctly classified 88.2%, 83.5% and 92.8% of the P, S and PS lambs, respectively (88.2% on average), when the measurement was made on subcutaneous caudal fat at slaughter, and 90.8%, 94.9% and 89.9% of the P, S and PS lambs, respectively (91.9% on average), when the measurement was made on subcutaneous caudal fat 24 h *post mortem*.

By using all the reflectance spectrum data at wavelengths between 400 to 700 nm, method 2 showed a higher performance (P<0.001) than method 1 (Fig. 1), which only used the reflectance spectrum data at wavelengths from 450 to 510 nm to calculate $I_{450\text{-}510}$. Taking both sites, both measurement times and all feeding treatments together, the overall proportion of correctly classified lambs was 64.7% for method 1 and 92.9% for method 2. The proportion of correctly classified lambs also differed between feeding treatments (79.8%, 84.8% and 71.8% for P, S and PS lambs, $P<0.0001$), measurement sites (83.9% for perirenal and 73.6% for subcutaneous caudal fat, $P<0.0001$) and measurement times (75.9% at slaughter and 81.6% at 24 h *post mortem*, $P<0.001$). Method 2 reliably discriminated the 3 types of lambs when the measurement was made on perirenal fat at slaughter (the proportion of correctly classified lambs ranging between 93.7% and 97.1%) and at 24 h *post mortem* (the proportion of correctly classified lambs ranging between 92.8% and 98.7%).

The PCA loadings of the two PC axes for perirenal fat measured at 24 h *post mortem* are shown in Fig. 2. PC1 and PC2 axes explained 60% and 24% of variability. The highest loading was situated around 460 to 480 nm for PC1, indicating the importance of carotenoid pigments in the discrimination between the lambs from three different feeding systems. The PC1 and PC2 axes loading values at wavelengths around 420 nm and the PC2 axis loading value at wavelengths around 550-560 nm indicated that haeminic pigments (Prache *et al.,* 1990) may also be involved in the discrimination between the lambs from three different feeding systems, as already suggested by Dian *et al.* (2007).

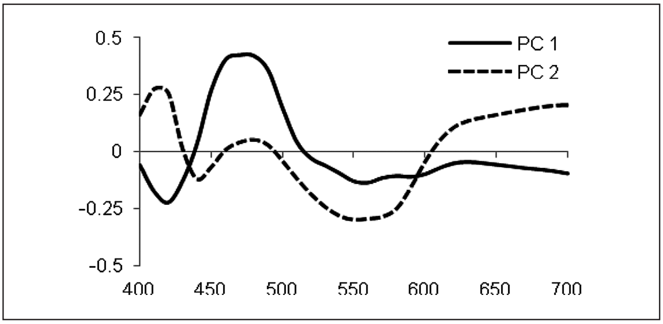

Fig. 2. Loadings for the two principal components axes (PC1 and PC2) for perirenal fat samples measured 24 h *post mortem.*

IV – Conclusions

Using the full set of the reflectance data of the carcass fat in the visible range (at wavelengths between 400 nm to 700 nm) enabled to reliably discriminate lamb carcasses from 3 production systems (pasture-feeding, concentrate-feeding and stall-finishing after pasture). The reliability of the discrimination at best with measurements made on perirenal fat at 24 h *post-mortem*. The proportion of lambs which were correctly classified using this method was 95.6% and 95.9% for measurements made on perirenal fat at slaughter and at 24 h *post mortem*. This method is of obvious practical interest for the meat industry, since it is non-invasive, rapidly and easily on-line implemented with a portable spectrophotometer.

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Fatty acid composition of Murazzano PDO cheese as affected by pasture vegetation types

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Abstract. The present study investigated the influence of botanically diverse pastures grazed by dairy ewes on the fatty acid (FA) composition of Protected Designation of Origin (PDO) Murazzano cheese. Twelve multiparous Delle Langhe ewes beyond peak of lactation were blocked according to stage of lactation, parity, milk yield, gross composition, and FA profile of milk fat, and randomly assigned to two groups. The groups were allowed to graze for three weeks on two different mountain vegetation types, either dominated by *Lolium perenne* L. and *Trifolium repens* L. (LT) or by *Bromus erectus* Huds., *Festuca* gr. *rubra* L. and *Thymus serpyllum* L. (BFT); both groups were also supplemented with 0.4 kg head^{-1} day^{-1} of concentrate during milking. Each week, bulk milk obtained from the two groups was separately used on three consecutive days to produce a total of eighteen Murazzano PDO cheeses. The FA profile of cheese was significantly influenced by the pasture vegetation type. Murazzano cheese manufactured with LT milk showed higher concentrations of total polyunsaturated FA, n3 FA, n6 FA, *trans*-C18:2 and -C18:1 biohydrogenation intermediates of dietary unsaturated FA, while cheese manufactured with BFT milk was significantly richer in branched-chain FA. The botanical composition of grazed pastures, significantly influencing the FA composition and nutritional quality of cheese, appears to be a key factor in the assessment of dairy products traceability.

Keywords. Botanical composition – Grazing – Lipids – Ovine cheese – Plant secondary metabolites.

Composition en acides gras du fromage Murazzano AOP influencée par le type de végétation du pâturage

Résumé. *L'étude a examiné l'influence botanique de différentes prairies pâturées par les brebis laitières sur la composition en acides gras (AG) du fromage Murazzano d'Appellation d'Origine Protégée (AOP). Douze brebis Delle Langhe ont été sélectionnées selon le stade de lactation, la parité, la production laitière, la composition chimique et le profil en AG du lait, et réparties de façon aléatoire en deux groupes. Elles ont pâturé pendant trois semaines sur deux types différents de végétation, soit dominé par* Lolium perenne *L. et* Trifolium repens *L. (LT) soit par* Bromus erectus *Huds.*, Festuca gr. rubra *L. et* Thymus serpyllum *L. (BFT). En supplément, tous les animaux ont reçu 0,4 kg de concentré par jour. Chaque semaine, pendant trois jours consécutifs, le lait des deux groupes des brebis a été séparé et utilisé pour produire dix-huit fromages Murazzano AOP. Le fromage fait à partir du lait de LT a montré des concentrations plus élevées en AG polyinsaturés totaux, AG n3, AG n6, trans-C18:2 et -C18:1 (intermédiaires de la bio-hydrogénation des AG insaturés alimentaires), tandis que le fromage fait à partir du lait BFT a été plus riche en AG à chaîne ramifiée. La composition botanique des pâturages, influençant significativement la composition en AG et la qualité nutritionnelle des fromages, semble être un facteur clé dans l'évaluation de la traçabilité des produits laitiers.*

Mots-clés. *Composition botanique – Fromage de brebis – Lipides – Métabolites secondaires – Pâturage.*

I – Introduction

Some studies have revealed that the botanical composition of forages can significantly affect the fatty acid (FA) composition of milk and cheese (Lourenço *et al*., 2009). Such an effect is even more important for quality-identified dairy products (e.g., Protected Designation of Origin – PDO – cheeses) because local forage-based diets strictly bind them with their geographical production site. The goal of this study was to investigate the influence of botanically diverse pastures grazed by dairy ewes on the FA profile of Murazzano PDO cheese.

II – Materials and methods

The experiment was carried out from May 26 (day 1) to June 23 (day 29) in a dairy sheep farm located in North-Western Italy (latitude: 44°26'46" N; longitude: 08°01'25" E). Twelve multiparous Delle Langhe ewes in mid-lactation were divided into two balanced groups according to their stage of lactation, lactation number, milk yield, milk gross composition, FA profile of milk fat, and estimated Δ9-desaturase activity. The groups were then randomly allowed to graze one of two mountain pastures, dominated by (i) *Lolium perenne* L. and *Trifolium repens* L. (LT) and by (ii) *Bromus erectus* Huds., *Festuca* gr. *rubra* L., and *Thymus serpyllum* L. (BFT). The ewes grazed during day and night. They were moved indoors twice daily for milking, when they were supplemented with 0.2 kg head^{-1} of concentrate.

The botanical composition of LT and BFT pastures was assessed before exploitation (Daget and Poissonet, 1971). Herbage samples were collected three times during the trial (on days 14, 21, and 28) and analysed for dry matter (DM), crude protein (CP), ether extract (EE), neutral detergent fibre (NDF), starch and FA profile as reported by Renna *et al*. (in press).

Separate bulk milk tanks (one per treatment) were used on three consecutive days for three weeks (from June 7 to June 23) to produce a total of eighteen Murazzano PDO cheeses. After a six-day ripening period, cheese samples were collected and analysed for FA profile. Cheese total lipids extraction, and fatty acid methyl esters separation, identification and quantification were performed as described by Renna *et al*. (in press).

Herbage and cheese data were subjected to analysis of variance using the GLM procedure of the SAS software package, version 9.1.3 (SAS Institute Inc., Cary, NC, USA). Significance was declared at $P \leq 0.05$.

III – Results and discussion

The specific contribution (SC, percentage presence of each botanical species) in LT and BFT pastures is reported in Table 1. More than 90% of the species belonged to Poaceae (52%), Fabaceae (32%) and Geraniaceae (7%) in LT and to Poaceae (68%), Lamiaceae (17%) and Fabaceae (7%) in BFT. No significant differences were observed in DM, EE and starch contents between pastures. LT vegetation type showed higher CP (11.0 *vs* 8.6% DM; $P<0.05$) and lower NDF (64.4 *vs* 68.5% DM; $P<0.01$) content compared to BFT. The concentration of main FA also differed between pastures (C16:0, 298 *vs* 218 mg 100g^{-1} DM; C18:2 *c*9*c*12, 408 *vs* 299; C18:3 *c*9*c*12*c*15, 731 *vs* 564, in LT and BFT, respectively).

The FA composition of Murazzano PDO cheese was significantly affected by the pasture vegetation type (Table 2). LT cheeses were significantly richer in total polyunsaturated fatty acids (PUFA), total n3 FA, total n6 FA, total *trans*-C18:2, total *trans*-C18:1, linoleic acid (LA, C18:2 *c*9*c*12) and a-linolenic acid (ALA, C18:3 *c*9*c*12*c*15). Branched-chain fatty acids (BCFA), both *iso* and *anteiso* forms, were significantly lower in LT compared to BFT cheeses. Short- and medium-chain saturated FA (C4:0 to C16:0) and odd-chain fatty acids (OCFA, C15:0 and C17:0) showed comparable concentrations in LT and BFT cheeses.

The FA composition of milk and dairy products obtained from pasture-fed ruminants is simultaneously affected by the chemical composition of pastures and the presence and abundance of plant secondary metabolites (PSM) (e.g., polyphenol oxidase – PPO –, phenolic compounds – PC –, essential oils – EO –, etc.). Both factors are able to modify the rumen microbial ecosystem (Lourenço *et al*., 2010).

Table 1. Specific contribution (SC,%) of botanical species and plant secondary metabolites (PSM) in the main botanical species of LT and BFT vegetation types[†]

LT vegetation type			BFT vegetation type		
Species (Family)	SC	PSM	Species (Family)	SC	PSM
Lolium perenne L. (Po)	31.6	PPO	*Bromus erectus* Hudson (Po)	36.2	
Trifolium repens L. (Fa)	27.8	SA, PH	*Festuca* gr. *rubra* L. (Po)	24.1	
Bromus sterilis L. (Po)	9.0		*Thymus serpyllum* s.l. (La)	13.8	EO
Bromus hordeaceus L. (Po)	4.5		*Lotus* gr. *corniculatus* L. (Fa)	5.2	CT
Poa trivialis L. (Po)	4.5		*Bromus hordeaceus* L. (Po)	3.4	
Geranium pusillum L. (Ge)	3.8	HT	*Hypochoeris radicata* L. (As)	3.4	PH
Medicago lupulina L. (Fa)	3.8		*Poa annua* L. (Po)	3.4	
Erodium cicutarium (L.) L'Hér. (Ge)	3.0	AL, traces	*Salvia pratensis* L. (La)	3.4	EO
Plantago lanceolata L. (Pl)	3.0	PH	*Plantago lanceolata* L. (Pl)	2.6	PH
Dactylis glomerata L. (Po)	2.3	PPO	*Vicia* gr. *cracca* L. (Fa)	1.7	
Capsella bursa-pastoris (L.) Medicus (Br)	1.5				

[†] Only species with SC>1% are reported. Po, Poaceae; Fa, Fabaceae; Ge, Geraniaceae; Pl, Plantaginaceae; Br, Brassicaceae; La, Lamiaceae; As, Asteraceae; PPO, polyphenol oxidase; SA, saponins; PH, phenols; HT, hydrolysable tannins; CT, condensed tannins; EO, essential oils; AL, alkaloids.

Table 2. Effect of vegetation type grazed by Delle Langhe ewes on selected individual FA and FA groups (g 100g^{-1} fat) detected in Murazzano PDO cheese

	Vegetation type					Vegetation type			
FA	LT	BFT	SEM	P	FA	LT	BFT	SEM	P
ΣSFA	55.20	56.06	1.272	ns	C18:1 *t*6-11	3.02	2.92	0.294	ns
Σ*iso*-BCFA	1.07	1.22	0.087	***	C18:1 *t*12-14+*c*6-8	1.00	0.73	0.153	***
Σ*aiso*-BCFA	1.27	1.38	0.081	***	C18:1 *t*16+*c*14	0.44	0.37	0.038	***
ΣMUFA	20.79	21.05	0.158	ns	C18:2 *t,t*-NMID+*t*9*t*12	0.15	0.12	0.018	***
ΣC18:1	19.65	19.88	0.806	ns	C18:2 *c*9*t*13+*t*8*c*12	0.073	0.068	0.013	*
ΣC18:1 *trans*	4.04	3.68	0.358	**	C18:2 *c*9*t*12	0.23	0.19	0.029	**
ΣPUFA	5.59	4.91	0.371	***	C18:2 *c,c*-MID+*t*8*c*13	0.23	0.19	0.027	**
ΣC18:2 *trans*	1.93	1.76	0.191	**	C18:2 *t*11*c*15	0.40	0.35	0.055	**
Σn3	1.61	1.36	0.180	***	C18:2 *c*9*t*11+*t*7*c*9+*t*8*c*10	0.79	0.79	0.084	ns
Σn6	4.00	3.31	0.359	***	C18:2 *t*10*c*12	<0.001	<0.001	<0.0001	ns
ΣCLA	0.84	0.84	0.093	ns	C18:2 *t*11*c*13+*c*9*c*11	0.030	0.031	0.009	ns
C4 to C16	39.50	39.58	0.965	ns	C18:2 *t*9*t*11	0.022	0.022	0.003	ns
C15:0	0.84	0.85	0.039	ns	C18:2 *c*9*c*12	2.26	1.96	0.140	***
C17:0	0.67	0.65	0.044	ns	C18:3 *c*9*c*12*c*15	0.98	0.78	0.120	***
C18:0	11.34	11.81	0.721	ns	C20:5 *c*5,*c*8,*c*11,*c*14,*c*17	0.068	0.062	0.005	***

In general, if compared to Poaceae, Fabaceae have shown a higher transfer efficiency of PUFA to milk and cheese (Cabiddu *et al*., 2010), which is consistent with the results obtained in our experiment. The lower BCFA concentration in LT cheeses suggests that the ewes' ruminal microbial activity was inhibited. This could be the consequence of the overall higher richness of biologically active PSM in the LT compared to the BFT pasture (Buccioni *et al*., 2012). The lack of significant differences in OCFA concentrations between LT and BFT cheeses may be related to specific EO (such as carvacrol, thymol and *p*-cymene) occurring in the Lamiaceae species present in the BFT pasture. The above mentioned EO, in fact, have been described to decrease rumen propionate production *in vitro* (Macheboeuf *et al*., 2008) and OCFA can be synthesised *de novo* from propionate in the mammary gland of ruminants (Vlaeminck *et al*., 2006). The significantly higher levels of total PUFA, total n6 FA, total n3 FA, total *trans*-C18:2, total *trans*-C18:1, LA and ALA in LT cheeses could be ascribed to the higher concentrations of LA and ALA in the LT pasture. In addition, *Lolium perenne* and *Dactylis glomerata* were reported to contain relatively high levels of PPO, in its active form (Lee *et al*., 2006). This enzyme, forming protein-bound phenols, can inhibit lipolysis (LP) and can therefore reduce the initial step of dietary unsaturated FA biohydrogenation (BH), leading to increased likelihood of LA and ALA passing unaltered through the rumen (Lejonklev *et al*., 2013). While non-conjugated C18:2 isomers (both methylene interrupted (MID) and non methylene interrupted (NMID) dienes) were significantly more abundant in LT than BFT cheeses, the concentration of conjugated linoleic acid (CLA) isomers was relatively low and not significantly affected by the pastures. Such result may suggest selective inhibition exerted by PSM occurring in LT botanical species on specific microorganisms involved in the ruminal formation of CLA isomers from dietary PUFA, and merits further investigation. Estimated ∆9-desaturase activity (C14:1 *c*9/C14:0 in milk samples, data not shown) was not affected by pasture type. The comparable CLA *c*9*t*11+*t*7*c*9+*t*8*c*10 concentrations in LT and BFT cheeses are consistent with the lack of differences in their precursors (C18:1 *t*7 and C18:1 *t*11) for *de novo* synthesis within the mammary gland.

IV – Conclusions

Differences in the chemical composition and occurrence of plant secondary metabolites in the grazed forages can affect rumen lipolysis and biohydrogenation in dairy ewes. A strong link exists between the utilization of botanically diverse and locally produced forage resources by Delle Langhe ewes and the fatty acid composition of Murazzano PDO cheese. Pasture biodiversity is a key factor for the characterization and the traceability of this cheese and for the maintenance of its tipicity in relation to the original *terroir*.

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Session 1

Forage services for animal production and product quality

Posters articles – Forage production and quality

Performances of some fodder cultivars cultivated in pure stand or in association under semi-arid conditions of Algeria

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Abstract. This work is a part of REFORMA / ARIMNET Mediterranean project. The aim is to evaluate some alternative fodder systems witch could replace traditional wheat-fallow rotation. This strategy aims also to give more resilience to cereal/livestock rainfed systems strength to the climatic changes negative effects. Two grass species: triticale and oats, and three legumes species: Narbon vetch, common vetch and fodder pea (two cultivars) were tested. Results show that triticale and peas were earlier than oats and vetches in the different associations. Thus, the choice of a mowing date corresponding to the optimal stage in the case of associations was more or less difficult because of weak synchronization between flowering / heading stages. The productive performances (dry biomass) of all fodders tested were satisfactory; however, significant differences in favour of triticale and its associations were found. Balanced grasses / legumes ratio within associations were also satisfactory but especially in associations with oats.

Keywords. Fodder – Productivity – Phenology – Algeria – Semi-arid.

Performances de quelques espèces fourragères cultivées en pur ou en association sous les conditions semi-arides Algériennes

Résumé. *Ce travail est une partie du projet méditerranéen «REFORMA / ARIMNET». Le but est d'évaluer quelques systèmes fourragers pouvant remplacer le traditionnel blé-jachère. Cette stratégie vise également à donner plus de résilience au système pluvial céréales/élevage face aux effets négatifs des changements climatiques. Deux espèces de graminées, le triticale et l'avoine, ainsi que trois de légumineuses: la vesce de Narbonne, la vesce commune et le pois fourrager (deux cultivars) ont été testées. Les résultats ont montré que le triticale et les pois étaient plus précoces que l'avoine et les vesces quelque soit le type d'association. Ainsi, le choix d'une date de fauche correspondant à un stade physiologique optimal dans le cas des associations était plus ou moins difficile en raison de la faible synchronisation entre la floraison des légumineuses et l'épiaison des graminées. Les performances productives (biomasse sèche) étaient satisfaisantes pour la totalité des fourrages expérimentés; cependant, des différences significatives en faveur du triticale et de ses associations ont été trouvées. L'équilibre graminées/légumineuses dans les différentes associations était également satisfaisant, mais plus en particulièrement dans les associations avec l'avoine.*

Mots-clés. *Fourrages – Productivité – Phénologie – Algérie – Semi-aride.*

I – Introduction

Rainfed cereal-livestock systems are very widespread in Algeria and constitute the productive base of the major part of the cereal sector. These systems are threatened, however, by the marked insufficiency of high-protein feedstuff, the overexploitation of forage and pastoral resources, the increasing costs and/or the decreasing availability of irrigation water and mineral fertilizers, and the increasing drought and heat stress arising from climate change. Feed resources are then unable to satisfy the growing needs of livestock and a sharp deterioration in grazing lands has resulted in a feed deficit (Abd El Moneim and Cocks, 1986; Cocks and Thomson, 1988). This deficit should be overcome by developing forage crops such as forage legumes and legumes / grasses associations (Abdelguerfi,1976; Leeuwrik, 1976; Krausse *et al*., 2008). Among arable forage legumes in cereal semi-arid zones of Algeria, we can cite the genus *Vicia* (common vetch and Narbon vetch) and *Pisum* (peas). These legumes are grown in pure and/or in combination with one or more feed grains, including oats and/or triticale and could provide an abundant and of excellent quality hay (Rihawy *et al*., 1987). In this context, this paper gives the results of the first year of a set of forage crops conducted in pure stand and in association on fallow land in the semi-arid region of Sétif (Algeria).

II – Material and methods

An experiment was carried out in 2012-2013 at Sétif INRAA station (36° 9'26.30"N, 5°22'17.78"E, altitude: 970 m) on fallow field. The soil is clay loam with a total rate of 35% limestone and a pH of 7.2. The organic matter content is low. It has been worked lightly through 3 passages of cover-crop. Seeding was made on October 27, 2012 and mowing on May according to the physiological stages of each culture. Weather conditions were close to the typical climate of the region: mild and dry autumn, cold and somewhat rainy winter, wet spring, hot and dry summer. The cumulative annual rainfall is 403 mm and the snow concerned 18 days of February 2013. Forage resources used are shown in Table 1.

Table 1. Characteristics of crop material used

Crop material	Species	Varieties	Origin	Observation
Triticale	*Tritical secal*	Amarillo	CRA/ FLC (Italy)	
Common oat	*Avena sativa*	Bionda	CRA/ FLC (Italy)	
Pea 1 (P1)	*Pisum sativum*	*Attika*	CRA/ FLC (Italy)	Semi-dwarf
Pea 2 (P2)	*Pisum sativum*	*Linea* 1-27b	CRA/ FLC (Italy)	Tall
Common vetch	*Vicia sativa*	*Barril*	CRA/ FLC (Italy)	
Narbon vetch	*Vicia narbonensis*	Bozdag	Turkey	

The experimental design consisted of 4 blocks. Each block contained elementary plots of 4 x 3 m (12 m^2) for each experimental crop grown in pure stand and each association between 2 fodders (one grass and one legume) and 4 fodders (2 legumes and 2 grasses). The number of crop variants was 64 (16 x 4). Seeding was made manually in lines spaced 25 cm with doses presented in Table 2.

Table 2. Seed doses employed

Crop material	Seeding density (kg/ha)		
	Pure stand	Binary mixture (pure stand/2)	Complex mixture (pure stand/4)
Attika (P1)	168.73	84.37	42.18
Linea 1/27/b (P2)	159.16	79.58	39.79
Narbon vetch	144.90	72.45	36.23
Common vetch	81.05	40.53	20.27
Oat	91.37	45.68	22.84
Triticale	103.16	51.58	25.79

Grasses received 160 kg N/ha while the pure legumes or associations profited from 50 kg N/ha. The pure grasses received 50% nitrogen fertilizer at planting and the rest at tillering. Phosphorus fertilisation was 120 kg P/ha for pure grasses and 300 kg P/ha for legumes in pure stand and in association. The mowing was performed manually on the entire surface of each plot. Cuts were done at following stages: waxy pods for legumes and early heading for grasses. Fresh weight is made on site and the dry weight was obtained after oven drying (65°C for 72 h) of a sample of 200 g of each micro plot. A sample corresponding to the output of 1 m^2 was used for weighting different botanical components. Statistics (mean comparison between crops within pure legumes, pure grasses, binary associations and complex associations) were performed by XLSTAT ® software (2013).

III – Results and discussion

1. Phenologic traits

The flowering and heading dates are presented in Table 3. They coincide with the optimum mowing stage, corresponding to a satisfactory biomass and good nutritional quality. The crop material used has not shown good timing of these stages. Fodder peas were earlier than triticale and especially oats (3 to 4 weeks for triticale and 5 weeks for oats). Vetches also showed a relatively earliness (about 10 days for triticale and 2 weeks for oats). This prompted us to wait for the waxy stage pods of legumes which coincide with the early heading grasses.

Table 3. Flowering dates / heading observed in different crop materials studied

Crop material	Flowering / heading date	First pod
Pisum sativum Atika (p1)	6 April	28 April
Pisum sativum Linea 1-27b (p2)	1 April	21 April
Vicia narbonensis Bosdag	19 April	2 May
Vicia sativa	17 April	5 May
Avena sativa	5 May	
Triticosecale	28 April	

2. Dry biomass production

Pure legumes: dry matter (DM) yields were correct (Table 4) for rainfed conditions. Both peas and common vetch had productivities close to 4 t/ha. Narbon vetch showed a significantly lower yield (about 3 t/ha). **Pure grasses**: oats and triticale tested recorded high biomass production and close around 8 t/ ha. **Binary associations**: associations of different legumes with triticale tested gave a remarkable production of more than 8 t/ha except for associations containing the pea whose yields were around 7 t/ha. Legume crops with oats also gave significant results (between 5 and 6.5 t/ha approximately) except Narbon vetch witch gave a significantly lower yield unlike its combination with triticale. **Complex associations**: both grain forages, oats and triticale gave a higher result with vetches than peas. This suggests that peas used have a low capacity matching with tested triticale.

Table 4. Average yields of pure and in combination fodders expressed in t/ha of dry matter (whole plants)

Type of culture	Dry Matter Yield average	(T/ha) SD
P1	3.79 a	1.05
P2	4.09 a	1.33
Vetch	4.16 a	0.73
Narb. vetch	**2.83 ab**	0.87
Oat	8.38 a	2.83
Triticale	8.69 a	1.59
Oat – p1	7.39 b	3.43
Oat – p2	6.69 b	1.99
Triticale - p1	7.12 b	3.42
Triticale – p 2	6.66b	2.14
Triticale – vetch	**8.05 a**	0.55
Oat – vetch	6.63 b	0.94
Oat – Narb. vetch	**5.73 ab**	1.73
Triticale – Narb. vetch	**8.42 a**	1.52
Oat, triticale, p1, p2	**6.47 a**	0.84
Oat, triticale, vetch, Narb. vetch	7.65 b	2.07

A, b, ab: significant differences at 5% (comparisons made by type of crops (legumes in pure grasses in pure binary complex associations and associations).

3. Botanical composition of associations

The rate of weed infestation was around 30%, which is very important. This is due to previous crop (fallow) of the experimental field and the non use of herbicides. In all associations (Table 5) we see a balanced legume/grass ratio (1/3, 1/3) except in a few cases such as Triticale – Narbon vetch and oat-Narbon vetch where there is a clear dominance of weeds and triticale/oats. This relativizes the yields of these forage crops. At the complex associations, we note poor performance of semi-dwarf pea and Narbon vetch.

Table 5. Botanical composition of associations (% of DM)

	Triticale	Oat	Pea	Vetch	Narbon v.	Weeds
Oat – p1		32.19	35.96			31.85
Oat – p2		37.54	33.12			29.34
Triticale – p1	33.15		30.03			36.82
Triticale – p2	33.58		31.58			34.84
Triticale – vetch	31.97			30.75		37.28
Oat – vetch		30.91		30.83		38.25
Triticale – Narbon vetch	**36.41**				**17.42**	**46.17**
Oat – Narbon vetch		**36.29**			**20.94**	**42.78**
Oat, triticale, p1, p2	28.30	28.30	**0.00**	27.46		32.56
Oat, triticale, vetch, Narbon v.	31.29	26.78		19.07	**0.00**	34.02

IV – Conclusion

The results of the first year of this experiment showed interesting productive performance of tested materials except for Narbon vetch. Low pairing was observed between the tested grass (too late) and legumes (too early). The compromise on mowing stage of associations produced a slightly richer DM fodder. High weed infestation was noticed because of the previous crop. Despite these constraints the material tested has produced positive results and settings in the choice of variety of species (peas and oats) could provide clues as to encouraging the development of promising crops for fallow reduction and improved feeding conditions of livestock.

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Comparative study of chemical composition of three forages from South-East Algeria

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Abstract. The nutritive value of arid browse collected from South-East of Algeria at Biskra was studied on the basis of their chemical composition: dry matter (DM), organic matter (OM), ash, crude protein (CP), ether extract (EE), fiber: NDF, ADF, ADL and acid insoluble ash (ASHINS), Ca, P, Na, K, Mg, Cu, Zn and Mn. The browse species evaluated were the herbaceous *Cynodon dactylon*, *Cyperus conglomeratus* and the tree fodder *Tamarix africana.* Dry matter ranged from 253 to 509 g/kg fresh matter. The OM, CP, NDF and ADF contents in all plants ranged from 830 to 867, 110 to 143, 451 to 710, and 271 to 387 g/kg DM respectively. Acid insoluble ash and ADL levels were high in *C. dactylon*: 74 and 111g/kg DM respectively. Minerals contents in all plants varied widely. Macro minerals were present in sufficient concentrations to meet ruminant's requirement. Trace minerals levels were marginal in terms of requirements. *C. conglomeratus* had a high Mn level (187 mg/kg DM).

Keywords. Chemical composition – Nutritive value – Arid and semi-arid area – Forage plants.

Etude comparative de la composition chimique de trois plantes fourragères du Sud-Est algérien

Résumé. *La valeur nutritive des plantes fourragères de la zone aride du Sud-Est de Biskra en Algérie a été déterminée en se basant sur leur composition chimique. L'analyse a concerné les nutriments suivants. matière sèche (MS) matière organique (MO), matière minérale, les protéines, les extraits éthérés, les fibres NDF, ADF et ADL, les cendres insolubles dans l'acide et les minéraux (Ca, P, Na, K, Mg, Cu, Zn et Mn). Deux plantes herbacées,* Cynodon dactylon *et* Cyperus conglomeratus *et l'arbre* Tamarix africana *ont été prélevés. Les taux de MS varient de 253 à 509 g/kg de la matière fraiche. Les teneurs en MO, en protéines et en fibres NDF et ADF déterminées dans toutes les plantes sont variables respectivement de 830 à 867, 110 à 143, 451 à 710, et de 271 à 387 g/kg MS. Les teneurs élevées en cendres insolubles et en ADL ont été observées chez* C. dactylon*: 74 et 111g/kg MS respectivement. Les teneurs en minéraux varient d'une plante à une autre. Les minéraux majeurs sont présents en quantité suffisantes pour répondre aux besoins des ruminants. Les éléments trace sont déficitaires dans la majorité des plantes.* C. conglomeratus *avait le taux le plus élevé en Mn (187 mg/kg MS).*

Mots-clés. *Composition chimique – Valeur nutritive – Zones aride et semi-aride – Plantes fourragères.*

I – Introduction

The main forage plants in South-East of Algeria are the halophyte shrubs, some trees and herbaceous plants. The contribution of this native pastures to the nutritional requirements of domestic animals is important in this area. Scarce and irregular precipitations, excessive temperatures, drought, salinity and evapotranspiration in this area influence the life cycle and annual regrowth of xerophytes plant (Haddi *et al*., 2009). The herbaceous plants like *Cynodon dactylon* and *Cyperus conglomeratus* are well utilized by ruminants. Besides, our attention is focused on the tree *Tamarix Africana* following its abundance in this area, its utilization as browse by small ruminants and dromedaries and in addition it is evergreen over the year. The present study was undertaken to assess and compare chemical composition of the following herbaceous: *C. dactylon, C. conglomeratus* and the Tamaricaceae tree *T. africana, to* understand if the domestic animals meet their needs in terms of energy, nitrogen and mineral nutrients in these regions and to help to manage better the animal production and avoid possible nutritional deficits and their consequences on animal health.

II – Materials and methods

This study was carried out in south-east of Biskra at El-Haouch locality (5 N28'E30'15') in south-eastern Algeria. Forage plants were collected monthly (when available) from October 2002 to July 2003. *C. dactylon* and *C. conglomeratus* (as grass plant) were sampled at ten and seven occasions respectively. *T. Africana* (as a tree from Tamaricacae family) was sampled at nine occasions. All plants were dried in air forced oven at 55°C for 72h and milled to pass 1mm screen and stored in polypropylene bottles for subsequent analysis. Dry matter (DM), ash, crude protein (CP), ether extract (fat) were determined using the AOAC procedures (AOAC, 1990). Calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), copper (Cu), zinc (Zn) and manganese (Mn) were determined using an atomic absorption spectrophotometer after wet digestion in nitric and perchloric acid (Arab *et al*., 2009). The photometric method using molybdovanadate was used to measure phosphorus (P) concentrations in the forage plants (AOAC, 1990). Contents of neutral detergent fiber (NDF), acid detergent fiber (ADF) were analyzed according to Van Soest *et al*. (1991). Acid detergent lignin (72% H_2SO4, ADL) and acid insoluble ash (ASHINS) were determined as described by Robertson and Van Soest (1981). All samples were analyzed in duplicate. The chemical composition data obtained were analyzed statistically by using SAS procedure (1989). We performed a one-way factor analysis of variance by performing the Fisher multiple tests with significance levels of 5%.

III – Results and discussion

Table 1 shows the chemical composition of the forage. The DM levels were significantly high ($P<0.05$) in *T. africana,* and *C. dactylon* (509, 484 g/kg of fresh matter) compared with the level observed in *C. conglomeratus*. Our results are comparable with those obtained in shrubs located in North-West of Tunisia ranging from 26 to 53% (Ammar *et al*., 2005). OM levels were significantly higher in *C conglomeratus* (867 g/kg) compared to the levels of those observed in *C dactylon* and *T. Africana* respectively 830 and 837 g/kg. The herbaceous *C. dactylon* had a low DM level (830 g/kg), lower than the same plant in the tropical region: 945 g/kg. The ASHINS (insoluble ash) levels were significantly high ($P<0.05$) in *C. dactylon* and *C. conglomeratus* (74 and 53 g/kg DM respectively). This is explained by the nature of the plants that grow close to the ground and in the wadi beds and floodplains. Besides, climate in arid zones influences significantly and results in an abundance of ash and insoluble ashes (ASHINS) in forage. However *T. africana* had a low level of ASHINS (13 g/kg DM) compared to those of grain ranged from 28 to 41 g/kg DM (unpublished data).

The ether extract (EE) concentration in different plants species was low and ranging from 14 to 15 g/kg. These levels are very low compared to those obtained in trees at South-Africa ranging from 33 to 44 g/kg DM (Lukhele and Van Ryssen, 2003). Feedstuffs containing less than 80 g/kg DM of CP cannot provide the minimum ammonia levels required by rumen microorganisms to support optimum activity (Al-Masri, 2013).

The herbaceous *C. conglomeratus* and the fodder tree *T. Africana* had an essential content of CP respectively 143 and 142 g/kg DM versus 110 g/kg DM for *C. dactylon*. In many regions from the world, trees have been used as feedstuffs for livestock, mainly because of their high protein contents throughout the year that can be attributed to the ability of these plants to fix atmospheric nitrogen. All the plants contained high fiber (NDF and ADF) and the differences between forage species NDF and ADF contents were statistically significant ($P<0.05$) (Table 1).

Table 1. Chemical composition (g/kg DM) of arid plants (mean ± SD)

Forage	DM	OM	ASHINS	EE	CP	NDF	ADF	ADL
C. dactylon (n = 10)	$484^{a} \pm 12$	$830^{b} \pm 73$	$74^{a} \pm 21$	14 ± 0.4	$110^{b} \pm 22$	$710^{a} \pm 29$	$387^{a} \pm 70$	$111^{a} \pm 20$
T. Africana (n = 9)	$509^{a} \pm 76$	$837^{b} \pm 66$	$13^{c} \pm 14$	15 ± 0.4	$142^{a} \pm 41$	$451^{b} \pm 24$	$271^{b} \pm 26$	$89^{b} \pm 26$
C. conglomeratus (n = 7)	$253^{b} \pm 58$	$867^{a} \pm 15$	$53^{b} \pm 19$	15 ± 0.4	$143^{a} \pm 21$	$656^{a} \pm 12$	$344^{a} \pm 11$	$72^{b} \pm 29$

DM: dry matter; OM: organic matter; EE: ether extract; CP: crude protein; NDF: neutral-detergent fiber; ADF: acid-detergent fiber; ADL: lignin. [a,b,c,] Means in the same columns for each parameter with different superscript are different at P <0.05.

The NDF and ADF fiber are ranged respectively from 451 to 710 g/kg DM and from 271 to 387 g/kg DM. Similar results were reported for Tunisian and Mediterranean fodder shrubs (Ammar *et al.*, 2005) and for fodder trees from Syria (Al-Masri, 2013). It's known that the lignin is a physical barrier to microbial enzymes and the lignin concentration of forages is negatively related to the extent of digestion. *C. dactylon* was more lignified (P<0.05) than the two other species. The macro and trace mineral concentrations in different plants are presented in Table 2. Mineral imbalances (deficiencies or excesses) in soils and forages have long been held responsible for low production and reproductive problems among grazing ruminants (Mcdowell and Valle, 2000). All plants had P content varied from 2 g/kg (*T. africana*) to 3 g/kg DM (*C. conglomeratus*). These levels are higher than that of trees fodder reported by Lukhele and Van Ryssen (2003) in South Africa. *T. Africana* had a high level of Ca: 21 g/kg DM. Ca: P ratio varied widely, being particularly high in *T. Africana* (11 g/Kg DM). The Ca: P ratios ranged from 1:1 to 2:1 are ideal for growth and bone formation for ruminants. Low P and high Ca concentration resulted in an unusually wide Ca: P ratios. It seems that browsing small ruminants (goats, sheeps and white-tailed deer) can sustain high Ca: P without being affected P metabolism (Ramírez-Orduna *et al.*, 2005). Levels of K and Na were high in different plants. The Mg concentration ranged from 2 to 9 g/kg DM in respectively *C. conglomeratus* and *T. Africana*. According to recommend requirements for ruminants (see Table 2), macro mineral levels in studied plants were well above requirements.

Table 2. Mean concentrations of minerals in the different plants species (g/kg DM for macro minerals and mg/kg DM for trace minerals)

Forage	P	Ca	Ca/P	K	Na	Mg	Mn	Cu	Zn
C. dactylon (n = 10)	$3^{a} \pm 0.4$	$13^{b} \pm 2$	$5^{b} \pm 1$	$30^{b} \pm 5$	$6^{c} \pm 1$	$3^{b} \pm 0.4$	$56^{b} \pm 24$	9 ± 2	$56^{a} \pm 7$
T. Africana (n = 9)	$2^{b} \pm 0.6$	$21^{a} \pm 8$	$11^{a} \pm 5$	$24^{b} \pm 6$	$46^{a} \pm 24$	$9^{a} \pm 4$	$27^{c} \pm 11$	9 ± 3	$42^{b} \pm 10$
C. congl. (n = 7)	$3^{a} \pm 0.6$	$10^{b} \pm 3$	$4^{c} \pm 1$	$62^{a} \pm 17$	$12^{b} \pm 5$	$2^{b} \pm 0.4$	$181^{a} \pm 71$	11 ± 2	$33^{c} \pm 6$
Ruminants requirements (mg/kg DM)*	1.8-4.8	1.8-8.2	–	6-8	0.6-1.8	1-2	50-60	10	50-60
Goat requirements (mg/kg DM)**	2.7	2.6	–	2.2	0.7	1.7	30	9	30

[a,b,c,] Means in the same columns for each parameter with different superscript are different at P <0.05.
* Recommended requirements by (INRA, 1978 and Meschy, 2010).
** Recommended requirements by (NRC, 1981; Kessler, 1991 and Ramírez-Orduna *et al.*, 2005).

Trace mineral concentrations of the three arid forages varied from deficient, lower and sufficient than the requirements for domestic ruminants according to the NRC (1981) and those reported by Meschy (2010). The Mn level in *C. conglomeratus* (181 mg/kg DM) was significantly higher ($P<0.05$) compared to other plants. The Cu concentrations in all plants were similar and the difference observed is not significant ($P>0.05$).

IV – Conclusions

Forage plants studied from arid area are essential in supporting basic nutritional requirements of domestic ruminants. The CP content in *T. Africana* and *C. conglomeratus* could be effective protein supplements for ruminants grazing poor quality grass. Regarding major minerals in these plants they were present at sufficient levels to fulfill in the requirements of ruminants. However, trace mineral was slightly deficient and supplementation could be necessary.

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Chemical composition and fatty acid profiles of some local forage resources in southern Tunisia

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Abstract. In arid areas, livestock feed is based on the use of rangelands and other local feeds harvested and dry range species and weeds as natural hay locally called "khortane". Other resources are commonly used such as dried *Stipa tenacissima* L. and dried olive leaves. The aim of this study was to evaluate chemical and fatty acid composition of local feeds (khortane*, S. tenacissima* and dried olive leaves and oat hay). A large variability in chemical composition was observed among the different feeds. Crude protein content was higher in khortane (12.17% DM). *S. tenacissima* had the highest NDF content (P<0.05). The results obtained for the fatty acids composition showed that the highest polyunsaturated fatty acids and monounsaturated fatty acids content were observed in khortane (7.64 and 47.7% respectively). The saturated fatty acids content was higher *(P<0.05)* in *S. tenacisima* followed by dried olive leaves, oat hay and khortane (67.09, 57.19, 45.99 and 44.66% respectively). The omega-3 was significantly higher (P<0.05) in the khortane (24.33%) compared to oat hay, dried olive leaves and *S. tenacissima* (12.51, 12.49 and 10.25% respectively) because it is rich in pastoral species.

Keywords. Arid area – Local resources – Chemical composition – Fatty acids.

Composition chimique et profils en acide gras de quelques ressources fourragères dans les zones arides de Sud-Tunisien

Résumé. *Dans les zones arides, l'alimentation du bétail, est basée sur l'utilisation de la végétation des parcours pâturée ou par la récolte des espèces spontanées séchées sous forme de foin localement appelé le « khortane ». D'autres aliments de récolte sont couramment utilisés, tels que les feuilles d'olivier séchées et le* Stipa tenacissima*. L'objectif de ce travail était d'évaluer la composition chimique et le profil en acides gras de quelques ressources locales (khortane,* S. tenacissima*, feuilles d'olivier séchées et le foin d'avoine).* Les *fourrages analysés* présentaient une *grande variabilité de composition chimique. La teneur en matières azotées totales était supérieure dans le khortane (12,17% MS). Les teneurs en NDF étaient les plus élevées dans* S. tenacissima*. Les résultats obtenus sur la composition en acides gras ont montré que le khortane avait les plus fortes concentrations en acides gras polyinsaturés et mono-insaturés (7,64 et 47,7% respectivement). La teneur en acides gras saturés était plus élevée chez* S. tenacissima *(67,09%) comparé aux feuilles d'olivier (57,19%), au foin d'avoine (45,99%) et au khortane (44,66%). Les oméga-3 étaient significativement plus élevés dans le khortane (24,33%) que pour le foin d'avoine (12,51%), les feuilles d'olivier séchées (12,49%) et* S. tenacissima *(10,25%) parce qu'il est riche en espèces pastorales (2,33, 12,51, 12,49 et 10,25% respectivement pour le khortane).*

Mots-clés. *Zone aride – Les ressources locales – La composition chimique – Les acides gras.*

I – Introduction

In arid areas, ruminants depend mainly on pasture and grain cereals. Because the high feed prices in the market, it is difficult to provide enough grain to feed the animals. Other feed resources are used to maintain the production of ruminants such as hay of natural grass (khortane), oat or alfalfa, agricultural by-products (cereal bran and straw, dried olive and fig leaves, olive cakes, wasted palm dates and stones) and harvested *S. tenacissima* (Visser *et al.*, 2002). These feeds may contain variable amounts of fat and polyunsaturated (PUFA). Diets based on pasture can improve the nutritional quality of milk and meat by shifting their fatty acids (FA) composition toward less saturated FA and more PUFA, especially omega-3 (Dewhurst *et al.*, 2006). Recently, much effort has been made to study the fatty acid (FA) profile of forage in relation to meat and milk quality with regard to potential health aspects. Most studies on the FA composition of individual species were carried out on legume species (Dewhurst *et al*., 2001; Elgersma *et al*., 2003). Data on alternative forage species are scarce. The pastoral resources are an important part of the diet of ruminants producing milk and meat. The aim of this study was to determine the chemical and fatty acid composition of some feeds used in Tunisia.

II – Material and methods

Feedstuffs used in the study were: oat hay, khortane, dried *S. tenacissma* and dried olive leaves. Oat hay was purchased in the market. *S. tenacissima* L, was hand-harvested on native rangelands from the Benikdeche Mountains (South-East Tunisia) during the late growing period (April), air-dried, stored in a dry area and then used in periods of drought. Khortane was harvested during the spring season from Djefera region. It was composed of several annual and perennial species of which the most representative were *Launaea resedifolia* (44%) and *Lolium multiflorum* (30%) on specific contribution basis. Dried olive leaves were supplied from the neighbouring private farmers.

Forages dried at 60°C were ground to 1-mm screen size to determine the chemical composition. The ash content was determined by incinerating samples in a furnace at 600°C for 6 h and crude protein (CP) was determined by Kjeldahl method (AOAC, 1190). Analysis of neutral and acid detergent fiber (NDF, ADF) was done according to the method described by Goering and Van Soest (1970).

The fatty acid composition was determined after extraction by the method of Folch *et al.*, (1957). Methylation was carried out according to the method of Chin *et al.*, (1992).

1. Statistical analysis

Data were statistically analysed by ANOVA (SPSS, 11.5) to determine the effect of feed types (oat hay, khortane, dried *S. tenacissma* and dried olive leaves) on the chemical composition and fatty acid profile. Statistical significance of the difference between feeds was tested using Duncan's new multiple range test (α = 5%).

III – Results and discussion

1. Chemical composition

The chemical composition showed differences (P<0.05) in nutrient content between feeds (Table 1).The DM content of khortane was high, which can be explained by the late stage of maturity of the foliages at the time of collection. The ash content ranged from 2.93% DM in *S. tenacissima* to 11.40% DM in oat hay. The CP content (% DM) ranged from 5.39 in *S. tenacissima* to 12.17 in khortane. The CP content in oat hay was comparable (6% DM) to the value in tables (Jarrige, 1988). In the case of khortane, floristic composition influences the chemical composition. The increase of Leguminosae and Compositae families proportion increase the CP content (Ayeb, 2009). The CP content of *S. tenacissima* was in the range of values observed by Genin *et al.*, (2007). CP content obtained in olive leaves was between the values (77-105 g/kg DM) recorded by Moujahed *et al.* (2000). The CP content in forage was related both to the presence of leaves and to the stage of cutting. Among the forages measured, we can assume that khortane has the advantage of supplying to the animal a diet rich in CP. Therefore, these feed types could be associated with a feed of low nitrogen content, such as straw, *S. tenacissima* and oat hay, to improve the level of CP in the diet.

The NDF and ADF content were different ($P<0.05$) among the forages. They tend to be higher in *S. tenacissima* followed by oat hay, khortane and dried olive leaves (Table 2). In oat hay, NDF and ADF content in the present study was lower than the value (75.7 and 48.1% DM) observed by Moujahed *et al.* (2011). The NDF and ADF values for *S. tenacissima* were higher than those reported by Laudadio *et al.* (2009) (74.6 and 47.2% DM). In dried olive leaves, ADF content was higher than the values 29.9% DM reported by Moujahed *et al.* (2000).

Table 1. Chemical composition of the used feeds (% DM)

Feeds	Khortane (n = 6)	*S. tenacissima* (n = 5)	Dried olive leaves (n = 6)	Oat hay (n = 4)	*P*
DM (% FM)	88.86 ^{bc}	92.51 ^{a}	87.25 ^{c}	90.04 ^{b}	<0.0001
Ash	11.34 ^{a}	2.93 ^{b}	11.32 ^{a}	11.40 ^{a}	<0.0001
CP	12.17 ^{a}	5.39 ^{c}	8.80 ^{b}	6.60 ^{bc}	<0.0001
NDF_{mo}	53.06 ^{c}	73.99 ^{a}	31.03 ^{d}	57.71 ^{b}	<0.0001
ADF_{mo}	29.32 ^{c}	55.51 ^{a}	30.35 ^{c}	42.72 ^{b}	<0.0001
CUD_{mo}	59.87 ^{a}	33.98 ^{b}	59.84 ^{a}	55.10 ^{a}	<0.0001

DM, dry matter (en % of fresh matter; CP, crude protein; NDF, neutral detergent fibre; ADF, acid detergent fibre.

Table 2. Fatty acids composition (% fatty acids methyl ester) of studied forages

Fatty acids	Khortane (n = 7)	*S. tenacissima* (n = 8)	Dried olive leaves (n = 8)	Oat hay (n = 8)	SEM	P
C16 :0	26.68 ^{b}	20.48 ^{c}	32.98 ^{a}	30.35 ^{ab}	0.08	<0.0001
C18 :0	4.09 ^{b}	6.08 ^{a}	6.43 ^{a}	5.47 ^{a}	0.26	0.0083
C18 : 1	6.94 ^{b}	6.43 ^{b}	17.36 ^{a}	16.17 ^{a}	1.12	<0.0001
C18:2	20.50 ^{a}	11.20 ^{b}	9.84 ^{c}	21.00 ^{a}	1.37	0.0006
C18:3	24.33 ^{a}	10.25 ^{b}	12.49 ^{b}	12.51 ^{b}	1.07	<0.0001
C22 :0	4.89 ^{a}	4.49 ^{a}	2.16 ^{b}	2.99 ^{b}	0.25	<0.0001
C20:5	2.87 ^{b}	4.50 ^{a}	2.38 ^{b}	3.01 ^{b}	0.23	0.0027
C24 :0	3.24 ^{c}	24.17 ^{a}	5.58 ^{b}	1.27 ^{c}	1.72	<0.0001
SFA	44.66 ^{c}	67.09 ^{a}	57.19 ^{b}	45.99 ^{c}	2.06	<0.0001
MUFA	7.64 ^{b}	6.96 ^{b}	18.01 ^{a}	17.05 ^{a}	1.18	<0.0001
PUFA	47.07 ^{a}	25.95 ^{c}	24.71 ^{c}	36.52 ^{b}	1.91	<0.0001

SEM: Standard error of mean.

a,b: Means in the same line with different superscripts are significantly different ($P < 0.05$).

SFA: saturated fatty acids; PUFA: polyunsaturated fatty acids; MUFA: monounsaturated fatty acids.

2. Fatty acid composition

All feeds have a significantly different ($P<0.05$) FA composition (Table 2). Saturated fatty acids (C16:0; C18:0; C 22:0 and C 24:0) were higher in *S. tenacissima* than other feeds. The values of C18:1 were higher in dried olive leaves. However, Conte *et al.* (2010) reported that the oleic acid (C18:1) was largely predominant in olive by- products. The highest ($P<0.0001$) concentrations of PUFA, particularly C18:3, were observed in khortane, which can be explainedby it's composition of grass. French *et al.* (2000) showed that the grass accumulate higher levels of n-3 fatty acid and PUFA and lower AGS. Also, The forage with high amounts of PUFA, particularly C18:3, are searched in diet of animals. Moreover, the linolenic acid content in forage increases the content of omega-3 fatty acids in animal products (Wyss *et al.*, 2006).

VI – Conclusion

It could be concluded that the chemical composition of used feeds is diversified; some of them is rich in CP and others are rich in FA. Diets with forage-rich pastoral species, showed a clear advantage in terms of PUFA, which have very positive impact on human health.

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The effects of forage turnip (*Brassica rapa* L. var. *rapa*) as companion crop on alfalfa yield and quality

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Abstract. The effect of seed rate and harvest stage of forage turnip as companion crop on forage yield and quality of alfalfa stand in the establishment year was studied. Beside to yield, crude protein, ADF, NDF, Ca, Mg, P and K ratios were determined for pure stands and mixtures. Yield values were given as total of season for all plots. The results showed that companion crop, its seed rate and harvest stage showed significant effect ($p < 0.01$) on yield and quality of alfalfa stand in the establishment year. Total yield of mixtures was higher than pure stand alfalfa. In general, forage and protein yield were higher when plots are harvested at the full flowering stage of companion crop. The highest forage (10.91 t ha^{-1}) and protein yield (2.01 t ha^{-1}) were obtained from the alfalfa seeded with 0.6 kg/da companion crop harvested at full flowering stage.

Keywords. Alfalfa – Forage turnip – Companion crop – Forage yield.

Les effets du navet fourrager (*Brassica rapa *L. var.* rapa*) cultivé en association sur la production et la qualité de la luzerne

Résumé. *L'effet de la densité de semis et de la date de récolte du navet fourrager cultivé en association avec la luzerne a été étudié sur la production et la qualité du fourrage. En plus de la production, les teneurs en matières azotées totales, en ADF, NDF, Ca, Mg, P et K ont été déterminées sur les cultures pures et les mélanges. Les valeurs de production sont données pour l'ensemble de la saison. Les résultats montrent que la culture associée, sa densité de semis et son stade de récolte ont un effet significatif ($P<0.01$) sur la production fourragère totale et la qualité de la luzerne. La production des mélanges était supérieure à celle de la luzerne seule. En général, la production de biomasse et de protéines était supérieure lorsque les parcelles ont été récoltées à la pleine floraison de la culture associée. Les productions fourragère (10,91 t ha^{-1}) et de protéines (2,01 t ha^{-1}) maximales ont été obtenues lorsque la luzerne est semée avec 0,6 kg/ha de navet fourrager récolté en pleine floraison.*

Mots-clés. *Luzerne – Navet fourrager – Culture associée – Production fourragère.*

I – Introduction

Alfalfa is a small-seeded, slow-growing perennial legume, making it sensitive to adverse soil and climatic conditions and weed infestation during early growth. So, sowing with companion crop is a common practice for alfalfa. Companion crops also provide additional forage in the seedling year. Using small grains such as wheat, oats and barley to establish alfalfa is a long-standing tradition, however, cereals compete with alfalfa seedlings for light, water and nutrients (Cupina *et al*., 2000). To limit this competition, proper selection of companion crop species and varieties, and timely harvest are critical for long-term highly productive alfalfa stand.

Early maturity is important character to avoid competition and allow more time to grow the alfalfa seedlings. In this respect, brassicas can be good alternative as companion crop. The turnip

(*Brassica rapa* L. var. R*apa)* belongs to the Brassicaceae family, is an important vegetable source and is also used as forage for sheep and cattle. Turnip is deep-rooted cover crop that can reduce surface and subsoil compaction, scavenge N, and suppress weeds (USDA 2013).

In this study, we determined the effect of forage turnip as companion crop on total yield and quality of alfalfa stand in the establishment year.

II – Materials and methods

The effect of the forage turnip (*Brassica rapa* L. var. *rapa*) as a companion crop, its seed rates and harvest stages on alfalfa stand was investigated in seedling year. The experiment was established in Yozgat-Turkey ecological conditions (39°39'00'' N / 34°29'37'' E) in autumn 2012. The soil at the experimental site taken 30 cm depth is classified as clay-loam with pH:7.34, low organic matter (1.82%), medium P_2O_5 (6.07 kg/da) and high K_2O (201.77 kg/da) content. Annual rainfall, average temperature and moisture are 330 mm and. 11.8 °C and 54.8% respectively in the experimental site.

Bilensoy variety of alfalfa and Lenox variety of turnip were used as plant material. Forage turnip was sown at four seeding rates (0, 0.4, 0.6, 0.8, 1, 1.2 kg/da) with alfalfa (2 kg/da) in the 6 alternative rows (FT:A:FT:A.) with 20 cm distance and 5 m lenght. Alone turnip was sown by 1 kg /da seed rate with 40 cm row distance. The experiment was sown according a split-plot design with three replications on October 16. A dose of 4 kg/da N and 12 kg /da P_2O_5 was applied to plots after sowing. The plots were harvested at two different stages depending on turnip, at 50% flowering and full flowering stages. After companion crop removed in the first cutting, alfalfa was harvested five times when it comes to early flowering stage and, was irrigated after each cutting. To create similar effect as in the mixture, alone alfalfa plots were divided two parts and each part was cut at the same time and same height with companion crop. Total forage yield and mean quality in the treatments were determined as fallows;

$$\text{Quality} = \frac{(Y_{FT}{*}X_{FT}\%)+(Y_{A1}{*}X_{A1}\%+..+Y_{A5}{*}X_{A5}\%)}{Y_{Total}} \quad ; \qquad \text{Yield}_{Total} = (Y_{FT}) + Y_{A1} +...+ X_{A5}$$

Qality: CP, AND, NDF and mineral content. Y: yield A: alfalfa. FT: turnip. X; ratio of quality traits in forage.

To determine forage yield, plant samples were dried at 68°C until constant weight. Then samples were ground to pass though 1 mm screen for quality analyses. Crude protein (CP), Acid Detergent Fiber (ADF), Neutral Detergent Fiber (NDF), Ca, P, Mg and P contents were determined by using Near Reflectance Spectroscopy (NIRS, 'Foss XDS') with software package program 'IC-0904FE'. The data were subjected to analysis of variance by means of SPSS V 10.0 (SPSS Inc., 1999). Differences among means were separated by using Duncan Multiple Range Test.

III – Results and discussion

The effect of seed rate and cutting stage of companion crop was significant ($p<0.05$, $p<0.01$) on yield and many of quality traits of alfalfa in the establishment year (Table 1). Compared with sole sowing, forage yield was markedly higher in alfalfa seeded with companion crop. However, majority of this yield was produced by the companion crop at the first cutting. Total forage yield of alfalfa was higher when the companion crop was removed at full flowering stage compared to 50% flowering stage (Table 2), clearly due to the further growth of companion crop. In addition, sole alfalfa produced more yield in the second cutting treatment. Although it is very early for alfalfa, to create similar effect, alone alfalfa plots were harvested at the same period as the mixtures. So, this result indicates that alfalfa growth is adversely affected by early harvest.

Considering seed rate of companion crop, the optimum ratio was 0.6 kg/da (Table 2). This mixture produced the highest forage yield at both harvest stages of companion crop. Lower rate of companion crop created low plant density per area, led to formation of robust plant which were more leafy and tall, while higher rates of it led to dense but weak plants. In both cases, the pressure on alfalfa increased, but the yield of companion crop markedly decreased.

Table 1. Analysis of variance for quality and yield traits on cutting stage and seed ratio of companion crop in alfalfa

Traits	HY	CP	CPY	ADF	NDF	Ca	K	P	Mg
Cutting	**	ns	ns	ns	Ns	*	*	ns	ns
Treatments	**	**	**	ns	Ns	*	**	ns	**
Cut. X Treat.	**	*	ns	ns	Ns	*	**	**	ns

* P<0.05, ** P<0.01, *** P<0.001, ns: non significant.

Table 2. Forage yield, crude protein content and yield of alfalfa under different seed ratio and cutting regime of companion crop

Treatments	Hay yield (t ha^{-1})			Crude protein (g kg^{-1})			Crude protein yield (t ha^{-1})		
	Stage 1	Stage 2	Mean	Stage 1	Stage 2	Mean	Stage 1	Stage 2	Mean
Alfalfa (A)	4.73 ef	5.34 de	5.03 d	248.5 a	237.9 abc	243.2 a	1.18	1.27	1.22 b
Turnip (T)	1.66 g	4.69 ef	3.17 e	242.5 ab	149.1 d	195.8 b	0.39	0.70	0.56 c
A + T $_{(0.4\ kg)}$	4.86 ef	8.37 b	6.61 bc	201.7 ad	162.9 d	182.3 b	0.99	1.35	1.16 b
A + T $_{(0.6\ kg)}$	6.41 c	10.91 a	8.66 a	183.1 cd	183.0 cd	183.2 b	1.18	2.01	1.59 a
A + T $_{(0.8\ kg)}$	5.56 cde	8.40 b	6.98 b	179.7 cd	171.2 d	175.3 b	1.00	1.46	1.23 b
A + T $_{(1.0\ kg)}$	6.05 cd	6.07 cd	6.06 c	195.5 ad	192.8 a-d	194.0 b	1.18	1.16	1.17 b
A + T $_{(1.2\ kg)}$	3.98 f	6.56 c	5.27 d	174.8 d	189.9 bcd	182.5 b	0.70	1.25	0.97 b
Mean	4.75 B	7.19 A		203.7	183.8		0.94	1.31	

As excepted, mean crude protein content was the highest in pure alfalfa (Table 2). However, the greatest protein yield was obtained from the treatment of A + T 0.6 kg/da owing to its high yield. The effect of the treatments was not significant on final ADF and NDF content in forage (Table 3). Mineral matter contents showed significant changes depending on cutting stage and treatment. After detailed examination of the data, it can be stated that the change is largely caused by the companion crop. The changes in Ca and K content between cutting stages can be attributed to maturity of forage turnip.

In terms of mineral content, pure stands were advantageous with a slightly higher values compared to mixtures. This deficiency can be compensated with supplementary feeding. So, forage turnip as companion crop can offer great benefits for producing high yielding and quality forage in alfalfa stand in the establishment year. This contrasts with Waddington and Bittman (1984), who stated that rapeseed which is taxonomically in the same family as turnip should not be used as a companion crop for legumes.

Table 3. Quality values of alfalfa under different seed ratio and cutting regime of companion crop

Treatments	ADF (g kg^{-1})			NDF (g kg^{-1})		
	1st Cut.	2st Cut.	Mean	1st Cut.	2st Cut.	Mean
Alfalfa (A)	261.9	282.1	272.0	393.9	415.0	404.5
Turnip (T)	279.5	389.2	334.4	354.5	498.8	426.7
A + T (0.4 kg)	297.8	370.7	334.3	390.7	509.1	449.9
A + T (0.6 kg)	305.8	348.3	327.1	413.0	483.5	448.2
A + T (0.8 kg)	304.2	363.6	333.9	415.1	501.4	458.3
A + T (1.0 kg)	286.6	350.3	318.5	387.2	467.7	427.5
A + T (1.2 kg)	306.5	354.6	330.6	410.5	493.3	451.9
Mean	291.8	351.3		395.0	481.3	
Treatments	**Ca (g kg^{-1})**			**K (g kg^{-1})**		
	Stage 1	**Stage 2**	**Mean**	**Stage 1**	**Stage 2**	**Mean**
Pure Alfalfa	13.80 a	14.53 a	14.17 a	26.87 c	25.93 cd	26.40 c
Pure Turnip	14.13 a	12.20 a	13.17 a	39.73 a	22.50 de	31.12 a
A + T (0.4 kg)	13.50 a	13.80 a	13.65 a	35.47 b	20.77 e	28.12 bc
A + T (0.6 kg)	13.57 a	14.03 a	13.80 a	32.90 b	25.23 cd	29.07 ab
A + T (0.8 kg)	13.00 a	12.87 a	12.93 a	32.17 b	21.23 e	26.70 bc
A + T (1.0 kg)	13.10 a	13.77 a	13.43 a	33.77 b	24.37 cde	29.07 ab
A + T (1.2 kg)	5.83 b	12.83 a	9.33 b	33.20 b	22.80 de	28.00 bc
Mean	12.42 B	13.43 A		33.44 A	23.26 B	
Treatments	**P (g kg^{-1})**			**Mg (g kg^{-1})**		
	Stage 1	**Stage 2**	**Mean**	**Stage 1**	**Stage 2**	**Mean**
Pure Alfalfa	4.03 bc	3.87 bcd	3.95	2.97	2.70	2.83 a
Pure Turnip	4.83 a	3.13 e	3.98	2.47	1.80	2.13 b
A + T (0.4 kg)	4.07 b	3.13 e	3.60	2.17	2.17	2.17 b
A + T (0.6 kg)	3.80 bcd	3.43 cde	3.62	2.17	2.17	2.17 b
A + T (0.8 kg)	3.80 bcd	3.33 de	3.57	1.87	1.93	1.90 b
A + T (1.0 kg)	4.07 b	3.60 b-e	3.83	1.83	2.10	1.97 b
A + T (1.2 kg)	3.73 b-e	3.47 b-e	3.60	2.07	2.07	2.07 b
Mean	4.05	3.42		2.22	2.13	

IV – Conclusions

The present study showed that alfalfa seeded with companion crop produced high forage and protein yield compared to pure stand in the establishment year. However harvest stage and seed rate of companion crop had also significant effects. The seed rate of 0.6 kg/da for the companion crop and removed at full flowering is a best treatment in alfalfa establishment for yield and quality.

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Trifolium isthmocarpum Brot: biosaline agriculture for forage and livestock production

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Abstract. *Trifolium isthmocarpum* Brot. (*Leguminosae)*, occurs in different habitats in Morocco. It grows in moderately saline areas where traditional forage legumes cannot be cultivated. However, its existence has not been widely studied despite its good palatability. The salt tolerance was studied between natural field conditions and greenhouse. The extensive field studies have recorded the species in many different habitats ranging from healthy agricultural lands to abandoned saline areas. The plants maintained high nodulation capacity (ranging between 70% and 97%) and nitrogenise activities (average 2.05 µmol C_2H_4 plant^{-1} h^{-1}) in different habitats. Shoot systems of plants collected from salt-affected soils exhibited higher concentrations of Na^+ and Cl^- than those collected from healthy soils. Greenhouse experiments showed that germination percentage and vigor value of the studied species was not significantly ($P > 0.05$) affected at 160 mM NaCl, and that 25% of the germination ability was maintained when growing on substrates containing 220 mM NaCl. The growth rate of seedlings was not significantly affected by 160 mM NaCl but was reduced by 38% under 220 mM NaCl. This study recommends the cultivation of *T. isthmocarpum* in salt-affected soils, which are widespread and pose a problem for the farmers of Morocco and other countries in the world's arid belt.

Keywords. Pasture crop – Salt-affected land – *Trifolium isthmocarpum* Brot. – Wild Legumes.

Le* Trifolium isthmocarpum *Brot : culture sur sols salins pour la production de fourrage et l'élevage

Résumé. *L'espèce* Trifolium isthmocarpum *Brot., est une légumineuse présente dans différents habitats au Maroc. Elle pousse dans les zones modérément salines, où les légumineuses fourragères traditionnelles ne peuvent pas être cultivées. Cependant, elle n'a pas été largement étudiée malgré sa bonne appétence. La tolérance au sel a été étudiée dans les conditions naturelles et en serre. Des études de terrain ont recensé l'espèce sur différents habitats, allant de terres agricoles saines aux zones salines. Sur les habitats étudiés, l'espèce a maintenu une capacité de nodulation élevée (entre 70% et 97%) ainsi que son activité de nitrogénase (en moyenne 2,05 µmol C_2H_4 plant^{-1} h^{-1}). Les plantes prélevées dans les sols salins présentent des concentrations plus élevées en Na^+ et Cl^- que celles prélevées dans les sols non salins. Les expériences en serre ont montré que le pourcentage de germination et la vigueur de l'espèce étudiée n'ont pas été significativement ($P > 0,05$) affectées à 160 mM de NaCl, et que 25% de la capacité de germination a été maintenue lors de la croissance sur des substrats contenant 220 mM de NaCl. Le taux de croissance n'a pas été significativement affecté par 160 mM de NaCl. Toutefois, il a été réduit de 38% sur 220 mM de NaCl. Cette étude suggère de recommander la culture de* T. isthmocarpum *sur des sols salins, qui sont largement répandus et posent un problème pour les agriculteurs du Maroc ainsi que d'autres pays des zones arides.*

Mots-clés. *Pâturage – Terres salinisées –* Trifolium isthmocarpum *Brot. – Légumineuse sauvage*

I – Introduction

Morocco is one of the countries which is seriously affected by salinity; 33% of its cultivated land is salinized (Cherkaoui *et al*., 2007). However, an understanding of the range of salinity that various legumes can tolerate is central to their use in programs for re-vegetation of saline lands (Behdani *et al*., 2008). The present study focused on salt tolerance of annual legumes, which can offer economic and environmental benefits. Moreover, they avoid salinity concentrations which reach the peak in summer and autumn in Mediterranean environment. *Trifolium* is a leguminous genus, characterized by high seed yields, high nitrogen fixation rates, and important value in crop rotations. Generally, *Trifolium* species are recognised as being salt-sensitive. However, research undertaken on a limited number of species (Gibberd *et al*., 2001) suggests that species do vary in their response and that further research, may be beneficial in identifying species, that are suited to mild or moderate saline. *Trifolium isthmocarpum* Brot (annual clover) is one of these clovers that have not been researched largely. It is grown in moderately saline areas where traditional forage legumes cannot be grown in different habitats in Morocco. Few authors mentioned *T. isthmocarpum* in their studies and generally occurred in laboratory. For example, Rogers and West (1993) noted the superior tolerance of *T. isthmocarpum* compared to *T. subterraneum* L. and *T. purpureum* Loisel. However, salt tolerance may differ between laboratory or greenhouse and natural field conditions owing to the complex interaction of a number of edaphic and climatic factors. The present work investigates the performance of *T. isthmocarpum* under both field and laboratory conditions to evaluate its potential for use as a fodder crop in salt-affected soil in Morocco.

II – Materials and methods

The seeds of *T. isthmocarpum* used were from the seed bank of the National Institute of Agronomic Research of Rabat. The study was conducted in two sites: the experimental station Guich in Rabat (34º03' N, 06°46' O) on sandy soil, pH 7.3, organic matter (1.5%), phosphorus (65 ppm) and potassium (159 ppm) (determined by atomic absorption spectrometry Perkin-Elmer Corp., Norwalk, CT, USA). Subhumid bioclimatic domain. Average rainfall is 500 mm. This site was used as a control essay, with unsalted irrigation water: 0.56 dS/m. The second site was Benabid, affected by the problem of salinity, 10.9 dS/m of irrigation water (wells). This site is an agricultural area, subjected to a continental and oceanic influence. It is located at 33°51' N, -07°81'on sandy loam soil, pH 7.5, moderately rich in organic matter (2.28%), with sufficient phosphorus content (222.54 ppm) and potassium (386.5 ppm). The average annual rainfall was 480 mm when the experiment was carried out (December 8, 2010). The experimental design was a randomized complete block design with three replications, the basic plots are 1 m² each containing 24 plants. The space between the plots was 1 meter and the space between the two blocks was two meters. The irrigation frequency was: 10 days at the beginning of the culture and twice per week from the beginning of the four leaf stage. The plants were analysed to determine nodule number and nodulation percentage. They were determined at the beginning of flowering, from germination at 10% of heading. Nitrogenase activity of the legume-*Rhizobium* symbiosis was determined according to the methods described by Witty and Minchin (1988). The concentrations of soil minerals Na^+, K^+, Fe^{3+}, Ca^{2+}, and Mg^{2+} were determined using a Perkin 403 atomic absorption spectrophotometer (Anghel *et al*., 1999). Cl^- was quantified following titrametric method (Begum *et al*., 1997). The germination rate was measured to determine the ability of the plant to reproduce after its culture under saline conditions. The seeds of *T. isthmocarpum* were placed in sterilized Petri dishes with 5 ml of the treatment solution: 0 (control), 80, 160, and 220 mM of NaCl. Three replicates of 20 seeds were used in each treatment. The germination rate is expressed as the ratio of number of germinated seeds on the total number of seeds (TG = (n / N) x 100) where n: number of germinated seeds, N: total number of seeds placed in germination. Germination speed (vigor value) was calculated using the following formula: V = (a/1 + b/2 + c/3 + d/4 +…+ x/n) 100/S, where a, b, c,…x, respectively, represent the number of seeds that germinated after 1, 2, 3,…n days of incubation, and S is the total number of germinated seeds. The data were analysed using the Statistical Analyses System software. Significant differences between treatment means were determined using LSD test at the 0.05 probability level.

III – Results and discussion

The studied plants showed high nodulation percentages (ranging between 70% and 97%) and nitrogenase activities (average 2.05 µmol C_2H_4 plant^{-1} h^{-1}) at two different habitats (Table 1). The highest values of protein content were recorded in plants collected from salt-affected soil (Benabid). The nodulation percentage varied among individuals collected from different habitats. Giller (2001) provides a general overview of environmental constraints to nodulation and nitrogen fixation, as indicative of the importance of environmental stresses to *Rhizobia*. This variation can be also explained by the different prevailing environmental conditions. One of the interesting finding in this study was the important nodulation percentage and nitrogenase activity recorded in the *T. isthmocarpum* plants, which gives the species economic importance as it can be used to enhance soil fertility. Shoot systems of plants collected from salt-affected soil exhibited higher concentrations of Na^+ and Cl^- than those collected from healthy soil by more than twofold, and showed a reduction in K^+ content of about 30% (Table 1). Nutrient deficiencies can occur in plants when high concentrations of Na^+ in the soil reduce the amounts of available K^+, Mg^{2+}, and Ca^{2+} (Al-Abdoulhadi, 2012) or when Na^+ displaces membrane-bound Ca^{2+}. In addition, Na^+ may have a direct toxic effect, such as when it interferes with the function of potassium as a cofactor in various reactions. Many of the harmful effects of Na^+, however, seem to be related to the structural and functional integrity of membranes (Hasegawa *et al*., 2000).

Table 1. Average of nodulation, nitrogenase activity, shoot ion content and protein content of *T. isthmocarpum* collected from different habitats. (Five plants per replication)

	Guich site	Benabid site
Nodule plant^{-1}	69 ± 4.2	56 ± 1.8
Nodulation (%)	97 ± 7.2	80 ± 3.6
Nitrogenase activity (µmol C_2H_4 plant^{-1}h^{-1})	3.1 ± 0.02	2.02 ± 0.07
Protein (g/kg dry weight)	267 ± 9.8	318 ± 5.5
Na^+ (mmol/g DM)	1.14 ± 0.01	2.48 ± 0.18
Cl^- (mmol/g DM)	0.68 ± 0.12	1.7 ± 0.09
K^+ (mmol/g DM)	1.87 ± 0.06	1.33 ± 0.05

There is no significant difference on seed yield between the two sites. However, the germination capacity of harvested seeds during the experiment was sensitive to salinity. It was highly dependent ($p < 0.001$) to culture conditions. The ability of seeds native of Benabid, to germinate in NaCl treatment was important than those native of Guich. Germination percentage and vigor value of seeds native of Benabid was not significantly ($P > 0.05$) affected at 80 or 160 mM NaCl, whereas, 26% germination ability was maintained at 220 mM NaCl (Table 2). The selection of species tolerant to salinity needs first to study the behavior of their seeds during germination.

Table 2. Effect of NaCl on germination, vigor value (germination speed) and seed yield of *T. isthmocarpum*

		0 mM	80 mM	160 mM	220 mM	LSD
Guich site	Germination %	100	90	40	26	0.4
	Vigor value	30	28	15	11	0.03
	Seed yield per plant (g)	24.2	19.1	17.2	13.0	0.78
Benabid site	Germination %	98	89	78	45	0.01
	Vigor value	30	30	26	15	0.26
	Seed yield per plant (g)	24.5	22.2	18.4	16.1	0.15

The high germination percentage and vigor value (germination speed) of *T. isthmocarpum* recorded under salinity treatment is a very important character from the ecological point of view. Nichols *et al*. (2008) suggest that annual pasture legumes adapted to saline environments must have high salinity tolerance as seedlings or mechanisms to avoid germination at times of high salinity. The ability to germinate and establish seedlings on saline land is particularly important for annual pasture legumes, which must repeat this process each year. The seeds were collected from plants living in saline soils, which would be expected to exhibit salt tolerance during the germination stage, as a result of natural selection (Hameed and Ashraf, 2008).

IV – Conclusions

The high ability of the studied species to germinate, grow, and fix nitrogen under salt stress in both field and laboratory studies recommends its cultivation as a fodder crop and as a soil amelioration plant on salt-affected soils. More long-term studies with a wider taxonomic base would be needed to reach general conclusions on the natural selection in response to salinity.

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Rumen degradability of some Algerian browse plant species from Algerian arid rangelands

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Abstract. The study was conducted in Boussâda district, in the arid Saharan Atlas region with the objective of evaluating the chemical composition and *in situ* rumen degradation of Algerian browse plants collected from arid rangelands. Six browse plant species were used in this study: four dicotyledon plants namely *Atriplex halimus*, *Artemisia herba-alba*, *Astragalus gombiformis* and *Calobota saharae* and two monocotyledon plants, namely *Lygeum spartum* and *Stipa tenacissima*. Nylon bags containing foliage samples of each species were incubated for 0, 24 and 96 h (as indicators of solubility, degradation rate and potential degradability of the forages) in the rumen of three Merino sheep fitted with rumen fistula. Forages showed different ($P<0.001$) DM and NDF dissapearance rates. After 96 hours of incubation time, the highest *in sacco* DM disappearance was observed for *A. gombiformis* (0.85 g/g DM incubated) and the lowest was obtained with *S. tenacissima* (0.31 g/g DM incubated). In summary, dicot plants with high protein, low fiber and high DM ruminal degradability could be regarded as interesting roughages for use as ruminant feedstuffs.

Keywords. Algerian arid areas – Browse plants – Chemical composition – Nutritive value – Rumen.

Dégradabilité ruminale de plantes Algériennes collectées dans les régions arides

Résumé. *Cette étude a été menée dans la région de Boussâda avec pour objectif l'analyse chimique et l'évaluation de la dégradation* in sacco *de plantes algériennes. Quatre plantes dicotylédones:* Atriplex halimus, Artemisia herba-alba, Astragalus gombiformis, Calobota saharae *et deux plantes monocotylédones:* Lygeum spartum *et* Stipa tenacissima *sont utilisées. Des sacs en nylon contenant un échantillon de chaque substrat sont incubés à 0, 24 et 96 h (comme indicateurs de solubilité, taux de dégradation et potentiel de dégradabilité des fourrages) dans le rumen de trois moutons de race Mérinos munis de fistules. Les disparitions* in situ *de la matière sèche (MS) et des parois végétales totales (NDF) ont été significativement différentes entre les fourrages (P<0.001). Aprés 96 heures d'incubation, la disparition* in situ *de la MS la plus élévée est observée pour* A. gombiformis *(0.85 g/g MS) alors que la valeur la plus faible est obtenue pour* S. tenacissima *(0.31 g/g MS). En conclusion, les plantes dicotylédones avec un contenu élevé en protéines, une faible concentration en fibres et une bonne dégradabilité ruminale, peuvent être envisagées comme des plantes intéressantes pour l'alimentation des ruminants.*

Mots-clés. *Composition chimique – Plantes – Rumen – Valeur nutritive – Zones arides algériennes.*

I – Introduction

The hill areas of northern atlas Algerian region have traditionally been used to rise sheep and goats, which can browse substantial amounts of shrubs to meet their nutrient requirements. Forages are the major and cheapest source of energy for ruminants. Improvement in forage fibre digestion increases the energy available to ruminants (Jalilvand *et al*., 2008). Despite their potential as feeds, little research has been completed to determine their nutritive value.

The *in situ* rumen disappearance and *in vitro* gas production techniques are useful for rapid screening of feeds to assess their potential as energy sources for ruminants (Preston, 1995). The gas production technique has proved to be more sensitive than the *in situ* nylon bag technique for determining the nutritive value of feeds containing inhibitory compounds, such as tannins. Khazaal *et al.* (1994) showed that physical binding of tannins to substrate could be detected in a nylon bag incubated in the rumen, although effects such as toxicity to microbes and binding to enzymes would be diluted and difficult to detect.

The objective of this study is to evaluate the nutritive value of various shrub species by determining chemical composition and *in situ* dry matter and NDF disappearances of these forages.

II – Materials and methods

Plant material was collected in Bousâada district, north central Algeria (N 35° 15.768', E 04° 13.885', 496-981 m altitude), in the Saharan Atlas region. Six browse plant species were used in this study: four dicotyledon plants namely *Atriplex halimus* L., *Artemisia herba-alba* Asso, *Astragalus gombiformis* Pomel and *Calobota saharae* (Coss. & Durieu) Boatwr. & B.-E. van Wyk (formerly *Genista saharae* or *Spartidium saharae*) and two monocotyledon plants, namely *Lygeum spartum* Loefl. ex L. and *Stipa tenacissima* L. Samples were collected when plants were at a flowering (*A. halimus, A. gombiformis* and *L. spartum*) or at a mature stage (the rest of species). Between six and ten specimens of each plant species were sampled to obtain a representative aliquot of the edible biomass, taken to the laboratory, pooled, oven-dried at 50ºC (Makkar, 2003), and ground to pass a 1 mm screen.

The procedure to measure *in situ* disappearance has been described in detail by López *et al*. (1999). *In situ* DM and neutral detergent (NDF) degradability in the rumen of each browse species was determined as the DM and NDF disappearances when samples (3 g DM) weighed in nylon bags (45 µm pore size and 7.5 x 15 cm size) were incubated in the rumen of three fistulated Merino sheep (body weight 49.4 ± 4.23 kg) for 24 and 96 h (3 bags per sample and incubation time, one in each sheep). At the end of incubation, bags were removed from the rumen, rinsed with cold tap water and washed in a washing machine with cold water for 3 cycles of 3 min each. The washed bags were dried in a forced draft oven at 100ºC for 48 h, and the residual DM used to calculate DM and NDF disappearances at each incubation time. Two bags per sample were washed following the same procedure without being previously incubated in the rumen to estimate DM disappearance at 0 h.

One way analysis of variance (Steel and Torrie, 1980) was performed on *in situ* data, with browse species as the only source of variation (fixed effect) and sheep (random effect) as a blocking factor. Tukey's multiple comparison test was used to determine which means differed from the rest. Analysis of variance was performed using the GLM procedure of the SAS software package (SAS Institute, 2008).

III – Results and discussion

Chemical composition and *in vitro* fermentation kinetics of the browse foliage have been reported elsewhere (Boufennara *et al*., 2012), and the results presented herein are complementary to the informational ready published.

The CP content (Boufennara *et al*., 2012) of the plant species samples varied widely, being particularly high for *A. gombiformis* (223 g kg^{-1} DM) and low for the grasses *L. spartum* and *S. tenacissima* (73 and 75 g kg^{-1} DM, respectively). Protein content in dicotyledon species ranged widely from 109 to 223 g kg^{-1} DM and was always greater than in monocotyledon grasses. In general, monocots had higher NDF and ADF and lower lignin contents than dicots, whereas *A. halimus* and *A. gombiformis* showed low lignin contents.

Data of DM and NDF disappearances are shown in Table 1. *In situ* DM disappearance were variable (P<0.05) across the examined forages. The lowest *in situ* DM degradabilities were observed in monocotyledons (being particularly low for *S. tenacissima*), whereas dicots had significantly higher values. Similar trends have been observed for the *in vitro* fermentation kinetics estimated form the gas production (Boufennara *et al*., 2012). After 96 hours of incubation time, the highest *in sacco* DM disappearance was observed for *A. gombiformis* (0.85 g/g DM incubated) and the lowest was obtained by *S. tenacissima* (0.31 g/g DM). These results could be explained for *A. gombiformis* by the low levels of cell wall fraction NDF, ADL and also by their high concentrations of CP. The increase in the DM disappearance observed in the case of *A. gombiformis* and *A. halimus* may be due either to solubilization and dilution of phenolic compounds or simply to the loss of fine particles from the bags. In agreement with Lucci *et al*. (1989), the potential of degradation of the dry matter of the legumes was higher than that of the grasses, although after 96 h *L. spartum* showed a higher value than *C. saharae*. *In sacco* NDF disappearance was consistently ranked with the exception for *L. spartum*: dicots > monocotyledons (P<0.05). The highest value was recorded for *A. gombiformis* while *S. tenacissima* showed the lowest cell wall degradability (P<0.001). These results are consistent with their respective cell wall content (Boufennara *et al*., 2012).

Particle losses by washing the substrates studied are comparable with those recorded by Ghorbani and Hadj-Hussaini (2000). However these results are high compared with those noted by Arhab *et al.* (2006). These differences may be due either to the nature of the substrate, or the pore size of the bags and/or to the sample/contact area ratio (Michalet-Doreau and Nozière, 1999) or to the technique of washing used (De Boer *et al*., 1987).

Table 1. *In situ* DM and NDF disappearances (g/g DM) of Algerian forages

Family	Substrate	DM			NDF		
		0 h	24 h	96 h	0 h	24 h	96 h
Dicotyledons							
Chenopodiaceae	*A. halimus*	0.414^{b}	0.739^{a}	0.810^{b}	0.206^{b}	0.496^{a}	0.604^{b}
Asteraceae	*A. herba-alba*	0.335^{c}	0.503^{c}	0.634^{c}	0.253^{ab}	0.409^{c}	0.487^{c}
Fabaceae – Leguminosae	*A. gombiformis*	0.498^{a}	0.676^{b}	0.849^{a}	0.189^{c}	0.501^{a}	0.645^{a}
	C. saharae	0.263^{d}	0.490^{cd}	0.538^{d}	0.173^{cd}	0.193^{d}	0.262^{d}
Monocotyledons							
Poaceae – Gramineae	*L. spartum*	0.261^{d}	0.486^{cd}	0.611^{c}	0.272^{a}	0.443^{b}	0.598^{b}
	S. tenacissima	0.114^{e}	0.196^{e}	0.314^{e}	0.122^{e}	0.155^{e}	0.225^{e}
R.S.D.[†]		0.012	0.017	0.018	0.067	0.013	0.016

[†] Residual standard deviation.

[a, b, c, d, e] Different superscripts in the same column indicate significant differences (P<0.05).

According to Mertens (1993), the factors of a physical nature such as crystallinity and degree of polymerization of the polysaccharides of the cell walls can have a significant effect on the kinetics of degradation, as well as lignin content. The specific examination of the kinetic data of the studied substrates reveals that the *in situ* NDF fraction degradation occurs mainly between 24 and 96 hours. Differences are also observed between species of the same family. These differences are principally attributed to the high lignin content and total nitrogen content, as well as the high losses of particles that may contain NDF fraction not recovered in the residue. The fraction of crude protein and phenolics compounds does not seem to play a significant effect on the process of *in situ* degradation of the cell wall. These results are consistent with the works of many authors (Apori *et al.*, 1998). The potential role of phenolic compound on ruminal fermentation is poorly detected by *in sacco* method (Apori *et al.*, 1998). Indeed, the effect of the anti-nutritive factors, which are unlikely to be detected using *in sacco* method, could account for the differences between the two methods. In the *in vitro* gas production technique, which is a batch system with limited supply of rumen fluid, these anti-nutritive factors remain in the fermentation medium and affect rumen microbial activity. Conversely, in the *in sacco* technique, which is an open system with real rumen environment with a continuous microbial activity and growth, the inhibition would be transient. Khazaal *et al.* (1994) reported that the technique of *in vitro* gas production is more sensitive than *in sacco* technique for determining the nutritive value of forages containing tannins.

IV – Conclusions

Combined use of chemical analysis, an *in vitro* gas production and an *in situ* incubation technique is advocated to determine the nutritive value of feeds containing phenolic compounds. On the basis of these techniques, *A. gombiformis*, *A. halimus* and *A. herba-alba* have better nutritive potential for sheep grazing hill areas of Boussâda district in north Algerian desert than *L. spartum*, *C. saharae* and *S. tenacissima*.

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Biomass production and quality value of pastoral species in the Rif Mountains

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Abstract. Rangelands represent the most important feed sources for goats in the Northern Morocco. The objective of the present study was to assess the biomass production and chemical composition of pastoral species in the Rif Mountains. This study was conducted in silvopastoral areas (Beni Arouss) exclusively used by goat herds. Five sample plots were selected using the method of stratification. To measure biomass of shrubs a reference module method was applied. For eight pastoral species, selected by the goats, dry matter (DM), crude protein (CP), mineral matter (MM), fat matter (FM), and crude fiber (CF) were performed according to the AOAC procedures. The pasture was characterized by an average diversity level of pastoral flora (60 species) dominated by shrubs. The biomass produced was 3,428 kg DM ha^{-1} composed for 75% *by Cistus crispus, Inula viscosa, Pistacia lentiscus* and *Quercus ilex*. For chemical composition, DM (20.2% to 50.4%), CP (1.3% to 3.5%), MM (3% to 16.8%), FM (3% to 12.5%), CF (11.1% to 24.8%) varies between *Calicotome villosa, C. crispus, Erica arborea, I. viscosa, Q. ilex, Lavandula stoechas, Olea europea,* and *P. lentiscus*. The continuous use of pastoral resources and lack of pasture management in Beni Arouss area has considerably reduced the palatable pasture species and has allowed the appearance of low pastoral value species such as *Arisarum vulgare,* and *Coriaria myrtifolia*. To ensure the sustainability of pastoral resources, breeders should lead appropriate rangeland management actions.

Keywords. Biomass – Chemical composition – Silvopastoral – Rif Mountain.

La production de biomasse et la qualité des espèces pastorales dans les montagnes du Rif

Les parcours représentent la source d'alimentation la plus importante pour les caprins dans le Nord du Maroc. L'objectif de cette étude est d'évaluer la production de biomasse et la composition chimique des espèces pastorales dans les montagnes du Rif. Cette étude a été menée dans des zones sylvo-pastorales (Beni Arouss) exclusivement utilisées par des troupeaux de caprins. Cinq placettes d'échantillonnage ont été choisies en utilisant la méthode de stratification. Pour mesurer la biomasse des arbustes, la méthode du module de référence a été appliquée. Pour huit espèces pastorales, les plus utilisées par les caprins, les teneurs en matière sèche (MS), matière azotée totale (MAT), matière minérale (MM), matière grasse (MG), et cellulose brute (CB) ont été déterminées selon les procédures de l'AOAC. Le pâturage est caractérisé par une diversité floristique moyenne (60 espèces) dominée par les arbustes. La biomasse produite est de 3428 kg MS ha^{-1} *composée à 75% par* Cistus crispus, Inula viscosa, Pistacia lentiscus *et* Quercus ilex. *Pour la composition chimique, la teneur en MS (20,2% à 50,4%), en MAT (1,3% à 3,5%), en MM (3% à 16,8%), en MG (3% à 12,5%), et en CB (11,1% à 24,8%) varient entre* Calicotome villosa, C. crispus, Erica arborea, I. viscosa, Q. ilex, Lavandula stoechas, Olea europea *et* P. lentiscus. *L'utilisation continue des ressources pastorales et l'absence d'une gestion des pâturages dans la région de Beni Arouss a considérablement réduit les espèces fourragères appétibles et a permis l'apparition d'espèces à faible valeur pastorale tels que* Arisarum vulgare *et* Coriaria myrtifolia. *Pour assurer la durabilité des ressources pastorales, les éleveurs doivent mener des actions appropriées de gestion des parcours.*

Mots-clés. *Biomasse – Composition chimique – Sylvopastoral – Montagne du Rif.*

I – Introduction

Mediterranean forests are rich in plant species and life forms (Le Houérou, 1981). They constitute an important year-round source of feed for livestock. In the Rif Mountains, forest pasture are traditionally an integral part of the feeding calendar of goats and consequently of the pastoral systems of the region. These forest pastures are used and overexploited throughout the year and most are characterized by shrub vegetation. The forest has undergone profound changes inducing major malfunctions between pastoral supply and demand in silvopastoral areas (FAO, 2011). This imbalance is mainly due to climate change, overgrazing, population and especially bad operating practices of silvopastoral resources such as limbing (Chebli *et al.*, 2012a).

For a sustainable and integrated development of pastoral and forest resources, it is essential to establish a resource assessment system.

We conducted this study in a pastoral area of the Moroccan Rif Mountains (Beni Arouss) exclusively used by goat's herds to assess pastoral production by botanical composition and biomass production of major pastoral species and their chemical composition.

II – Materials and methods

The study was carried out in Bouzahri, located in the Northern Morocco. Bouzahri is a part of the Beni Arouss region; it is characterized by private croplands and domanial forest. The pasture, concerned in our study, is located at 35°28' N 5° 60' W and between 260 to 430m above sea level. The climate is Mediterranean, with rainfall exceeding 500 mm/year.

The area of study is a forest rangelands exploited by goat breeders. The study was conducted over a period of eight months to assess the species composition and the productivity of pastoral plants by evaluating the vegetation qualitatively and quantitatively.

The qualitative evaluation of vegetation concerned floristic diversity and chemical composition. For floristic diversity, in each sampling period, a herbarium was collected to determine the floristic composition. For chemical composition, mainly for eight pastoral species, the most selected by the goats, dry matter (DM), crude protein (CP), mineral matter (MM), fat matter (FM), and crude fiber (CF) were performed according to the AOAC procedures (AOAC, 1997). This qualitative evaluation was performed during the month of May and June 2013.

For quantitative evaluation and in order to control spatial heterogeneity, the stratification method as proposed by Qarro (1996), Kouraimi (1997) and Chebli *et al.* (2012b) was used. Shrubs biomass was measured using a non-destructive method known as the reference module. We identified five quadrats in order to analyze the heterogeneity of silvopastoral area. The size of the quadrats adopted to measure the phytomasse is 2m x 5m. This quantitative evaluation was performed during the month of May 2012 and 2013, corresponding to the vegetative peak which is considered the ideal time for the measurement of the vegetation (Qarro 1996, Kouraimi 1997). Several interviews with breeders were carried out during the study period to gather information on grazing processes and to complete the database on the species characterization.

III – Results and discussion

The study area is characterized by a relatively rugged topography with moderately elevated slopes. The vegetation mainly consists in shrubs. The soil is poor and strongly susceptible to erosion.

1. Botanical composition

Floristic composition has revealed the existence of sixty plant species mainly dominated by shrubs. With our field observation and interviews conducted with breeders, different plant species dominating the site and who constitute more than 70% of the species selected by goats were identified: *Ajuga iva* L. (Schreber), *Calamintha nepeta* L. (Kuntze*), Cistus crispus* L.*, Cistus monspeliensis* L.*, Erica arborea* L.*, Lavandula stoechas* L.*, Lythrum junceum* L.*, Mentha pulegium* L.*, Mentha rotundifolia* L. (Hudson) and *Pistacia lentiscus* L. Compared to previous years breeders have noticed, appearance of other unpalatable species invading grazing areas. This situation is explained mainly by the lack of adequate management of rangeland, causing overexploitation of pastoral resources and contributes to appearance of low palatability species. According to observations and interviews conducted with breeders, we observed the appearance of degraded areas dominated by annual unpalatable plant species such as *Arisarum vulgare* (Targioni-Tozzetti) and *Coriaria myrtifolia* L.

2. Chemical composition

The chemical composition was performed for the most consumed species by goats in the pastoral area (table 1). Pastoral species in Bouzahri pasture have a DM content exceeding 29%, except *I. viscosa*. The content of MM is important in *I.viscosa* (16.82%) and *L. stoechas* (9.60%). It does not exceed 7% for the other species. The most palatable species are characterized by low levels of CP (1.30 to 2.90% DM), a moderate composition of CF (11.10 to 29.55% DM) and high levels of FM for 50% of the species analyzed (7.17 to 12.51% DM). The values of other parameters differ depending on pastoral species studied (Table 1).

Table 1. Chemical composition of the main pastoral species in Bouzahri pasture

Pastoral species	DM† (%)	MM (%)	SD	CP (%)	SD	FM (%)	SD	CF (%)	SD
Calicotome villosa	29.42	4.40	0.19	3.45	0.06	2.93	0.46	29.55	0.19
Cistus crispus	39.85	6.23	0.45	1.36	0.03	12.51	0.28	16.55	1.44
Erica arborea	45.13	2.97	0.10	1.30	0.03	8.68	0.21	22.59	0.25
Inula viscosa	20.16	16.82	0.28	2.83	0.06	10.20	0.10	16.22	1.18
Lavandula stoechas	36.09	9.60	0.38	1.78	0.02	4.90	0.13	22.95	1.35
Pistacia lentiscus	32.01	5.51	0.46	2.90	0.02	3.40	0.14	11.10	0.25
Olea europea	50.35	5.14	0.09	1.40	0.09	7.17	0.06	22.00	0.57
Quercus ilex	42.04	3.34	0.41	1.78	0.02	2.48	0.08	24.75	1.54

† DM: dry matter; MM: mineral matter; SD: standard deviation; CP: crude protein; FM; fat matter; CF: crude Fiber.

3. Biomass production

This pasture was characterized by an average diversity level of pastoral flora dominated by shrubs. Grazing is practiced throughout the year except during rainy days where breeders use limbing. The grazing time does not exceed 6 hours per day. Biomass production of palatable species is estimated to 3428 kg DM per hectare, composed for 75% by *C. crispus, I. viscosa, P. lentiscus* and *Q. ilex* (fig.1). The biomass production of pastoral species is decreased of 34.1% between 2012 and 2013 (5,205 kg ha^{-1} *vs* 3,428 kg ha^{-1} DM; Chebli, 2012c). This difference can be explained in part by continuous use of pastoral resources and lack of appropriate pasture management.

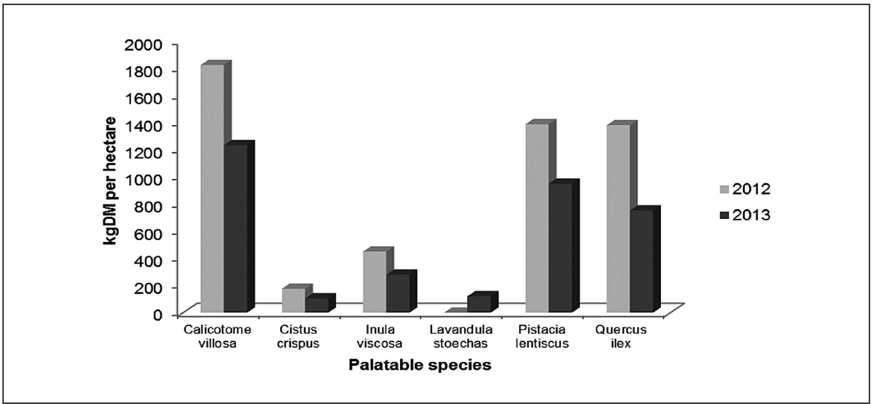

Fig. 1. Bimoass production of palatable species in Bouzahri pasture in 2012 and 2013.

IV – Conclusions

On the basis of our results related to the chemical composition we state that the most palatable species are characterized by a low levels of protein, a moderate amount of crude fiber and high levels of fat for 50% of the species analyzed. This pastoral area is under degradation and characterized by the presence of unpalatable species and the decrease of palatable biomass. To ensure the sustainability of pastoral resources in this area, breeders should adopt an appropriate rangeland management actions and reduce overgrazing by using rotational grazing systems to allow regeneration of palatable species. For further study, we suggest investigating the relationship between palatability and plant chemical composition or digestibility in order to complete the results obtained in this work.

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Evaluation of forage yield and quality of forage turnip x legume mixtures

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Abstract. Forage turnip (*Brassica rapa* L. var. r*apa)* was sown with common vetch (*Vicia sativa* L.), Hungarian vetch (*Vicia pannonica* Crantz) and pea (*Pisum sativum* L.) as binary mixtures with two seeding ratios (25:75, 50:50) for forage production. Each species was also sown as pure crop. The experiment was established in autumn 2012. The mixtures and pure forage turnip were harvested when forage turnip was at full flowering stage. Pure legume plots were harvested when they were at full flowering stage. Forage yield and quality (crude protein, ADF, NDF, Ca, Mg, P and K contents) were measured. Results revealed that all the mixtures, especially the mixture of 75% Hungarian vetch + 25% forage turnip, had higher forage yield than pure stands of forage turnip and legumes and satisfactory crude protein content.

Keywords. Forage turnip – Vetch – Pea – Mixture.

Evaluation de la production et de la qualité de mélanges navet fourrager x légumineuses

Résumé. *Du navet fourrager (*Brassica rapa *L. var.* rapa*) a été semé en mélange binaire avec de la vesce commune (*Vicia sativa *L.), de la vesce de Hongrie (*Vicia pannonica *Crantz) et du pois (*Pisum sativum *L.) avec deux proportions dans le semis (25:75, 50:50) pour la production fourragère. Chaque espèce a également été semée en pur. L'expérimentation a été implantée à l'automne 2012. Les mélanges et les espèces pures ont été récoltés lorsque le navet fourrager était en pleine floraison. La production et la qualité du fourrage (teneurs en matières azotées totales, ADF, NDF, Ca, Mg, P et K) ont été mesurées. Les résultats montrent que tous les mélanges, en particulier le mélange semé avec 75% de vesce de Hongrie + 25% de navet fourrager, avaient une production supérieure à celle des espèces pures de navet fourrager et de légumineuses et des teneurs en matières azotées totales satisfaisantes.*

Mots-clés. *Navet fourrager – Vesce – Pois – Mélange.*

I – Introduction

Livestock play a key role in the Turkish agricultural economy. However, quantity of animal products still remains below the country's needs mainly due to insufficient forage and feed production. The strategies performed for bridging the gaps in demand and supply of feeds and fodder include increasing forage yield and improving pastures. Considering that it takes a long time for perennial pasture improvement and there are economic limitations to increase forage area, the best way is seen to increase yield of annual forage crops. One way to increase forage yield should be to include forage legumes in mixed cropping systems (Ross *et al*., 2004).

Mixing forage pea and vetches with cereals to improve quality and yield is a common practice in the forage stands. These mixtures of legume and non-legume species also provide weed control, easy harvest, and reduce forage loss resulted from trait on the ground (Tan and Serin, 1996; Anlarsal *et al*., 1996). Besides cereals, other erect grown crops such as brassicas can be seeded with wrapping-growth (bed in plants) legumes. Rankin (1989) reported that positive results for forage turnip – legume mixtures in forage production regarding yield and quality.

Forage turnip is a popular crop especially in cold regions of the world. It has a broad-leafed, plenty habits and a high digestibility. Dry matter yield of forage turnip is close to legumes with slightly lower values. However, anti-nutritional compounds (erucic acid, glycosides, and nitrate sinapine) can cause damage to animals, in case it is used for animal feeding. Thus legume x turnip mixtures, in addition, eliminates or decrease the anti-nutritional effects of forage turnip (Hertrampf and Pascual, 2000). Maturation-dependent decrease in nutrient content in turnip is faster than in legumes and, best stages of turnip for quality are vegetative and flowering stages (Canbolat, 2013).

In the present study, forage turnip – legume mixtures established at different seed rates were evaluated for yield and quality.

II – Materials and methods

This study was conducted in the experimental fields of Agriculture and Natural Sciences Faculty, Bozok University in 2012-2013 growing season. The experiment was arranged in randomized block design with three replications. The soil taken from 30 cm depth is classified as clay loam with pH: 7.62, 2.17% DM, 7.7% $CaCO_3$, 11.57 kg da^{-1} P_2O_5 and 222,85 kg da^{-1} K_2O.

As plat material, Lenox variety of forage turnip (*Brassica rapa* L. *var. rapa*), Seymen variety of common vetch (*Vicia sativa* L.), Altınova-2002 variety of Hungarian vetch (*Vicia pannonica* Crantz) and Ozkaynak variety of pea (*Pisum sativum* L.) were used. Four different mixture rates (%100 legume, %75 legume + %25 forage turnip, %50 legume + %50 forage turnip, %100 forage turnip) were tested. Sowing was done manually in September 26, 2012. Four lines 5 m long and 30 cm apart were sown for each plot. The seed in pure stands were amounted 1 kg da^{-1} for forage turnip, 12 kg da^{-1} for legumes as reported by (Avcioglu *et al*., 2009).

The experiment was fertilized with 4 kg da^{-1} N and 12 kg da^{-1} P_2O_5 and irrigated for ensuring germination of plants (same N fertilisation for all plots, with or without legume). The mixtures and pure forage turnip were harvested when forage turnip was at full flowering stage. Pure legume plots were harvested when they were at full flowering stage.

After harvest, species were hand separated in samples of mixtures. Each species dried at 60^{o}C for 48 hours and was weighed. By using species dry weight, the rates of species in hay mixtures and total forage yield were determined. The dried samples were milled with a herb grinder. Crude protein, ADF (Acid detergent fiber), NDF (Neutral detergent fiber), Ca, Mg, P and K (g kg^{-1}) were determined by IC – 0904FE package program and device Near Infrared Reflectance Spectroscopy (NIRS) (Foss 6500). NIRS analyses were performed separately for legumes and forage turnip and results were multiplied by species yield percentage to calculate mixture quality. According to randomized blocks design, the data were evaluated by statistical package program SPSS10.0.

III – Results and discussion

The effects of the treatments on the investigated traits except K and Ca contents, in analysis of variance, were significant (Table 1, 2). Forage yield was the highest in Hungarian vetch (HV) x turnip (T) mixture with the 75% HV + 25% T and the lowest in pure turnip. The highest crude protein content was found in the mixture of 50% Common vetch (CV) + 50% T. However, 75% HV + 25% T mixture produced the highest protein yield owing to its high yield. Same authors, who have done similar research reported that legume x cereal mixtures produced higher forage yield compared to its pure stands (Suzer and Demirhan, 2005; Gummadov and Acar, 2007), and increase ratio of legumes in mixtures caused higher protein content in forage (Buyukburc *et al*., l989; Ross *et al*., 2004). Pure turnip had the highest ADF and NDF content while pure legumes especially pea had the lowest. There is no significant difference among mixtures for ADF and NDF contents.

Sowing treatments did not show significant effects on Ca and K content, statistically (Table 2). However, the effect of the treatments was significant for Mg ($p<0.05$) and P ($p<0.01$). The pure seeded common vetch had the highest Mg content while the highest P content was obtained from the mixture of 50% CV + 50% T. All these results indicate that forage turnip x legume mixtures investigated generally advantageous for forage yield and quality than their pure seeding.

Table 1. Average values of forage yield, crude protein content, crude protein yield, ADF and NDF in forage turnip x legume mixtures and pure crops

Treatments	Forage yield (t ha^{-1})†	Crude protein (g kg^{-1})†	Crude protein yield (t ha^{-1})†	ADF (g kg^{-1})†	NDF (g kg^{-1})†
Pure turnip	4.47 f	126.7 c	0.56 e	477.7 a	632.7 a
Pure Hungarian vetch	10.32 c	208.7 ab	2.15 bc	344.0 cd	445.3 c
Pure common vetch	7.54 e	206.3 ab	1.55 d	338.3 d	503.7 bc
Pure field pea	7.29 e	216.0 ab	1.56 d	293.0 e	457.7 c
50% HV + 50% T	8.77 de	199.7 ab	1.75 cd	388.0 bc	523.7 b
75% HV + 25% T	17.40 a	195.3 ab	3.40 a	400.7 b	553.0 b
50% CV + 50% T	8.57 e	228.7a	1.95 cd	380.7 bcd	562.7 b
75% CV + 25% T	12.85 b	201.0 b	2.59 b	383.0 bcd	533.3 b
50% FP + 50% T	10.05 cd	181.7 b	1.82 cd	386.7 bcd	554.7 b
75% FP + 25% T	8.54 e	220.0 ab	1.86 cd	357.3 bcd	551.3 b

†: $p<0.01$.

Table 2. Average values of Ca, Mg, P and K content in mixtures with forage turnip, common vetch, Hungarian vetch and pea and pure crops

Treatments	Ca (g kg^{-1})	Mg (g kg^{-1})†	P (g kg^{-1})††	K (g kg^{-1})
Pure turnip	11.00	1.67 d	3.00 d	25.00
Pure Hungarian vetch	13.33	2.00 bc	4.00 cd	30.33
Pure common vetch	12.67	3.00 a	4.00 cd	32.33
Pure field pea	12.67	2.67 ab	4.00 cd	30.00
50% HV + 50% T	13.67	2.00 bc	6.33 ab	32.00
75% HV + 25% T	12.67	2.33 abc	5.67 ab	31.33
50% CV + 50% T	13.00	2.33 abc	7.00 a	35.00
75% CV + 25% T	13.33	2.00 bc	5.33 bc	31.33
50% FP + 50% T	12.67	2.00 bc	5.33 bc	27.33
75% FP + 25% T	13.00	1.67 d	6.67 ab	33.33

††: $p<0.01$, †: $p<0.05$.

IV – Conclusions

The present study demonstrated that forage turnip can be seeded with legumes such as vetches and field pea and produce higher yield compared to pure seeding in the autumn sowing conditions. However, selected legume and its seed rate in the mixture are also significant. With these preliminary data collected in a single trial, Hungarian vetch – turnip mixture with the 75% x 25% seeding rate was the most suitable treatment for forage and protein yield.

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Evaluation of the competition between alfalfa and sainfoin sown in mixture

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Abstract. Alfalfa and sainfoin are pluriannual forage legumes that are well adapted to the agronomic conditions of NE Spain. However the persistence of sainfoin decreased when sown with alfalfa in mixture. It could be attributed to the fact that the cutting frequency was more suitable for alfalfa. In order to evaluate the persistence of sainfoin in mixture, the evolution of the annual forage yield in these species was compared, when sown in pure stands or using two types of mixtures, on alternate rows or mixed on the same row. Two harvesting rates were established, one that was most suited to alfalfa and the other to sainfoin. The study was conducted in rainfed conditions in Badules (Teruel) and under irrigation in Zaragoza during 2011-2013. The results confirm the lower yields and persistence of sainfoin when mixed with alfalfa under irrigation, which could be attributed to the allelopathic effects of alfalfa on sainfoin. There is no evidence of allelopathic phenomena arising in rainfed conditions in the two sowing modes employed. Cutting frequency had no influence on the occurrence of allelopathic phenomena.

Keywords. *Medicago sativa* L. – *Onobrychis viciifolia* Scop. – Dry matter – Crude protein – Allelopathy.

Évaluation de la compétition entre la luzerne et le sainfoin semés en mélange

Résumé. *La luzerne et le sainfoin sont des légumineuses fourragères pluriannuelles bien adaptées aux conditions agronomiques du nord-est de l'Espagne. Il a été constaté que la persistance du sainfoin diminue quand il est semé en mélange avec la luzerne. Cela est généralement attribué à la fréquence de coupes du fourrage, qui serait plus adaptée à la pousse de la luzerne. L'objectif de cette étude était d'évaluer la persistance du sainfoin, et le rendement annuel des fourrages obtenus à partir de cultures pures de luzerne et de sainfoin ou des mélanges luzerne-sainfoin. Deux types de mélanges ont été testés : les deux espèces ont été semées en lignes alternées ou mélangées dans la même ligne. Les parcelles ont été coupées à deux stades de maturité de la luzerne, début de floraison ou pleine floraison. L'étude a été réalisée en conditions naturelles à Badules (Espagne) ou en irrigation à Saragosse (Espagne) pendant la période 2011-2013. Sous irrigation, le rendement et la persistance du sainfoin ont été plus faibles dans les mélanges luzerne-sainfoin. Ces résultats peuvent être attribués aux effets allélopathiques de la luzerne sur le sainfoin. Par ailleurs, en conditions naturelles, les effets allélopathiques n'ont pas été mis en évidence.*

Mots-clés. Medicago sativa *L.* – Onobrychis viciifolia *Scop.* – *Matière sèche – Protéine – Allopathie.*

I – Introduction

Alfalfa (*Medicago sativa* L.) and sainfoin (*Onobrychis viciifolia* Scop.) are pluriannual forage legumes that are well adapted to the agronomic conditions of NE Spain. They are particularly valued for their yield, their ability to restore soil fertility and their feed value (Aufrère *et al*., 2013). Alfalfa is furthermore characterized by the proportional distribution of its annual forage yield and its persistence, however it has the disadvantage that it causes bloating in animals; for sainfoin most of its forage yield is obtained from the first cut in spring, used for hay-making, and it is valued for its hardiness and not-bloating qualities. Given these complementing characteristics, it has been suggested that both species should be included in meadows in the Ebro valley (Hycka and Benítez-Sidón, 1979; Delgado *et al*., 2009). However persistence of sainfoin decreases when sown with alfalfa in a mixture and this has been attributed to the cutting frequency at the start of blooming in alfalfa (Hycka and Benítez-Sidón, 1979; Delgado *et al*., 2009).This practice may be indirectly detrimental to the persistence of sainfoin since it blooms later than alfalfa and its optimal use is recommended at full bloom (Koch *et al*., 1972; Borreani *et al*., 2003), furthermore this cutting frequency gives the plant less time to recover its nutrient reserves.

The lack of persistence of sainfoin when sown with alfalfa may also be due to allelopathic phenomena between the two species. Both alfalfa and sainfoin display strong allelopathic effects with other species (Chung and Miller, 1995; Li, 2009). Chocarro y Lloveras (2012) compared allelopathic effects between alfalfa and sainfoin, finding that alfalfa has a greater allelopathic effect on sainfoin, which may be one of the causes for the rapid disappearance of sainfoin in meadows that also contain alfalfa. In order to assess the persistence of sainfoin in a mixture, the species dynamics, in terms of annual forage yield, was compared when sown in pure stands and using two types of mixtures, on alternate rows and mixed in the same row, in two standard sites, under irrigation and in rainfed high lands.

II – Materials and methods

The study was conducted in rainfed conditions in Badules (41°9'N; 11°15'W, altitude 930 m a.s.l.) and under irrigation in Zaragoza (41°3'N; 0°47'W, altitude 225 m a.s.l.) during 2011-2013. In Badules climatic and edaphologic conditions showed monthly mean temperatures of 8.9ºC min and 18.5ºC max, annual precipitations of 320.6 mm, loam soil, salinity 0.2 CE (1:5 dδ/m), pH (H_2O) 8.5, P (Olsen) 18 mg/kg, K (extracted in NH_4NO_3) 250 mg/kg and organic matter 2.33%. Conditions in Zaragoza were monthly mean temperatures of 21.4ºC max and 8.1ºC min, annual precipitations of 245.7 mm, silty-loam soil, salinity 0.24 CE (1:5 dδ/m), pH (H_2O) 8.24, P (Olsen) 7 mg/kg, K (extracted in NH_4NO_3) 134 mg/kg and organic matter 1.99%.

Two cultivars of alfalfa were tested: 'Tierra de Campos', under rainfed conditions and 'Aragón' under irrigation, and one "two-cut" type sainfoin cultivar from Reznos (Soria). The cultivars were sown in plots of 5 x 2 m, in pure stands or using two types of mixtures, on alternate rows and mixed in the same row, with two cutting frequencies: alfalfa at early bloom and at full bloom, in four replications. Sowing took place on 11 March 2011 in Badules and 21 October 2010 in Zaragoza, using, for the pure stands of alfalfa a sowing rate of 15 kg ha^{-1} in rainfed conditions and 30 kg ha^{-1} under irrigation, and 80 kg ha^{-1} and 100 kg ha^{-1} respectively for sainfoin. The mixture comprised 50% seed density of both species in each of the conditions. An N-P-K basic dressing of 20-37.5-37.5 kg ha^{-1} in rainfed conditions and 40-75-75 kg ha^{-1} in irrigated conditions was applied the first year and both quantities were replicate in winter every two years in rainfed conditions and every year in irrigated conditions.

Dry matter (DM) was obtained by cutting two 0.5 m^2 per plot and drying in a forced ventilation stove at 60ºC until a constant weight was achieved. Dry samples were used to determine crude protein (CP) contents, evaluated by the Dumas method (AOAC, 1990) and neutral detergent fibre (NDF), evaluated by the Van Soest method (Van Soest *et al.,* 1991). Mortality rate is presented as the percentage of dead plants at the end of the trial.

The results underwent a variance analysis according to a split-plot model, considering "species" on the main plot and "cutting frequency" on the split-plot. The statistical analysis was performed using the ANOVA procedure of the SAS statistical package (SAS, 2004), considering the cutting date as treatment. Comparison of means was performed by the LSD test. The percentages were arcsine-transformed prior to statistical analysis.

III – Results and discussion

Table 1 shows the mean annual DM yield and CP and NDF contents in the first three productive years under irrigation and two years in rainfed conditions (the sowing year has not been considered as productive given that the establishment of the trials in these conditions is a slow process).

Table 1. Annual dry matter yield (DM), crude protein (CP) and neutral detergent fibre content (NDF), three years mean under irrigation and two years mean in rained conditions. In brackets, the percentage of alfalfa (L) in the mixture

Location	Zaragoza (irrigation)			Badules (rainfed)		
	DM kg/ha	%CP	%NDF	DM kg/ha	% CP	%NDF
Species						
Alfalfa on pure stand	11931a	20.4 a	41.0 b	3964 ab	19.7 a	37.9 a
Sainfoin on pure stand	9456 b	17.8 c	43.1 a	4292 a	16.1 c	38.0 a
Alfalfa and sainfoin on alternate rows	11675 (87.9% L)	19.9 b	41.5 b	3857 b a (61.9% L)	18.3 b	37.9 a
Alfalfa and sainfoin on mixed rows	12043 a (89.6% L)	19.9 b	41.6 b	3763 b (66.3% L)	18.6 b	37.9 a
Species significance	***	***	**	*	***	NS
Cutting frequency						
Early bloom of alfalfa	11453 a (90.4% L)	19.9 a	41.1 b	3752 b (68.5% L)	19.0 a	37.0 b
Full bloom of alfalfa	11099 a (87.0% L)	19.1 b	42.5 a	4186 a (59.7% L)	17.4 b	38.5 a
Cutting frecuency significance	NS	***	***	**	***	***
Species x Cutting frequency interaction	NS	**	NS	NS	NS	NS

* $P<0.05$, ** $P<0.01$, *** $P<0.001$, NS: non significant. Different letters within each column indicate $P<0.05$%.

The results show that alfalfa is more productive ($P<0.001$) than sainfoin under irrigation but in rainfed conditions alfalfa and sainfoin yields were the same. The two cutting frequencies established to benefit either alfalfa or sainfoin, did not show any significantly greater yields under irrigation although it did in rainfed conditions where the delay in cutting afforded a greater yield of dry matter ($P<0.01$).

When alfalfa and sainfoin were sown in a mixture, the mixture yield was not significantly different to that of the pure stands of alfalfa, both under irrigation and in rainfed conditions. The percentage participation of each species in the mixture varied substantially. Under irrigation alfalfa accounted for 89% of the yield since after the first year sainfoin disappeared from the mixture. This would explain why the forage CP content was closer to that of alfalfa than sainfoin. In rainfed conditions, the DM yield participation of sainfoin in the mixture was 40% when the cutting frequency was carried out with alfalfa in full bloom, this being significantly greater ($P<0.01$) compared to its 31% participation when cutting took place at early bloom of alfalfa.

These results corroborate the findings of other authors (Monserrat, 1956; Martiniello, 1998; Peel *et al*., 2004; Delgado *et al*., 2008), in so far as alfalfa is more productive under irrigation than sainfoin but has the same yield as sainfoin in rainfed conditions. With regard to the mixture of the two species, sainfoin quickly disappeared under irrigation and this can be attributed mainly to the allelopathic effects of alfalfa on sainfoin and not to the maturity state of the plants at the time of cutting. Although sainfoin did not adapt well to irrigated conditions, its yield was much higher when sown alone compared to when it was sown in a mixture (100% mortality the second year).

However, the percentage of sainfoin plants present in the pure stand by the third year was 19% *vs* 37% of alfalfa plants. The mortality of sainfoin, both in the pure stand and in the mixtures was lower in rainfed conditions. At the end of the third year the persistence of sainfoin in the pure stand was 25% *vs* 62% alfalfa when cutting was carried out at the start of blooming and 17% vs 57% respectively when cutting was carried out at full bloom. The progressive disappearance of sainfoin in the mixture in rainfed conditions, from the first to the third year, could be attributed to the lower persistence of sainfoin rather than to allelopathic effects. Such effects would indeed be more active under irrigation due to the fact that irrigation, which encourages the dispersion of allelopathic chemical components and greater intensity of production, may well accelerate allelopathic actions (de Albuquerque *et al*., 2011).

IV – Conclusions

The interest held by alfalfa under irrigation and alfalfa and sainfoin in rainfed conditions can be confirmed. There is not evidence that frequency cutting impact on disappearance of sainfoin in the mixture, but their disappearance under irrigation could be attributed to allelopathic phenomena. In rainfed conditions there is no evidence of allelopathic phenomena.

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The water relations of two perennial grasses in a Mediterranean grassland

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Abstract. The Mediterranean zone is frequently prone to extended periods of drought, especially during the summer. Thus, water is a restrictive factor that affects the growth and the productivity of Mediterranean grass species. The aim of this study was to investigate the water relations of two perennial grasses, *Phalaris aquatica* and *Dactylis glomerata*, which are common in Mediterranean grasslands. The experiment was conducted during the growing season in a low elevation grassland in Northern Greece. The midday leaf water potential (Ψ) was measured while the leaf Relative Water Content (RWC) and the Relative Drought Index (RDI) were estimated. Different responses under water deficit conditions were evident between the two species. *P. aquatica* presented higher drought tolerance and completed its biological cycle later than *D. glomerata* under water deficit conditions. In the last phenological stages, *P. aquatica* exhibited higher values of Ψ and RWC but lower values of RDI in relation to *D. glomerata*. As it was expected, the two species presented different critical threshold points. Our results showed that, *P. aquatica* is more adapted to arid or semi-arid conditions of the low elevation Mediterranean grasslands. *P. aquatica* seems to display mechanisms that enable continue growth and giving high forage production under xeric conditions.

Keywords. Water potential – Relative Water Content – Relative Drought Index – Tolerance.

Les relations hydriques de deux graminées pérennes dans une prairie méditerranéenne

Résumé. *La zone méditerranéenne est fréquemment sujette à des périodes étendues de sécheresse, en particulier au cours de l'été. Ainsi, l'eau est un facteur restrictif de la croissance et de la productivité des espèces de graminées méditerranéennes. L'objectif était d'étudier les relations hydriques de deux graminées pérennes,* Phalaris aquatica *et* Dactylis glomerata*, très communes des prairies méditerranéennes. L'expérimentation a été réalisée au cours de la saison de croissance dans une prairie de plaine au nord de la Grèce. Le potentiel hydrique des feuilles (Ψ) a été mesuré à midi, la teneur en eau relative des feuilles (RWC) et l'indicateur relatif de sécheresse (RDI) ont été estimés. Des réponses différentes ont été mises en évidence entre les deux espèces sous des conditions de déficit hydrique. La tolérance à la sécheresse de* P. aquatica *a été meilleure que celle de* D. glomerata*. À la fin de la période de croissance,* P. aquatica *a présenté des valeurs Ψ et RWC plus élevées, mais les valeurs RDI étaient plus basses par rapport à celles de* D. glomerata*. Simultanément, comme attendu, les deux espèces ont présenté différents seuils de réponse. Il semble que l'espèce* P. aquatica *est plus adaptée aux conditions arides ou semi-arides des prairies méditerranéennes de plaine. Probablement,* P. aquatica *développe des mécanismes qui permettent son développement constant et une production de fourrage accrue en conditions de déficit hydrique.*

Mots-clés. *Potentiel hydrique – Teneur en eau relative – Indicateur relatif de sécheresse – Tolérance.*

I – Introduction

Water availability is the most essential factor that affects the growth and the productivity of Mediterranean rangelands. Thus, water deficit unsettles plant physiological processes which may have a decisive influence on the capacity of forage plant production (Rodriguez-Iturbe and Porporato, 2004). This can be better explained by the gradual increase in the average air temperature and the substantial drop in the intensity of annual rainfall, especially during summer, that is predicted to be continued even after years to come across Europe and particularly in regions of the Mediterranean zone (IPCC, 2013).

The maintenance of favourable internal water status and plant functions at low leaf water potential is the main physiological process that contributes to the maintenance of high production under drought periods (Blum, 1996). The intensity of water shortage may cause instability in the internal water balance and variations in plant growing cycles (Volaire *et al*., 2009). Several physiological and/or morphological mechanisms can be expressed by plants in order to withstand drought conditions (Gurevitch *et al*., 2006; Blum, 2011). These responses may vary among species even belonging to the same growth and/or life form or genus (Volaire *et al*., 2001; Blum, 2011; Karatassiou *et al*., 2010). Therefore, determining the most tolerant species under the prevalence of xeric conditions is obligatory, in order to improve forage plant productivity towards preventing range desertification.

The aim of the current study was to investigate the water relations at leaf level of two common perennial grasses, under moderate drought conditions, in a low elevation Mediterranean grassland.

II – Materials and methods

The experiment was carried out in the farm of the Aristotle University of Thessaloniki, Northern Greece (longitude: 40º31'91'', latitude: 22º59'58''), 6m a.s.l. The climate of the area is characterized as Mediterranean semi-arid with cold winters. The monthly average precipitation (mm) and the minimum temperature (ºC) during the experimental period ranged from approximately 17.2 to 55.6 mm and from 9.6 to 24.1ºC respectively.

Measurements were taken in two perennial grass species: *Phalaris aquatica* L. and *Dactylis glomerata* L. These species are widespread in grasslands of the low zone of Northern Greece and their contribution to the grassland production is essential. All measurements were taken during the growing season (April-June), in approximately 10-day intervals, on clear sunny days at solar noon (12:00-14:00h) on five mature and intact fully expanded upper leaves per species. The Vapor Pressure Deficit (VPD) was evaluated by five replicates that have been taken over the canopy with a portable thermohygrometer (Novasina ms1, Novasina AG, CH) on the same date and time that the plant physiological parameters were measured (Fig. 1). Leaf water potential (Ψ) was measured using the pressure chamber technique (Koide *et al*., 1991) while the leaf Relative Water Content (RWC) and the Relative Drought Index (RDI) were estimated. Relative Water Content (RWC) was determined on 4 mm discs from leaves similar in age and orientation, and from the same plant to those used for the Ψ determination, following Iannucci *et al.* (2002) and Blum (2011). Meanwhile, leaf RDI was calculated as the ratio of actual leaf water saturation deficit (WSD_{act}=100-RWC) to the critical water saturation deficit (WSD_{crit}=45%): RDI=WSD_{act} / WSD_{crit} (Larcher, 2003).

To determine differences in the responses of the two species during the growing season we performed a two way analysis of variance (ANOVA) on all parameters studied (Steel and Torrie, 1980). T-test was used to compare two means. All statistical analyses were performed using the SPSS statistical package v. 20.0 (SPSS Inc., Chicago, IL, USA).

III – Results and discussion

The seasonal changes of Ψ showed differences between the two species (Fig. 2). *P. aquatica* maintained higher Ψ compared to *D. glomerata* except for the period from end March to the middle of April and probably better internal water balance. This assumption is supported by the seasonal patterns of RWC and RDI (Fig. 3, 4). *P. aquatica* presented significantly (P<0.05) higher

RWC in relation to *D. glomerata* from the most part of the growing season (Fig. 3). In the first phenological stages, under no water deficit conditions, both species presented the same high value of Ψ but different RWC (Fig. 2, 3). Nevertheless, from late May up to the end, under water deficit conditions, *P. aquatica* maintained higher values of Ψ and RWC than *D. glomerata*. During the growing season, RWC and Ψ showed in both species a constant declining trend against the increased values of VPD (Fig. 1) and temperature (Prenger and Ling, 2006). It seems that the gradual increase of VPD from 3.3 to 4.1 KPa over the canopy, during mid to late phenological stages (May-June), induced different ecophysiological responses in plants (Volaire *et al.,* 2009).

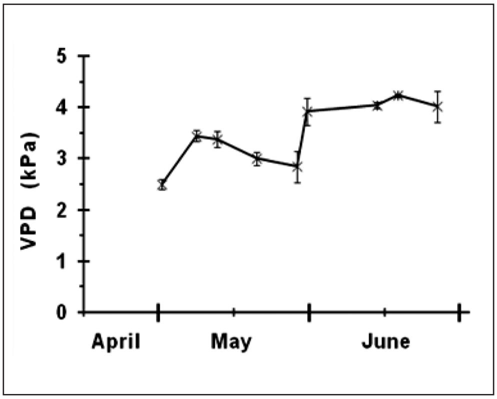

Fig. 1. Midday Vapor Pressure Deficit (VPD) during the experimental period. Values presented means ± SE.

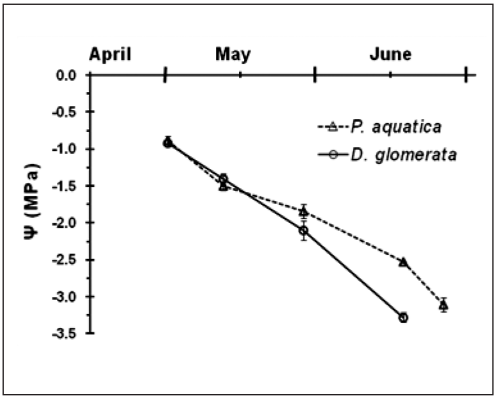

Fig. 2. Seasonal patterns of leaf water potential (Ψ) in two perennial grasses. Values presented means ± SE.

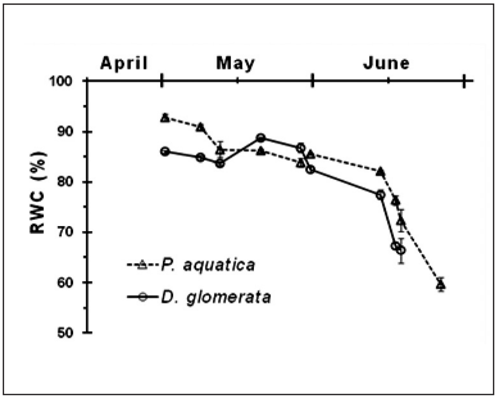

Fig. 3. Seasonal patterns of leaf Relative Water Content (RWC) in two peren-nial grasses. Values presented means ± SE.

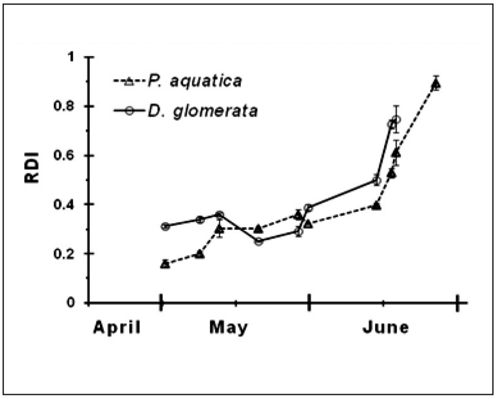

Fig. 4. Seasonal patterns of leaf Relative Drought Index (RDI) during the expe-rimental period. Values presented means ± SE.

The critical threshold point (CTP) accounts for early termination of growth and plant desiccation and is defined as the value of RWC below which turgid is lost (Larcher, 2003; De Diego *et al.,* 2013). As it was expected, the CTP was different between the two species (Fig. 3). *D. glomerata* was desiccated earlier (middle of June) than *P. aquatica* (end of June) in a value of CTP 66.4%

and 59.6% respectively. The hydrodynamic differences between the two species are also obvious from the changes of RDI thoughout the growing season (Fig. 4). Under the same environmental conditions, *P. aquatica* presented lower values of RDI in relation to *D. glomerata* and, therefore higher resistance to water deficit conditions (Larcher, 2003).

Consequently*,* the favourable inernal water balance of *P. aquatica* compared to that of *D. glomerata*, probably implies a higher photosynthetic capacity probably because of efficient regulation of the stomatal apparatus and/or osmotic adjustments or morphological chara-cteristics (e.g. bulbs) (Volaire *et al.,* 2001; Chaves *et al.,* 2003). Similar results have been obtained by Karatassiou and colleagues (2012) who have also demonstrated high productivity and growth of *P. aquatica* under water deficit conditions. On the other hand, *D. glomerata* higher sensitivity under drought conditions, which may be related either to its inability to maintain cell turgor under low Ψ and relative high vapor deficit conditions or to reduce transpiration losses and/or to absorb larger amounts of water (Jones, 1992; Blum, 2011).

IV – Conclusions

Our results demonstrate that perennial grasses express differential capacity to regulate the internal water balance under water deficit conditions in the low elevation Mediterranean grasslands. It seems that P. aquatica exhibits lower sensitivity to desiccation than *D. glomerata*. Hence, *P. aquatica* should be considered as a suitable species for semi-arid pastures.

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Rate of progress to flowering in annual species of genus *Trifolium* grown for silage in Galicia (NW of Spain) as affected by sowing date

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Abstract. With the objective of gaining insight on the relationship between sowing date and the onset of flowering of annual *Trifolium* species in Galicia (NW Spain), commercial genotypes of arrowleaf clover (5), balansa clover (5), berseem clover (2), crimson clover (6), persian clover *ssp. majus* (2) and *ssp. resupinatum* (3) were sown in small plots from 15th September 2012 to 15th April 2013 at monthly intervals following a split-plot design with two replications. The time from sowing to flowering, measured as days after planting (DAP) was significantly affected by species and sowing dates, ranging from 175 to 124 days for the latest (berseem clover) and the earliest (balansa clover) species and from 218 to 79 days for the September and April sowings dates, respectively, which represented the least and the most inductive flowering conditions. Although a significant effect in DAP was detected for the interaction species x sowing date, the earliness of annual clovers studied ranked in a similar way (balansa clover > persian clover *ssp. resupinatum* and crimson clover > arrowleaf clover > persian clover *ssp.majus* > berseem clover) across sowing dates. Phenological models that related the rate of progress to flowering $(DAP)^{-1}$ with temperature and photoperiod during the growing cycle accounted for 65% and 90% of the variability, showing that in the agroclimatic conditions of NW Spain flowering of annual clovers was more sensitive to photoperiod than to temperature.

Keywords. Development – Phenology – Winter legumes – Rate of flowering.

Influence de la date de semis sur la vitesse de floraison d'espèces annuelles du genre Trifolium cultivées pour l'ensilage en Galice (NO Espagne)

Résumé. *Dans le but d'approfondir la connaissance de la relation entre la date de semis et la floraison de diverses espèces de trèfles annuels en Galice (NO Espagne), des génotypes commerciaux de trèfle vésiculeux (5), trèfle de Micheli (5), trèfle d'Alexandrie (2), trèfle Incarnat (6), trèfle de Perse* ssp. majus *(2) et* ssp. resupinatum *(3) ont été semés mensuellement dans de petites parcelles entre le 15 septembre 2012 et le 15 avril 2013, en adoptant un dispositif aléatoire en blocs avec des parcelles divisées en deux répétitions. Le temps entre la date de semis et celle de la floraison, mesuré en jours après le semis (DAP) a été influencé de manière significative par l'espèce et la date de semis. Ainsi, cet intervalle a varié de 175 à 124 jours pour l'espèce la plus tardive (trèfle d'Alexandrie) à la plus précoce (trèfle de Micheli) et de 218 à 79 jours pour les dates de semis de septembre et d'avril, respectivement, ce qui représente les conditions de floraison les moins et les plus favorables. Bien qu'un effet significatif de l'interaction (espèces) x (semis) ait été observé sur le DAP, la précocité des trèfles annuels étudiés se classe d'une façon similaire pour toutes les dates de semis, à savoir : trèfle Balansa > trèfle de Perse* ssp. resupinatum *et trèfle Incarnat > trèfle vésiculeux > trèfle de Perse* ssp.majus *> trèfle d'Alexandrie. Les modèles phénologiques qui corrèlent la vitesse de progression de la floraison* $(DAP)^{-1}$ *avec la température et la photopériode au cours du cycle de croissance, expliquent jusqu'à 65% et 90% de la variation. Ces résultats démontrent que dans les conditions agro-climatiques du NO de l'Espagne, la floraison des trèfles annuels est plus sensible à la photopériode qu'à la température.*

Mots-clés. *Dévelopement – Phénologie – Légumineuses d'hiver – Vitesse de floraison.*

I – Introduction

Results of the evaluation of annual legumes of genus *Trifolium* in Galicia performed the last four years have yielded promising results showing a high productivity of these species grown as winter crops for silage, indicating that can be fit in an annual rotation with maize (Valladares *et al.*, 2012). Another interesting feature of these species is their good nutritive value along the growth cycle (Pereira-Crespo *et al.*, 2012) but, as indicated by these authors, annual legumes loose quality fairly rapid after the flowering stage is reached. For a given genotype, flowering time is mainly affected by environmental variables like temperature and daylength, while water and light intensity are of secondary importance (Bernier and Périlleux, 2005). In order to support crop management decisions like sowing or harvest dates, it is of interest to study the relationships which describe time to flowering of these species as a function of measurable climatic variables. Simple linear models relating the rate of progress to flowering with temperature and photoperiod during the growing cycle have been described, showing additive effects of both variables (Roberts and Summerfield, 1987). With the aim of gaining insight on the prediction of flowering time of annual legumes sown in Galicia, it is the objective of this work to (a) analyze the effect of genotype and planting date on time to flowering of twenty three commercial cultivars from six annual *Trifolium* species and (b) apply the linear models to quantify the effects of temperature and photoperiod on the rate of progress to flowering of these species.

II – Materials and methods

Field experiment was carried out at the Centro de Investigacións Agrarias de Mabegondo research station farm (Galicia, NW Spain: 43º 15´ N, 8º 18´ W, 100 m above the sea level) from September 2012 to August 2013. The species evaluated were: Arrowleaf clover (*Trifolium vesiculosum* Savi.) cv. Arrowleaf, Cefalu, Vesiculoso, Yuchi and Zulu II; Balansa clover (*T. michelianum* Savi.) cv. Balansa, Bolta, Frontier, Micheliano and Paradana; Berseem clover (*T. alexandrinum* L.) cv. Alex and Akenathon; Crimson clover (*T. incarnatum* L.) cv. Cardinal, Conete, Contea, Dixie, Linkarus and Viterbo; Persian clover (*T. resupinatum* L.) ssp. *majus* cv. Laser and Maral and Persian clover ssp. *resupinatum* cv. Gorbi, Lightning and Nitroplus. The experimental design was a split plot where the sowing date (eight dates, from 15 September 2012 to 15 April 2013, at monthly intervals) was the main plot and the legume cultivar the subplot arranged in a randomized block design with two replications. Each subplot consisted of three rows 3 m long, 30 cm apart, hand-sown with a seed dose of 20 kg ha^{-1} (500 seeds m^{-2}) for crimson clover and 10 kg ha^{-1} (750 seeds m^{-2}) for the rest of legume species. Plots were observed three times per week from the beginning of March onwards and flowering time was recorded as the day in which 5% of the plants of a given plot showed open flowers. Mean air daily temperature (T) was obtained from the records of the automatic Meteorological Station located *in situ*, and photoperiod (P) was calculated as the time in hours from sunrise to sunset corresponding to the latitude of the experimental site using the formulae proposed by List (1971) and Klein (1977). The number of days from sowing to beginning of flowering stage (days after planting, DAP) for each species in each plot was recorded and the rate of plant development (1/f) defined as the inverse of DAP for each species was regressed on T, P, or both using three linear models where the coefficients are constants specific for each species (Roberts and Summerfield, 1987): a thermal model ($1/f = a + bT$), a photoperiodic model ($1/f = a' + b'P$), and a photothermal model ($1/f = a'' + b''T + c''P$). Base temperature (t_0) was calculated as $t_o = -a/b$, and Thermal time for flowering (T_t) was computed as the accumulated mean daily air temperature minus the base temperature between planting and flowering dates for every plot. ANOVA analysis of DAP and regression procedures were performed using Proc GLM of SAS (SAS Institute, 2009).

III – Results and discussion

The time from sowing to flowering, measured as days after planting (DAP) was significantly affected by species and sowing dates (Table 1). DAP period ranged from 218 to 79 days for the September and April sowings dates, respectively, which represented the least and the most inductive flowering conditions. On average, for every month of delay in sowing, DAP was reduced in 19.9±5.5 days in a fairly constant way along the experiment. As an average of planting dates, flowering precocity of clover species ranked as follows: Balansa > Persian *resup.* ≥ Crimson > Arrowleaf > Persian *majus* > Berseem. The interaction sowing date x clover species on DAP was also significantly and, as can be seen in Fig. 1 (left), whilst species relative precocity maintained as exposed above, the absolute differences among species markedly tightened when delaying the sowing date towards spring.

Table 1. Effect of sowing date and clover species on time from sowing to flowering (DAP)

	Sowing date								
	15-SEP	**15-OCT**	**15-NOV**	**15-DEC**	**15-JAN**	**15-FEB**	**15-MAR**	**15-APR**	**p**
DAP	218.7 [a]	195.5 [b]	174.0 [c]	155.9 [d]	136.2 [e]	110.2 [f]	101.3 [g]	79.7 [h]	<.0001
n	46	46	46	46	46	46	46	46	

	Clover species						
	Arrowleaf	**Balansa**	**Berseem**	**Crimson**	**Persian *majus***	**Persian *resup.***	**p**
DAP	157.0 [c]	124.4 [e]	175.0 [a]	143.2 [d]	164.1 [b]	141.4 [d]	<.0001
n	80	80	32	96	32	48	

Means sharing a letter in their superscript are not significantly different (p>0.05).

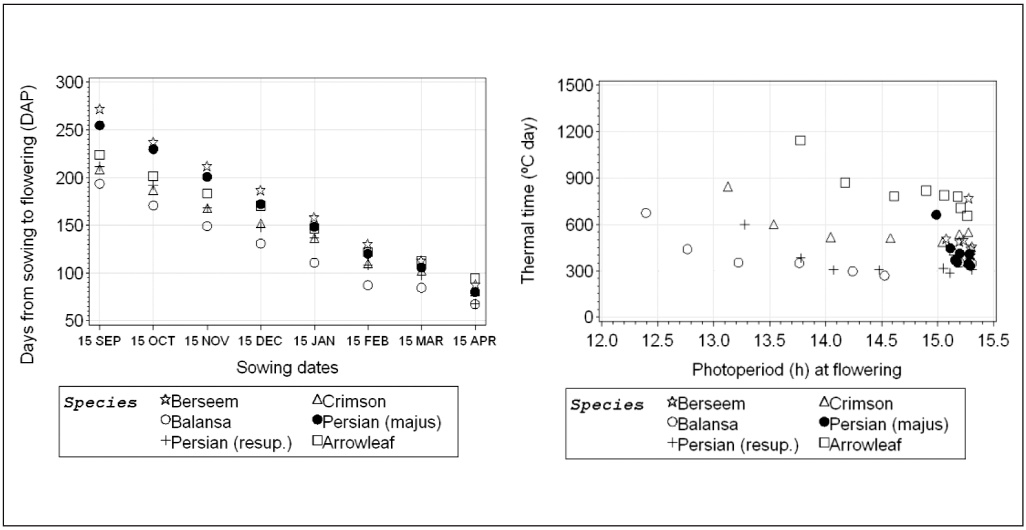

Fig. 1. Interaction between clover species x sowing date on time from sowing to flowering (left) and plot of thermal time in this period (ºC day) vs. photoperiod (h) in the day of flowering (right).

Regression analysis of the data showed that temperature is an important factor controlling flowering time, in accordance with the observations of other authors which studied the flowering behaviour of annual clovers in Mediterranean countries (Iannucci *et al.*, 2008 in Italy and Papastylianou and Bilalis, 2011 in Greece). Explained variance of the thermal model (ranging from 0.53 to 0.80 for Balansa and Berseem clovers, respectively) was markedly lower than that of the photoperiodic model (ranging from 0.86 for Persian *resup*., Crimson and Arrowleaf clovers to 0.95 for Berseem clover), indicating a superior effect of daylenght compared to mean air temperature on flowering developmental rate in the conditions of our study (Table 2). Additionally when temperature and photoperiod are included in the model, temperature effect was non-significant for any species but for the earliest flowering species Balansa clover. This marked effect of photoperiod compared with temperature on the control of flowering time of annual clovers differs from the response observed by the above cited authors which reported the temperature as the main factor determining time to flowering in experiments performed in southern latitudes.

Table 2. Values of constants (x 10^{-4}) and explained variance (R^2) of the linear models based on mean temperature (1/*f*) = a+b*T*, on mean photoperiod (1/*f*) = a'+b'*P*, and on both mean temperature and photoperiod (1/*f*) = a"+b"*T*+c"*P* obtained in the regressions of the rate of progress to flowering (1/*f*)

		Thermal model			Photoperiodic model			Photothermal model			
Clover species	**n**	**a**	**b**	**R^2**	**a'**	**b'**	**R^2**	**a"**	**b"**	**c"**	**R^2**
Balansa	80	-192.4^{***}	26.1^{***}	0.53^{***}	-130.8^{***}	18.7^{***}	0.91^{***}	-80.6^{***}	-9.3^{***}	23.0^{***}	0.93^{***}
Persian (resup)	48	-227.5^{***}	27.9^{***}	0.64^{***}	-145.3^{***}	18.5^{***}	0.86^{***}	-156.4^{***}	2.1^{ns}	17.4^{***}	0.86^{***}
Crimson	96	-105.1^{***}	16.3^{***}	0.58^{***}	-98.3^{***}	14.3^{***}	0.86^{***}	-93.9^{***}	-1.1^{ns}	15.1^{***}	0.86^{***}
Arrowleaf	80	-62.6^{***}	11.4^{***}	0.64^{***}	-86.8^{***}	12.6^{***}	0.86^{***}	-86.6^{***}	-0.1^{ns}	12.7^{***}	0.86^{***}
Persian (majus)	32	-183.0^{***}	22.2^{***}	0.72^{***}	-183.5^{***}	20.2^{***}	0.94^{***}	-180.3^{***}	-1.2^{ns}	21.0^{***}	0.94^{***}
Berseem	32	-151.4^{***}	18.5^{***}	0.80^{***}	-175.4^{***}	18.9^{***}	0.95^{***}	-177.1^{***}	1.7^{ns}	17.4^{***}	0.95^{***}

^{ns} p>0.05; * p<0.05; ** p<0.01; *** p<0.001.

Base temperature (t_0), computed from the coefficients of thermal model, averaged 7.3 ± 1.1 ºC, ranging from 6.0 ºC for Arrowleaf clover and 8.5 ºC for Persian *majus* and Berseem clovers. Thermal time for flowering (T_t) averaged 507.2 ± 170.0 ºC day, ranging between 360.5 and 819.3 ºC day for Persian *resup.* and Arrowleaf clovers, respectively. The plot of T_t on photoperiod at flowering (P_i), averaged across varieties of each clover species for the different planting dates (Fig. 1 right), shows that flowering is prevented until a minimum P_i is reached, independently of the thermal time accumulated. This threshold daylength ranks from 12.3 to 15.1 h for the earliest and latest flowering species Balansa and Berseem clover, respectively. Also, there is a minimum number of degree-days for the flowering of a species, ranking from 300 to 650 ºC day for Balansa and Arrowleaf clovers, respectively.

IV – Conclusions

There is a different response in flowering time among annual clover species to temperature and photoperiod conditions. Photoperiod explained most of the variability of the developmental rate to flowering compared with temperature. Flowering was observed to initiate when a minimum requirements of daylength and temperature was reached for each species.

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Nutritive value of by-product from dates for use in animal feed

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Abstract. In date packing and processing operations a number of by-products become available, therefore they should be used to improve the economics of the operation as a whole and to decrease disposal problems and costs. The main byproducts of date industry are cull dates and date pits from packing operations, and pits and press cakes from date processing. This study aims to evaluate the chemical composition and in vitro dry matter (DM) digestibility of pits, cull date and infested date for incorporation in animal feed and to evaluate the effect of tannins on *in vitro* fermentation through the use of tannin biding polyethylene glycol (PEG). The statistical results revealed a highly significant difference between by-products. Pits presented relatively high content of crude fiber (37.72% DM), crude protein (8.87% DM), and fat (6.29% DM) but low in vitro DM digestibility (22.78%). However cull date and infested dates had a high digestibility (87-89%). They were relatively high in carbohydrates but poor in crude protein (4.48-4.73% DM) and fat (0.42-0.45% DM). Because of their high carbohydrate content and relatively low fiber, cull and infested dates have a high energy value, as high as that of barley grain.

Keywords. Date –Tannins – In vitro fermentation – PEG.

Valeur nutritive des sous-produits de dattes pour l'alimentation du bétail

Résumé. *Lors du conditionnement et de l'emballage des dattes destinées à l'exportation, des quantités importantes de déchets et de sous produits sont obtenues et constituent une charge couteuse pour leur élimination. Ces déchets pourraient être valorisés par le bétail et constituer une source d'alimentation non négligeable. Cette étude vise à évaluer la composition chimique et la digestibilité* in vitro *des pédicelles, des noyaux, des dates infestées, des dates fermentées et des dates sèches et l'effet des tanins sur la fermentation* in vitro*. Les résultats statistiques ont révélé une différence hautement significative entre les différents types de déchets de dattes. Les noyaux ont présenté une teneur relativement élevée en cellulose brute (37,72% MS), protéines brutes (8,87% MS) et en matières grasses (6,29% MS), mais une faible digestibilité de la MS* in vitro *(22,78%). Les dattes infestées, fermentées et sèches étaient relativement riches en sucres totaux, très digestibles (87-89%), mais pauvres en protéines brutes (4,48 à 4,73% MS) et en matière grasse (de 0,42 à 0,45 % de MS). En raison de leur richesse en sucres et leur faible teneur en cellulose, ces différents types de dattes déclassées présentent une valeur énergétique comparable à celle de l'orge grain.*

Mots-clés. *Dattes – Tanins – Fermentation* in vitro *– PEG.*

I – Introduction

Date palm (*Phoenix dactylifera* L.) is one of the most important fruit tree growing in desert areas (Ramawat, 2010). The date palm industry produces fresh and dried dates, whole dates and pitted (stoned) dates, date paste, date syrup, and date wine with important quantity of by-products. Date by-products include cull dates, immature dates, date pedicels, date seeds, date press cake and date molasses. In the south of Tunisia, trade of wasted dates and stones is widespread on local markets and most of livestock owners use date by-products for feeding livestock (Genin *et al.*, 2004). This study aims to evaluate the chemical composition and in vitro dry matter (DM) digestibility of pedicels, pits, fermented, infested and dry dates for incorporation in animal feed and to evaluate the effect of tannins on *in vitro* fermentation through the use of tannin biding polyethylene glycol (PEG).

II – Material and methods

Date by-products were obtained from a Tunisian factory (Boudjbel SA VACPA) for processing and exporting Tunisian dates mainly the Deglet Nour variety. Samples were dried in a forced-air oven (60°C) and ground to pass a 1-mm screen in a Wiley Mill. Nitrogen content was measured by the Kjeldahl method and crude protein (CP) was calculated as N×6.25. Total sugar (TS) was determined following the procedure of Dubois et al. (1956). Phenolic compounds were extracted in an ultra-sound bath with 10 ml of aqueous acetone solution (Makkar, 2003). Total phenols (TP) and total tannins (TT) were determined by adding 0.25 ml Folin-Ciocalteau reagent (2 N) and 1.25 ml sodium carbonate solution (200 g Na_2CO_3 l^{-1}) to an aliquot of the supernatant and absorbance readings at 725 nm. The concentrations of TP and TT were calculated as tannic acid equivalents.

Ruminal contents were collected from three ruminally fistulated rams weighing 47 ± 3 kg and fed twice daily with a total mixed ration containing 60% oat hay and 40% concentrate (consisting of 75% barley, 23% soybean meal, 1% vitamin and mineral mixture, 0.6% calcium carbonate and 0.4% salt).

The in vitro dry matter digestibility (DMD) was determined following the procedure of Tilley and Terry (1963). Cellulase was from *T.* V*iride* and pepsin was obtained from porcine stomach mucosa. The incubation inoculum was prepared by diluting the digesta inoculum with the artificial saliva (Tilley and Terry, 1963) in a 1:4 (vol/vol). Samples (0.5 g DM) of pedicels, pits, fermented, infested and dry dates were incubated into plastic tubes (six replicates for each) with 20 ml of the incubation inoculum for 48 h at 39°C. After 48 h incubation, tube contents were acidified by adding 6 M HCl to reach a final pH of 1.3-1.5 and pepsin was added to a final concentration of 0.2% (wt/vol). After 48 h of incubation, the tubes were centrifuged at 2500×g for 15 min, and the supernatant was discarded. A quantity of 50 ml of water was added to the pellet and the tubes were centrifuged to wash out the residual acid and dried in a forced-air oven at 60°C for 48 h to determine the residual DM weight. In vitro DMD was calculated as the DM which disappeared from the initial weight incubated into the tubes.

The in vitro fermentation and tannin activity were determined using the method of Menke and Steingass (1988). Samples (200 mg) with and without PEG (200 mg) were weighed into 100 ml glass syringes and incubated at 39°C for 48 hours. *In vitro* incubation of the samples was conducted in triplicate and three syringes without substrate (blanks) were included as a laboratory controls. The syringes were hand shaken frequently and the volume of gas produced was recorded after 48 h of incubation. The ME values of the by-product were calculated as follows: ME (MJ / Kg DM) = 2.20 + 0.136 Gp + 0.057 CP (Menke and Steingass, 1988).

Data were analyzed by SAS (SAS, 2002) using the general linear models procedure as a completely randomized design. Statistical differences between the five date palm by-products were determined using Turkey's test. Mean differences were considered significant at P<0.05.

III – Results and discussion

The results of chemical analyses of the date by-products (pedicel, pit, fermented, infested and dry fruits) are shown in Table 1. They show that date by-product samples had different chemical compositions. Infested and fermented dates had lower CP contents compared with pits and dry dates. Pits had the highest CF and EE values (P < 0.05), however they contained as much PT and TT as pedicels (P > 0.05), but more (P < 0.05) TS and EE than pedicels, and the difference was particularly pronounced for EE with pedicels having about one-third of the EE content of pits. The three wasted dates, infested, fermented and dry fruits, had different CP, TS and TP concentrations ($P < 0.05$), with fermented date being highest in TS and lowest in TP. All date by-product had low CP contents (<9%) as found in literature; Al-Showiman et al. (1990) found that the percentage of protein ranged from 4.79 to 7.50% in date pits from seven varieties from Saudi Arabia. Lower values (<7%) were reported for date palm by-product of Deglet Nour variety (Genin *et al.,* 2004).

Table 1. Chemical analysis (DM basis) of date palm by-products

Date by-products	DM	OM*	Ash*	CP*	CF*	EE*	TS**	TP**	TT**
Pedicels	816.9	946.8 d	50.4 a	50.6 bc	317.9 b	13.4 b	68.9d	17.5 a	15.9a
Pits	858.8	985.9 a	14.1 e	88.7 a	377.2 a	62.9 a	149.3c	17.9 a	14.6 a
Infested date	868.2	975.7 b	24.2 d	44.8 c	38.9 c	4.5 c	147.3c	14.3 b	9.9b
Fermented date	781.1	971.9 b	28.1 c	47.3 c	54.1 c	4.6 c	517.1a	9.6 c	9.5 b
Dry date	828.8	964.2 c	35.7 b	64.9 b	67.5 c	4.1 c	279.2b	14.1 b	10.7 b
SEM	*23.07*	*0.70*	*0.26*	*6.95*	*26.99*	*0.97*	*30.1*	*1.63*	*1.63*
Probability	*0.2507*	*0.0001*	*0.0001*	*0.0002*	*0.0001*	*0.0001*	*0.0001*	*0.0001*	*0.0002*

*In g/kg DM: DM, dry matter; OM, organic matter; CP, crude protein; CF, crude fibre; EE, ether extract; **In mg/100 g DM: TS: total sugar; TP: Total phenol; TT: total tannin; SEM, mean standard error. Means within the same column with differing superscripts (a-c) are significantly different at P<0.05.

Table 2 shows DMD, ME and in vitro gas production of date by product samples. Data showed high DMD (68.37-89.85%) and in vitro gas production with PEG (22.92-30.75 ml/200 mg DM) and without (22.44-25.56 ml/200 mg DM) for wasted fruits. These results fit with those reported by Genin *et al*. (2004) who mentioned higher in vitro DMD of wasted dates in respect to other date palm by-products. Metabolisable energy was estimated to be lower for pedicels and pits. This finding could be attributed to the higher CF, TP and TT contents. The increase in gas production with PEG emphasizes the negative effect tannins may have on digestibility of pits. This improvement was possibly due to an increase in the available nutrients to rumen micro-organisms, especially the available nitrogen. Tannins might form a less digestible complex with dietary proteins and might bind and inhibit the endogenous protein, such as digestive enzymes (Kumar and Singh 1984).

Table 2. Dry matter digestibility (%), gas production (ml/200 mg DM), and metabolisable energy (ME, Kcal/kg DM) of date by-products

	DMD (%)	ME (Kcal/kgDM)	Gas 48 h ml/200 mg DM	
			- PEG	+ PEG
Pedicels	51.56 c	4680	15.13 c	16.17 c
Pits	22.79 d	3570	6.46 dB	13.33 cA
Infested fruits	89.85 a	5990	24.48 b	26.01 ab
Fermented fruits	87.94 a	5940	25.56 ab	30.75 a
Dry fruits	68.37 b	5460	22.44 b	22.92 b
SEM	*2.87*	*nd*	*0.99*	*1.08*
Probability	*0.0001*	*0.0001*	*0.0001*	*0.0001*

Means with differing superscripts are significantly different (P < 0.05) within the same column (a-c) and row (A,B) for gas production with and without PEG.

The date palm by-product examined in this study showed a great variation in chemical composition, in vitro degradation and in vitro fermentation. Similar trends have been reported in literature (Al-Farsi *et al.*, 2007).

IV – Conclusion

Because of their high sugar content and relatively low fiber, wasted dates (infested, fermented and dry dates) are highly digestible and have a high energy value, as high as that of barley grain. However, protein supplementation is required when wasted dates are included in the diet of ruminants.

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Floristic and chemical composition of an organic, natural pasture used for fattening lambs in the region of Sidi Bouzid, Tunisia

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Abstract. The present work aimed to determine the botanical composition of a natural pasture in the region of Sidi Bouzid and to study its effect on performances of Barbarine lambs. The floristic composition showed that the plant communities of the natural pasture are characterized by the dominance of annual species (63.2%). Results obtained indicated that the floristic composition revealed the presence of 19 species. The natural pasture composed by *Cynodon dactylon* (62.3%), *Sisymbrium irio* (20.7%), *Anagallis arvensis* (5%), *Medicago ciliaris* (3.3%) and other species. The botanical composition was represented by grasses (62.4%), cruciferous (21.3%), legumes (3.6%), compositae (2.4%) and other family (10.1%).The chemical composition of the pasture showed a crude protein and fiber content of 10.7% and 25.5% respectively. Lambs grazing under this pasture had a low average daily gain (65.2 g/day) and a fat depth of 2.26 mm. These results indicated that this pasture is characterized by limited energy supply and it should be regenerated in order to assure a sustainable productivity of this production system.

Keywords. Sheep breeding – Natural pasture – Annual species.

Composition floristique et chimique d'un parcours naturel certifié biologique, utilisé pour l'engraissement des agneaux dans la région de Sidi Bouzid, Tunisie

Résumé. *Ce travail a pour objectif de déterminer la composition floristique d'un parcours naturel dans la région de Sidi Bouzid et d'étudier l'effet de son utilisation sur les performances zootechniques des agneaux de race barbarine. La composition du parcours est caractérisée par la dominance des espèces annuelles (63,2%). Les résultats obtenus indiquent que l'étude de la composition floristique du parcours naturel a montré la présence de 19 espèces pastorales. Le parcours est formé essentiellement de* Cyndon dactylon *(62,3%),* Sisymbrium irio *(20,7%).* Anagalis arvensis *(5%),* Medicago ciliaris *(3,3%) et autres espèces. Ces espèces appartiennent aux familles des graminées (62,4%), des crucifères (21,3%), des légumineuses (3,6%), des composées (2,4%) et d'autres familles (10.1%). La composition chimique montre que le parcours naturel présente une teneur en protéines brutes de 10,7% et en cellulose brute de 25,5%. Les agneaux ont montré un GMQ faible (60.5 g/jour) et une épaisseur du gras faible (2,26 mm). Ces résultats indiquent que ces parcours naturels doivent être régénérer afin d'assurer une productivité durable des systèmes de production.*

Mots-clés. *Élevage ovin – Parcours naturel – Espèces annuelles.*

I – Introduction

In Tunisia, sheep production was based mainly on extensive system based on pasture in the center and the south of the country. The contribution of pastoral resources was estimated at 80% of the diet of these animals (Ben Salem, 2011). At the beginning of the second half of the 20th century, the natural's pastures were characterized by a rich and diversified flora. During the last three decades, changes in agricultural practices and over grazing have caused their degradation. For these reasons, sheep feeding system had undergone profound changes. It is moving from extensive pastoral livestock transhumance to intensive farming mainly based on feeding concentrate diets (Kayouli, 2006; Ben Salem, 2011). In organic system, the access to pasture is inevitable for lamb fattening system. The aim of this study was to determine the floristic composition of an organic natural pasture used for fattening Barbarine lambs in the region of Sidi Bouzid and to evaluate the effect of this pasture on growth performances.

II – Materials and methods

The composition of the vegetal species of 4 ha natural pasture in the farm "El Attizez", Sidi Bouzid (Tunisia) was studied. This pasture was used for fattening 27 weaned Barbarine lambs (11 females and 16 males) of an average weight of 24.1 ± 5.4 kg and 8 month-old, according to the organic system. In addition, lambs received 200 g of organic oat hay and 400 g of concentrate (63.7% organic barley, 18.2% organic broad bean, 13.6% faba bean, 4.5% mineral vitamin supplement). During the grazing period, we determined the herbaceous biomass and specific richness of the pasture using the quadrat method described by Floret (1988). The herbaceous biomass was estimated by the determination of the herb quantity present in the quadrat which was cut and weighted. The floristic composition of the natural pasture was determined using the linear analysis (line intercept) described by Daget and Poissonet (1971). Plant covers (RV), specific contribution (SCi) and specific index (ISi) of each species are determined. The pastoral value (PV) of pasture was calculated by the equation given by Floret (1988):

The animals were weighed to calculate the average daily gain (ADG). Herbage daily intake of lambs was estimated by the use of enclosure. The vegetal biomass in enclosure was determinate by harvesting and weighing the herb biomass before and after lambs grazing. Feed conversion rate (FCR) was calculated. Chemical composition of natural pasture was determinate according to the method of AOAC (1995). Six male lambs were slaughtered at the average weight of 38 kg. Fasting body weights (FW), and cold carcass weights were determined to calculate commercial dressing (CCW*100/FW). Subcutaneous fat depth was measured according to Fisher and De Boer (1994).

III – Results and discussion

1. Floristic and chemical composition

The biomass per hectare averaged 1066.5 kg DM/ha. Natural herbaceous plant cover represented 57.7%. As for the floristic composition, plant communities of the natural pasture were characterized by the dominance of annual species (63.2% *vs* 36.8% for perennial species).

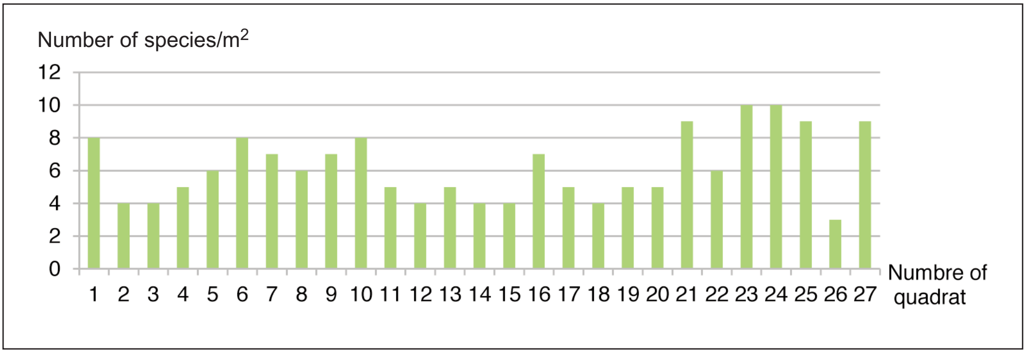

Fig. 1. Evolution of specific richness of species in natural pasture in the region of Sidi Bouzid.

The analysis of Fig.1 showed that species richness varied from 3 to 10 species/m^2 with an average of 6.2 species/m^2.The high coefficient of variation (CV = 33.6%) in the specific richness can be caused by lamb selection during grazing.

Table 1. Characteristics of floristic composition of natural pasture in the region of Sidi Bouzid

Species	Frequency	Specific contribution (%)	Specific index†	CS * IS
Cynodon Dactylon	719	62.3	4	250.1
Lolium rigidum	2	0.17	5	0.9
Sisymbrium irio	239	20.7	3	62.3
Eruca vesicaria	8	0.69	4	2.3
Medicago ciliaris	38	3.3	5	16.5
Astragalus hamosus	4	0.34	3	1
Launeae nudicaulis	16	1.38	4	5.6
Launeae resedifolia	5	0.43	4	1.7
Onopordon nervosum	5	0.43	2	0.9
Carduus pycnocephalus	1	0.08	2	0.2
Centaurea dimorpha	1	0.08	2	0.2
Anagallis arvensis	57	5	0	0
Convalvulus arvensis	23	2	4	8
Chenopodium murale	18	1.55	2	3.1
Malva parviflora	7	0.60	3	1.8
Polygonum aviculare	5	0.43	4	1.7
Glaucium flavum	1	0.08	2	0.2
Adonis oestivalis	5	0.43	0	0
Reseda alba	1	0.08	1	0.1
Total	**1155**	**100**	**–**	**357.13**

† 0: without value; 1: mediocre; 2: average; 3: good; 4: very high; 5: excellent; SC: Specific contribution; IS: Specific index.

Results in Table 1 indicated that the natural pasture was composed of herbaceous cover. The floristic composition revealed the presence of 19 species: *Cynodon dactylon* (62.3%), *Sisymbrium irio* (20.7%), *Anagallis arvensis* (5%), *Medicago ciliaris* (3.3%), *Convalvulus arvensis* (2%) and other species. *Cynodon dactylon* and *Sisymbrium irio* were the most dominating species, representing more than 80% of the total herb in term of frequency and vegetal biomass. The pasture was composed of grasses (62.4%), cruciferous (21.3%), legumes (3.6%), compositae (2.4%), and other family (10.1%). This result can be explained by the drought that characterized the 2010-2011 year. Few species (*Cyndon dactylon and Sisymbarium irio*) can be really adapted to drought.

The pastoral value was 41.19%. This value indicated that this pasture is classified average. This result was explained by a smaller specific contribution of the legumes family. In fact, legumes species are characterised by a better nutritional quality and are more palatable by animals. In addition, the dominance of *Cyndon dactylon* which is an invasive species resulted in the limitation of other herb species growth. In fact, Cervasio et *al*. (2009) reported that the expansion of invasive species in pasture reduced especially the pastoral value of species characterised by the best nutritional quality.

Chemical composition of natural pasture indicated high dry matter (45.97%) and ash (12.19%) values. The crude protein content was 10.69% and this result can be explained by the low contribution of the legumes family (3.6%) in the floristic composition of this pasture. In addition, this pasture had low fiber content (26.62%).

2. Growth performances and carcass characteristics

Lambs grazing in this natural pasture had a low weight gain of 6.24 kg during 103 day of feeding period. ADG was 60.5 g / day It was lower than the potential of Barbarine breed (Djemali *et al.*, 1994). FCR was high (17.22 kg DM/kg gain) and could be associated to the low energy content of the natural pasture and the low supply of concentrate. At an average fasting weight of 36.9 kg, commercial dressing was of 46.72%. These results agreed with those reported by Majdoub-Mathlouthi *et al*. (2013) for Barbarine lambs receiving low energy level. The subcutaneous fat thickness (2.26 mm) was acceptable and indicated lower carcass fatness (Diaz *et al*., 2002).

IV – Conclusions

Preliminary results of the qualitative and quantitative characterisation of this natural pasture in the region of Sidi Bouzid indicated a lower specific richness and the dominance of two species: *Cynodon dactylon* and *Sisymbrium irio*. In addition, the botanical flora of the studied pasture is characterized by greater percent of annual species. Then, and despite concentrate supplementation, grazing lambs had moderate performances. It may be associated to a limited energy supplementation. For these reasons and in order to maintain the organic system based on pasture, it seems very imperative to find other organic feeding resources and to recover these pastures in order to increase the pasture production in the critical period.

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Nutritive value of *Paliurus spina-christi* and herbaceous vegetation in Mediterranean shrub-lands of central and northern Greece

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Abstract. Christ's thorn (*Paliurus spina-christi* Mill.), a very common species in the Mediterranean region, usually forms shrublands of high species richness. Despite being a rather spiny shrub, it is browsed by goats, especially during spring and early summer. The objective of the present study was the comparative evaluation of the nutritive value of Christ's thorn and accompanying species of the herbaceous layer in shrublands of central and northern Greece. Vegetation sampling was performed during the flowering stage in May 2011. Dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined both in Christ's thorn and herbaceous vegetation. Forage DM production in the shrubland from central Greece was significantly higher compared to the one from northern Greece. Similarly, the CP and NDF contents of *Paliurus spina-christi* from central Greece were higher, while there were no statistically significant differences for the ADF and ADL between the two regions. The CP of the herbaceous vegetation was higher in central Greece, unlike the ADF of the herbaceous vegetation which was higher in the north. These differences, possibly related to genetic factors and different climatic conditions, have to be taken into consideration for obtaining optimal livestock productivity.

Keywords. Christ's thorn – Woody species – Forage quality – Mediterranean basin.

Valeur nutritive de* Paliurus spina-christi *et de la végétation herbacée dans des parcours arbustifs méditerranéens du centre et du nord de la Grèce

Résumé. *L'épine du Christ (*Paliurus spina-christi *Mill.) est une espèce très commune dans la région méditerranéenne. Il forme d'habitude des parcours arbustifs avec une richesse d'espèces élevée. Bien que ce soit un buisson assez épineux, il est utilisé par les chèvres, surtout pendant le printemps et au début de l'été. L'objectif de cette étude était d'évaluer la valeur nutritive de l'épine de Christ et des espèces qui l'accompagnent dans la couche herbacée, dans les parcours de la Grèce centrale et du Nord. L'échantillonnage de végétation a été réalisé pendant le stade floraison en mai 2011. La teneur en matière sèche (DM), en protéine brute (CP), en fibres au détergent neutre (NDF), en fibres au détergent acide (ADF) et en lignine (ADL) a été déterminée dans l'épine de Christ et dans la végétation herbacée. La quantité de DM de fourrage dans les parcours de la Grèce centrale a été significativement plus élevée que dans la Grèce du Nord. De même les teneurs en CP et en NDF de* Paliurus spina-christi *de la Grèce centrale étaient plus élevées que les teneurs mesurées au Nord, alors qu'il n'y avait aucune différence statistiquement significative pour les teneurs en ADF et ADL. La teneur en CP de la végétation herbacée était aussi plus élevée dans la Grèce centrale, alors que la teneur en ADF de la végétation herbacée était supérieure dans la région du Nord. Ces différences pourraient être liées aux facteurs génétiques et aux différentes conditions climatiques et doivent être pris en compte pour obtenir une productivité animale satisfaisante.*

Mots-clés. *Epine de Christ – Espèces arbustives – Qualité du fourrage – Bassin Méditerranéen.*

I – Introduction

Shrub-lands occupy large areas in the Mediterranean region and play a significant role in animal production (Le Houerou, 1993). It is well documented that more than 60% of goat diet comes from shrubs (Perevolotsky *et al.*, 1998). Ainalis *et al.* (1998) and Parissi (2001) suggested that some deciduous woody species are essential animal feeds especially during the dry season, due to their high nutritive value.

Christ's thorn (*Paliurus spina-christi* Mill.) is a very common deciduous shrub species in the Mediterranean region (Parlak *et al.*, 2011). It usually forms shrublands of high species richness. Despite the fact it is a rather spiny shrub, it is browsed by goats, especially during spring and early summer (Manousidis *et al.*, 2014).

Limited information is available regarding the nutritive value of this species although it has been reported to be superior to other shrubs (Temel and Tan, 2011). As a consequence, there is a lack of information about the nutritive value of various natural populations of the species. Thus, the objective of the present study was the comparative evaluation of forage production and of the nutritive value of Christ's thorn and accompanying species of the herbaceous layer in shrublands of central and northern Greece.

II – Materials and methods

The study was conducted in shrublands dominated by *Paliurus spina-christi*, in two areas located in central (Lamia) and northern (Evros) Greece. The climate of both study areas is classified as sub-Mediterranean, with a mean air temperature of 16.5°C and 14.7°C, respectively. Average annual rainfall in Lamia is 574 mm and in Evros 664 mm. Both areas are grazed mainly by goats and sheep.

Vegetation sampling was performed during the flowering stage in May 2011. Ten transect lines of 20 m long were established in every study area. Samples for shrubs (leaves and thin twigs) were collected from two randomly selected shrubs across each transect. The sampling of forage was carried out in two 0.5 m x 0.5 m quadrates in each transect established in each study area. Plant material was clipped at ground level and placed in individual paper bags. All samples were oven dried at 50°C for 48 h, weighed and then ground in a mill to pass through 1 mm screen prior to analyses.

Nitrogen content was measured by the Kjeldahl method (AOAC 1990) and crude protein (CP) was calculated by multiplying N by 6.25. Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF), Acid Detergent Lignin (ADL) were measured using the procedure described by Van Soest *et al.* (1991) with the ANKOM fibre analyzer (ANKOM Technology Corporation, Macedon, NY, USA), using sodium sulphite, but not α-amylase to the solution for the NDF determination. All analyses were carried out on duplicate samples and results reported on DM basis.

For all measured parameters differences between the study areas were calculated using one-way ANOVA (Steel and Torrie, 1980). All statistical analyses were performed using the SPSS® statistical software v. 18.0 (SPSS Inc., Chicago, IL, USA).

III – Results and discussion

Forage DM production was 42% lower in northern Greece compared to central Greece (Fig. 1). This difference in DM production could be attributed to the variability of climate and soil properties as well as to the differences in species composition (unpublished data).

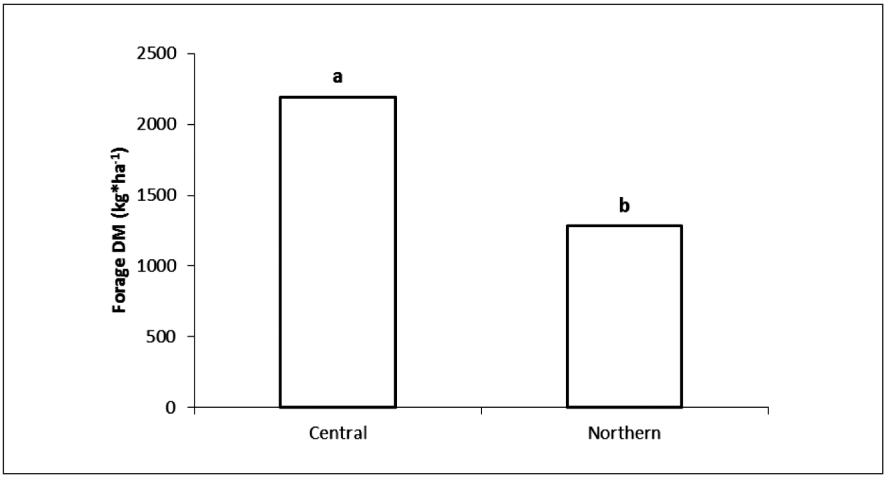

Fig. 1. Forage DM in *Paliurus spina-christi* shrublands of central and northern Greece. Means followed by the same letter are not significantly different (P≥0.05).

The CP and NDF contents of *Paliurus spina-christi* from central Greece were higher than the corresponding from the north, while there were no statistically significant differences for the ADF and ADL (Table 1). These differences in CP and NDF contents could be attributed to different climate and soil characteristics in the diverse growing habitats, as chemical compositions of plants are not the same in each region (Stephens and Krebs, 1986). Additionally, they could be related to genetic factors that control accumulation of foliage nutrients in the plants (Corleto *et al.*, 1994). It has to be noted that the CP content of Christ's thorn is very high, almost double than that in the majority of the non-legume woody species of the Mediterranean region (Ammar *et al.*, 2005; Gokkus *et al.*, 2011; Temel and Tan, 2011).

Table 1. Chemical composition ($g*kg^{-1}$) (Means ± SE) of *Paliurus spina-christi* of central and northern Greece

Effect	CP	NDF	ADF	ADL
Central Greece	249.9 ± 3.9 a	339.8 ± 4.5 a	156.5 ± 6.9 a	84.2 ± 2.7 a
Northern Greece	215.7 ± 3.9 b	289.5 ± 4.5 b	161.8 ± 6.9 a	80.2 ± 2.7 a

Means in the same column followed by the same letter are not significantly different (P≥0.05).

The CP of the herbaceous vegetation was higher in central Greece, unlike the ADF of the herbaceous vegetation which was higher in the northern region (Table 2). Differences in species composition might account for these differences (unpublished data).

Table 2. Chemical composition ($g*kg^{-1}$) (Means ± S.E.) of the herbaceous vegetation from *Paliurus spina-christi* shrublands of central and northern Greece

Effect	CP	NDF	ADF	ADL
Central Greece	154.3 ± 5.6 a	523.1 ± 12.7 a	326.4 ± 5.6 b	91.8 ± 3.1 a
Northern Greece	114.5 ± 5.6 b	522.8 ± 12.7 a	360.3 ± 5.6 a	90.3 ± 3.1 a

Means in the same column followed by the same letter are not significantly different (P≥0.05).

More specifically, the higher CP content found in the understory herbaceous vegetation of the Christ's thorn shrubland of central Greece is probably related to the higher percentage of legumes (15% *vs* 10% in northern Greece) as according to Bakoglu *et al*. (1999) legumes have higher concentration of CP than other species. No statistically significant differences were recorded for the NDF and ADL contents (Table 2).

IV – Conclusions

The results of the present study confirm that *Paliurus spina-christi* Mill. is an important deciduous shrub species in terms of animal feed due to its high CP content and to its relatively low NDF, ADF and ADL contents. The recorded differences in DM production and in chemical composition between the study areas in central and northern Greece could be related to genetic factors and different climatic conditions and have to be taken into consideration for obtaining optimal livestock productivity.

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Medium term effects of water availability and N-P fertilization interactions on the productivity and composition of natural grasslands of Uruguay

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Abstract. Irrigation and fertilization could be a strategy to ensure forage production in a high climate variability scenario in Uruguay. Nevertheless, there are gaps in our knowledge of productive and environmental responses. An experiment was performed to evaluate the effects of supplementary irrigation and N-P fertilization on native grassland forage yield and composition from October 2011 to September 2013. First year results showed, under drought, that the interaction between irrigation and N fertilization explains the variations in productivity and composition. Irrigation enhanced N response doubling forage production and the contribution of valuable species. The second year was rainy and forage production was higher than the first one in all treatments. Besides, N-P interaction was detected, explained by an increase on production caused by P mainly at the higher levels of N. These results underline the importance of studying cumulative effects of fertilization and irrigation for a more sustainable grassland management.

Keywords. Pampas – Biome – Pasture – Productivity.

Effets à moyen terme des interactions entre la disponibilité en eau et la fertilisation N-P dans les prairies naturelles d'Uruguay

Résumé. *En Uruguay, l'irrigation et la fertilisation peuvent être des options pour assurer la production de fourrage dans le cas de scenarios ayant une forte variabilité climatique. Néanmoins, il existe un manque de connaissances sur les réponses environnementales et productives. Un essai a été conduit pour évaluer l'effet d'un supplément d'irrigation et d'une fertilisation N-P sur la production de fourrage et la composition d'une prairie entre octobre 2011 et septembre 2013. En première année (sèche), l'interaction entre irrigation et N fertilisation explique les variations à court terme de la production et de la composition. L'irrigation a amélioré la réponse de l'apport d'engrais en doublant la production de fourrage et la contribution d'espèces de valeur fourragère élevée. En deuxième année (pluvieuse) la production de fourrage a été plus forte que dans la première et ceci pour tous les traitements. Par ailleurs, une interaction N-P a été observée à travers l'augmentation de la production des parcelles fertilisées avec P, principalement à fortes doses de N. Ces résultats montrent l'importance d'étudier les effets cumulatifs de la fertilisation et l'alternance de conditions sèches et humides sur la prairie dans l'objectif d'une conduite durable.*

Mots-clés. *Pampas – Biome – Prairie – Productivité.*

I – Introduction

Native grasslands of Uruguay are part of the "Pampas" biome, one of the largest areas of South American grasslands. This vegetation type supports traditional livestock production and provides many ecosystem services including carbon sequestration, maintenance of high biodiversity in both plants and animals and the preservation of soil fertility (Sala and Paruelo, 1997). Although grasslands represent the largest biome in the region, and provide valuable economic and ecosystem services, in the past decades its area has decreased due to land use changes (Díaz *et al*., 2006). Grasslands have to be considered not only as a mean for food production but also for providing ecosystem services (Lemaire, 2012), so specifically sustainable strategies are needed to maintain or increase the productivity while preserving ecological functions. In this context, there is a growing interest to understand the impact of different management practices on the sustainability of native grassland ecosystems. In Uruguay, grasslands are exposed to a high variability in rainfalls that causes large fluctuations in forage production and quality, which could be even higher in the most likely climate change future scenario (Giménez *et al*., 2009). To mitigate these impacts of climate variability, one of the technological options is to lay out areas of high intensity forage production. To achieve this, supplemental irrigation could be a strategic tool to ensure a feed base for animals, but there are gaps in our knowledge about productive and environmental responses.

In most of the world, pasture productivity is limited by soil water and nutrient availability, even in grasslands with high fertilizer inputs (Gastal and Durand, 2000). As well as water availability improves forage growth, also plant demands increase, so it is expected that the contribution of these soils, typically low in both N and P, would not be enough to cover the nutrients demand, requiring fertilization. In this context, it is necessary to generate technical coefficients of response to irrigation in grasslands of Uruguay and its interaction with N-P fertilization. From this background, we propose a medium term experiment in order to assess the extent of water and fertility limitations to the production and composition of natural basaltic grassland. This paper intends to answer the following questions: (i) how primary production is affected by supplementary irrigation, N-P fertilization, and their interactions? and (ii) what are the main changes in the botanical composition?

II – Materials and methods

Research was conducted from October 2011 to December 2013, in an experimental field near Tacuarembó-Uruguay (31.53´ S, 56.14´ W). The botanical composition of the native grassland was characterized by dominance of warm-season perennial grasses of *Paspalum* genera, mixed in a lesser extent with cool-season perennial grasses. The mean annual rainfall of the site is 1300 mm, with mean temperatures of 25 °C in summer and 12 °C in winter. The experimental design was a split plot with three replications in randomized blocks. In the main plots (24 x 16 m) supplementary irrigation (SI) and rainfed (RF) treatments were located. In the split plots (8 x 4 m) seven fertilization treatments and one unfertilized control were suited. Such fertilization treatments consisted of a dose of P (80 kg P_2O_5 ha^{-1}), three doses of nitrogen (50, 100 and 200 kg N ha^{-1}) and three NP combinations (80 P_2O_5 - 50 N; 80 P_2O_5 -100 N; 80 P_2O_5 - 200 N). SI, when necessary, was performed throughout the growing season (October–April) by spraying, with the goal of maintaining soil humidity above a threshold criterion of 50 % of available water. To do this, soil moisture (0-20 cm) was monitored through water balances using the WinIZAREG model (Pereira *et al*., 2003). N fertilization was done by 1, 2 and 4 applications of 50 kg N / ha for treatments 50, 100, and 200 kg N/ha, respectively.

Aboveground net primary production (ANPP) of forage was assessed by cuts every 40-50 days in spring and summer and 90-120 days during autumn and winter, by clipping at five cm height in 3 central stripes, totalizing 6 m^2. Prior to each cut, botanical composition was evaluated in the high fertilization (80 P_2O_5 – 200 N) and in the control plots, both in SI and RF. The ‘Botanal method’ adapted by Millot and Saldanha (1998) was performed in five 0.25 m^2 quadrants per split plot with a minimum score of 5%. In the first experimental period (10/2011-9/2012) the cumulative rainfalls totalized 1004 mm and 13 additional irrigations were performed which accumulated 324 mm. In the second experimental period (10/2012-9/2013) the cumulative rainfalls totalized 1790 mm and three additional irrigations that accumulated 110 mm were done. An analysis of variance model was adjusted to analyze the cumulative forage production considering the effects of SI, N and P Fertilization and the interaction of factors. Means of significant effects were compared using the LSD test at 5%. A Principal Components analysis of the 13 most abundant species was performed using standardized Euclidean distances.

III – Results and discussion

In the first year of assessment (10/2011-9/2012) ANPP showed a significant interaction between SI and N (Table 1a). This interaction was mainly related to a 20% increase in ANPP on average of N under SI compared to RF. Treatment of 200 kg N under SI resulted in a 100% increase of ANPP compared with the control (RF and unfertilized). These results are in accordance with López *et al*. (2002) who stated that with favorable moisture conditions N fertilization stimulates mineralization in soils with high contents of potentially mineralizable N. In the second year (10/2012-9/2013) ANPP was higher than the previous year and showed a significant triple interaction between SI, N and P fertilization (Table 1b). Treatment of 200 kg N and 80 P_2O_5 under SI resulted in a 110% increase in ANPP when compared with the control situation. The triple interaction was explained by a different response of ANPP increase to N together with P in the SI respect to the RF. Within N treatments, P response in SI was detected in 50 N, while in RF condition the response was in N 200. Besides that, higher ANPP was found in RF situation compared to SI in N 50 in the absence of P, whereas with P fertilization, ANPP was superior in RF at N 100 and N 200. These findings suggest that soil water variability may play an important role in nutrient availability for this kind of grassland.

Table 1. Responses in ANNP to N and SI: 1a) in the first year; 1b) in the second year

1a) 2011/2012			1b) 2012/2013							
SI	N	ANPP	SI	N	P_2O_5	ANPP	SI	N	P_2O_5	ANPP
No	0	2500 a	No	0	0	4088 a	Yes	0	0	3931 a
No	50	2887 b	No	50	0	5682 bc	Yes	50	0	5197 b
No	100	3286 c	No	100	0	6500 ef	Yes	100	0	5814 cd
No	200	3982 e	No	200	0	7506 gh	Yes	200	0	7642 h
Yes	0	2798 b	No	0	80	4267 a	Yes	0	80	4255 a
Yes	50	3410 c	No	50	80	5486 bc	Yes	50	80	6012 cde
Yes	100	3700 d	No	100	80	7024 fg	Yes	100	80	6239 de
Yes	200	4978 f	No	200	80	8498 i	Yes	200	80	7952 h

Means with different letters are significantly ($p < 0.05$) ANPP (kg Dry Matter ha^{-1} yr^{-1}) N= (Nitrogen) SI= Supplementary Irrigation

The principal component ordination of species associated with SI and NP fertilization confirm the relations of the dominant species with treatments, and explains both factors interaction (Fig. 1). The first component explained 45% of the variation and was related to a gradient from the control toward the condition of fertilization plus SI. Meanwhile, the second component explained 33% of variation and clearly separated NP fertilized from SI plots.

Mnesithea selloana and *Axonopus fissifolius* were the species that most increased their contribution in the SI and NP plots. These species have acquisitive traits (Jaurena *et al.,* 2012) to compete in concurrent SI and NP conditions. At the same time, *Paspalum notatum, Paspalum plicatulum*, and *Piptochaetium montevidense* were more related to the control, favored by their conservative strategy of stress tolerance. Sedges and *Botriochloa laguroides* were favored with the exclusive application of SI, while *Paspalum dilatatum* and *Bromus auleticus*, species of high forage value, increased in situations of exclusive NP fertilization, mainly in the RF condition. Higher water availability led to a significant increase in C_4 acquisitive perennial grasses in the NP and SI plots, meanwhile in the exclusively NP fertilized plots it enhanced both C_3 and C_4 acquisitive perennial grasses. This behavior suggests that C_4 grasses capture fertility and water improvements in spring and summer and C_3 grasses take advantage of fertility residual effects in winter and spring. In accordance with Yahdjian *et al*. (2011), both water and N availability limit primary production but probably at different times during the year. Therefore, a combination of plant functional strategies and growing cycles in grassland communities is the key to be adapted to changes or disturbances.

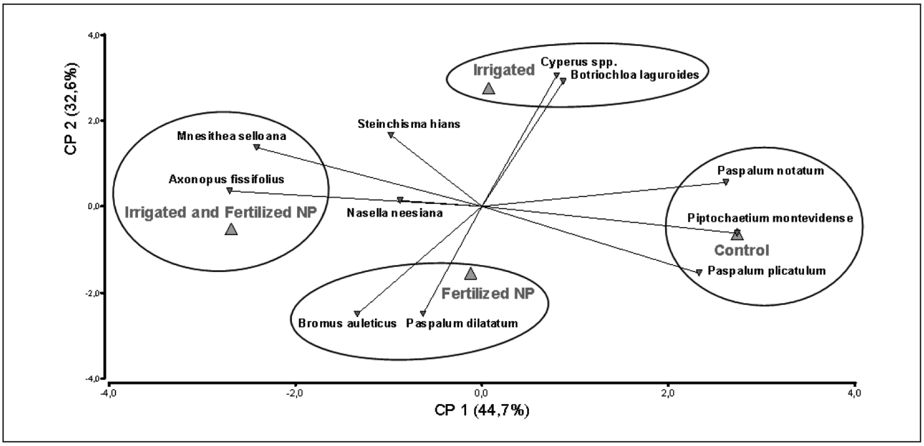

Fig. 1. Principal Component biplot of the main species according to SI and NP treatments.

IV – Conclusions

In summary, the 2-year assessment of NP and SI verified that complex interactions explained the short-term variations in forage productivity. In addition, this NP-SI interaction created conditions that increased the contribution of most valuable forage native species.

N fertilization response in the spring-summer period of a dry year was improved with SI, while in the following wet year the N response was improved with the combined application of N and P. The lack of response to SI in the second year highlights that water limitation may be important in dry years but not in others, and foremost the need to combine SI with NP fertilization.

The present findings underline the importance of studying cumulative effects of fertilization and water management in grasslands for a more sustainable management. From these results we recommend further long term research on the interaction between SI and NP fertilization, not only on the effects on productivity, also in grassland dynamics and the environmental impacts.

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Impact of limited irrigation on the growth characteristics of *Lotus corniculatus*

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Abstract. Drought is the most important environmental stress for plants. Inadequate amount of rainfall or irrigation can reduce plant growth and forage production more than all the other environmental stresses combined. In this experiment the influence of water stress on the growth parameters of *Lotus corniculatus* was investigated. Plants from a natural population of a semi-arid area of Northern Greece (Drama) were selected and transplanted to pots. After a period of plant establishment, two irrigation regimes were used: (a) irrigation up to field capacity and (b) partial irrigation in order to maintain water shortage conditions in the soil. All measurements were taken during the growing season at four different phenological stages. Total shoot weight, stem weight (SW), leaf weight (LW) and leaf area (LA) were measured during the growing season. Also, the specific leaf area (SLA), leaf area ratio (LAR) and leaf weight ratio (LWR) were calculated. The results showed that the limited irrigation significantly reduced the growth parameters LA, dry SW and LW, while it did not affect the allometric parameters SLA, LAR, and LWR of *L. corniculatus.*

Keywords. Leaf area – Leaf weight – Stem weight – Specific Leaf Area.

***Impact d'une limitation de l'irrigation sur les caractéristiques de croissance de* Lotus corniculatus**

Résumé. *La sécheresse est la contrainte environnementale la plus importante pour les plantes. Une quantité insuffisante de pluie ou d'irrigation peut réduire la croissance des plantes et la production de fourrage plus que toutes les autres contraintes environnementales combinées. Dans cette expérience, l'influence du stress hydrique sur les paramètres de croissance de* Lotus corniculatus *a été étudiée. Des plantes d'une population naturelle d'une zone semi-aride du nord de la Grèce (Drama) ont été sélectionnées et transplantées dans des pots. Après une période d'installation, deux régimes d'irrigation ont été utilisés: (a) l'irrigation à la capacité au champ et (b) l'irrigation partielle afin de maintenir des conditions de pénurie d'eau dans le sol. Toutes les mesures ont été prises au cours de la saison de croissance à quatre stades phénologiques différents. La masse sèche de la partie aérienne, des tiges (SW), des feuilles (LW) et la surface foliaire (LA) ont été mesurées au cours de la saison de croissance. En outre, la SLA, le LAR et le LWR ont été calculés. Les résultats ont montré que l'irrigation partielle réduit significativement les paramètres de croissance (LA, sec SW et LW) et n'affecte pas les paramètres allométriques (SLA, LAR et LWR) de* Lotus corniculatus.

Mots-clés. *Surface foliaire – Masse sèche de la feuille – Masse sèche de la tige – Surface Foliaire Spécifique.*

I – Introduction

Plants under natural or agricultural conditions are exposed to various abiotic or biotic stresses. Water deficit arises from both insufficient rainfall and soil water during the growing season (Lipiec *et al*., 2013). Inadequate amount of rainfall or irrigation can inhibit photosynthesis, limiting plant growth and survival more than all the other environmental stresses combined (Wang *et al*., 2003; Zlatev *et al*., 2012). Moreover, prolonged drought can restrict plant growth and biomass production and modify the biomass allocation patterns and even cause plant death (Puri and Swamy, 2001; Rodiyati *et al*., 2005; Li *et al*., 2009). The allocation pattern that maximizes growth or water use efficiency depends on the availability of water. Plants can acclimate to water stress through physiological, morphological and biochemical responses (Xiong *et al*., 2006; Lambers *et al*., 2008). Higher acclimation capacity and greater resistance is determined by the plant capacity to maintain its physiological processes (Valladares *et al*., 2007).

Legumes are important components of pastures because they are the main crude protein source in the animal food. Legumes are second after grasses in significance to agriculture and there is an essential need to increase drought tolerance in these species (Sanchez *et al*., 2012). The genus *Lotus* is widespread and includes a large number of species. *Lotus corniculatus* L. is the most important and widely distributed crop from the *Lotus* genus and grows under a wide range of environmental conditions (Díaz *et al*., 2005a; Escaray *et al*., 2012). The aim of the current study was to investigate the impact of limited irrigation on the growth and allometric parameters of *Lotus corniculatus* in four phenological stages.

II – Materials and methods

The experiment was conducted in the farm of the Aristotle University of Thessaloniki, Northern Greece (longitude: 40˚31'91'', latitude: 23˚59'58''), at an altitude of 6 m a.s.l. The climate of the area could be characterized as Mediterranean semiarid with dry summers. The mean annual precipitation is approximately 400 mm and the mean annual air temperature is 15.5°C.

Plants of *L. corniculatus* from a natural population of a semi-arid area of Northern Greece (Drama) were selected in September and October of 2012 and transplanted in small pots. At the beginning of March 2013, 32 plants were transferred in large pots (16 cm diameter and 45 cm height), filled with natural soil of medium texture and placed under a transparent shelter. After a period of plant establishment, drip irrigation was applied at two levels: full irrigation up to field capacity (FI) and limited irrigation (LI) that lasted nine weeks (40% water of that received by FI). The pots were placed in completely randomized design with four replicates. Measurements were taken during spring 2013 on four different dates corresponding to four phenological stages: early vegetative, vegetative, flowering and start of fruit formation. At each phenological stage four plants were harvested, and the leaf area (LA), as well as, the fresh weight of shoots, stems and leaves were measured. Leaf area was measured using the portable leaf area measurement system Li-3000A (LiCor Lincoln, Nebraska, USA). Then the samples (leaves, stems) were placed into an oven for 48 hours at 70°C to determine their dry weight. Specific leaf area (leaf area/leaf weight: SLA), leaf area ratio (leaf area/total shoot dry weight: LAR) and leaf weight ratio (leaf dry weight/total shoot dry weight: LWR) were calculated (Gurevitch *et al.,* 2006).

Analysis of variance (ANOVA) was used to determine effects of the irrigation treatments and the plant phenological stage ($P < 0.05$). Independent *t*-test was used to compare two means (Steel and Torrie, 1980). Statistical analysis was performed using the statistical package SPSS (SPSS for Windows, release 21.0; SPSS, Inc., Chicago, USA).

III – Results and discussion

Both water treatment and plant phenological stage affected shoot dry weight (SW), leaf dry weight (LW) and LA of *L. corniculatus* ($P<0.05$). Likewise, the interaction between these two factors was significant ($P<0.05$). Mean leaf and stem dry weights were significantly reduced under water limited conditions (Table 1). However, throughout the growing season plants under limited irrigation had significantly lower leaf dry weight (Fig. 1) compared to plants subjected to full irrigation. Only, at the early phenological stages, plants presented the same leaf dry weight in the two treatments. It is well demonstrated that increasing in water stress could decrease plant dry weight (Rad *et al.*, 2011). Moreover, throughout the growing season plants under limited irrigation had significantly lower mean leaf area compared to plants under full irrigation (Table 1). The decrease in total leaf area is considered one of the most important ways to reduce plant water consumption (Carter *et al.*, 1997; Moreno *et al.*, 2008).

Table 1. Average values (± SE) of growth parameters of *Lotus corniculatus* under two irrigation treatments of four phenological stages (n = 16)

Treatment	SW	LW	LA	SLA	LAR	LWR
Full irrigation	14.2 ± 0.8	10.65 ± 0.5	2194.8 ± 183.6	216.5 ± 5.9	92.5 ± 4.8	0.43 ± 0.02
Limited irrigation	6.8 ± 0.	5.084 ± 0.5	967.63 ± 78.2	218.8 ± 6.6	85.1 ± 5.7	0.40 ± 0.02
Sign. P<0.05	*	*	*	ns	ns	ns

From the changes of SLA (Table 1, Fig. 2) during the growing season it becomes apparent that *L. corniculatus* plants under limited irrigation had similar mean values compared to plants under full irrigation. Only, at the stage of fruit formation (Fig. 1) plants under limited irrigation presented significantly (P<0.05) higher SLA than under full irrigation. SLA is considered an essential trait of plants to survive through a Mediterranean climate, since it is associated with relative growth rate, leaf thickness and plant ability to use environmental resources, mainly light. The increased trend in SLA, especially under limited irrigation, and the decreasing pattern of leaf weight at the stage of fruit formation indicates that the species in the fruit formation stage developed thinner leaves (Carter *et al.*, 1997). Thus, similar SLA of *L. corniculatus* could be probably due to adaptation to resource poor environments (Li *et al.*, 2005). Moreover, no significant differences (P<0.05) in the values of mean LAR and LWR between the two treatments were found. This result is in accordance to the maintenance of *L. corniculatus* photosynthetic and photochemical performance under water deficit that we have found (unpublished data). Therefore, although limited water irrigation decreased the plant size, it did not change the plant morphology. It seems that *L. corniculatus* is capable of maintaining optimum water balance under drought conditions, allowing the function of its photosynthetic machinery (Díaz *et al.*, 2005b).

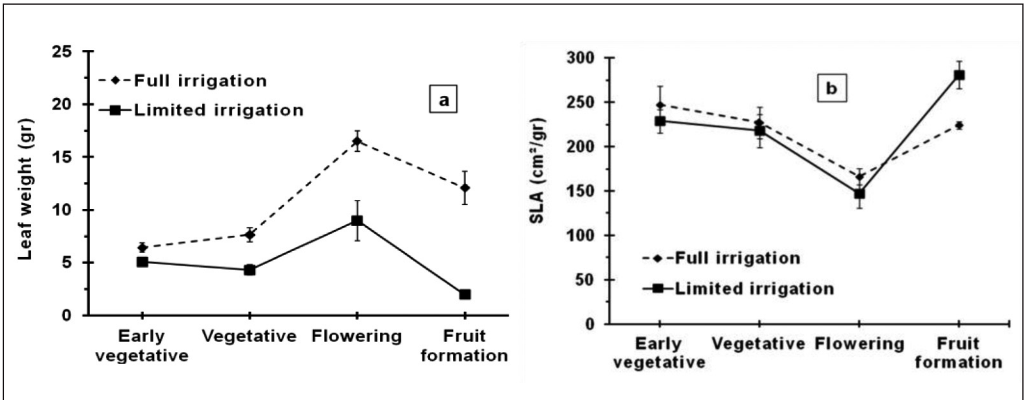

Fig. 1. Changes of a) leaf dry weight and b) Specific Leaf Area (SLA) of *Lotus corniculatus* at four different phenological stages under two irrigation treatments.

IV – Conclusions

The present pot study indicated that limited irrigation significantly reduced the growth parameters SW, LW and LA but it did not affect the allometric ones, SLA, LAR and LWR of *L. corniculatus*. However, further work is needed to test this population, including additional morphological and physiological traits and more severe drought conditions.

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Grassland yield variation and botanical composition in mountainous areas of Norway

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Abstract. In Norway, farms in the mountain region need high amounts of conserved forage for the long winter period. The agricultural statistics shows that the grassland yields have stagnated or even decreased in some regions during the last 10-20 years. The farm size and milk production per farm has increased in this period, due to more use of rented land and buying of milk quota. In a new project, we estimate grassland yields to examine yield variations on the field level. The aim of the project is to explain yield variations under practical farming conditions and identify bottlenecks for the grass production. We make registrations of the yield by counting, weighing and sampling big bales. The botanical composition of the fields is examined by the dry weight rank method. Information about soil conditions, land and fertilizer use is gathered from the farmers and the advisory service. In the first year, six farms in three districts have participated in the project. Preliminary results show large yield variations. Poor drainage conditions are common in parts of many fields, limiting grass growth. Heavy traffic in connection with grass harvest and spreading of animal manure might also give yield reductions. The botanical analyses show that coach grass (*Elymus repens*) has a high proportion in many fields compared to other Norwegian investigations. We hope to extend this project the coming years to make a sound basis for good advices in grassland production.

Keywords. Grassland – Agronomy – Yields – Botanical composition.

Composition botanique et variation de la production des prairies dans les zones de montagne en Norvège

Résumé. *En Norvège, les fermes de montagne ont besoin de grandes quantités de fourrages conservés pour la période de l'hiver. Les statistiques agricoles montrent que les rendements des prairies ont stagné ou même diminué dans certaines régions au cours des 10-20 dernières années. La taille de l'exploitation et la production de lait par exploitation a augmenté durant cette période, en raison de l'utilisation de terres louées et l'achat de quotas laitiers. Dans un nouveau projet, nous mesurons les rendements des prairies pour examiner les variations de rendement sur le terrain. Le projet vise à expliquer les variations de rendement dans des conditions de pratique agricole et à identifier les verrous pour la production d'herbe. Nous enregistrons les rendements par comptage, pesêe et échantillonnage des grosses balles de fourrage. La composition botanique des prairies est examinée par la méthode de classement de poids sec. Des informations sont collectées sur les conditions du sol, l'utilisation des terres et les engrais auprès des agriculteurs et des services de conseil. La première année, six fermes dans trois districts ont participé au projet. Les résultats préliminaires montrent de grandes variations de rendement. Les mauvaises conditions de drainage sont fréquentes dans certaines parties de nombreuses parcelles, ce qui peut limiter la croissance de l'herbe. La circulation des machines de récolte de l'herbe et d'épandage de fumier peut aussi être la cause des baisses de rendement. Les analyses botaniques montrent que le chiendent (*Elymus repens*) représente une forte proportion dans beaucoup de parcelles par rapport à d'autres enquêtes réalisées en Norvège. Nous espérons étendre ce projet dans les prochaines années pour développer une base solide de conseils pour la production des prairies.*

Mots-clés. *Prairies – Agronomie – Rendements – Composition botanique.*

I – Introduction

Grassland farming makes the basis of mountain agriculture in Norway. With a snow cover lasting from October-November until April-May, the yield of conserved grass for winter fodder is very important for the farmers. Traditionally, the grass was conserved as hay. However, during the last 50-year period silage has become the preferred method due to unstable weather conditions and technological development. Today, 75-80% of the grass is conserved in round bales with a short period of wilting between cut and baling. A two-cut system is most frequently used with a first cut in late June/early July and a second cut in late August/early September. At the highest altitude areas (900-1000 m a.s.l.), only one cut is taken. In addition, some of the silage meadows are grazed in spring, especially on sheep farms. Grazing in autumn is common for both sheep and cattle.

Grassland yield is difficult to measure precisely under practical farming conditions, and thus the official yield statistics for grassland is more uncertain than for cash crops like cereals or potatoes. The statistics indicate that the grass yield in Norway has levelled off during the last 10-20 years. The farm size in the mountain district is generally smaller than in the lowlands. Many farms have increased their milk or meat production during the past years, and most of their increased forage production comes from rented land. This leads to longer transport distances both for forage to the farm and for animal manure back to the fields. Many farmers want to increase their forage production on the closest fields to reduce the transport costs. This leads to more intensive cultivation of fields close to the farm and more extensive cultivation of fields far away from the farm.

In Norway, the goal is to increase the agricultural production by 20 % before 2030 to maintain the degree of self-sufficiency in food production (Landbruks- og matdepartementet, 2011). An increased production in the mountain district must be based on higher yields per area, or on a higher utilization of the pastures. The average farm size is increasing rapidly, and in many districts winter forage is limiting production. More knowledge on factors restricting forage production is needed to give better advice for the farmers. Therefore, this project was initiated measuring yield and botanical composition on farmer's fields to obtain better knowledge of grassland production.

II – Materials and methods

Forage yield and botanical composition in meadows was measured in 30 fields at six farms in the mountain district of southern Norway in 2013, three farms in Nord-Østerdalen, two farms in Valdres and one farm in Ottadalen. The majority of fields were cut twice; five high-altitude fields were cut only once, and in two fields the regrowth was grazed by sheep after the first cut. At all fields, the forage was conserved as round bales. All bales per field were counted, and three representative bales were weighed and sampled after conservation. The samples were dried at 60°C for 48 hours to determine the dry matter content. The area of each field was measured from digital maps. Dry matter yield per hectare was calculated by multiplying the number of bales with average bale weight and dry matter content, and dividing it with the field area. The method of estimating yield by counting and sampling grass bales worked out well. Counting the bales is simple, and sampling three bales per field for weight and dry matter content is not very labour intensive. The bales can be put aside and sampling and weighing can be done simultaneously for all cuts and fields from a farm. The measurement of bales gives a good estimate for the whole field together, both productive parts and less productive parts. This is difficult to address with other methods.

Botanical composition of the fields was examined using the dry weight rank method (t'Mannetje and Haydock 1963) with dominance factors of 70, 20 and 10 for the three most frequent species within each subplot. 15-20 subplots were registered within each field at random using a 50x50 cm frame. The fields were divided into three groups after age (1-3 yr, 4-7 yr, > 7 yr) to examine changes in yield level, tested by one-way analysis of variance. Botanical composition was tested with a general linear model: Proportion = μ + Age + Field within Age + Species, with field as random variable. In addition, information about each field about soil quality, cropping history, fertilization, drainage conditions and machinery use were collected from farmers.

III – Results and discussion

The botanical composition of the meadows changed as the age of the meadows increased; there was a significant interaction between age and species ($P<0.001$, Table 1). Almost all meadows were seeded with a mixture of *Phleum pratense*, *Festuca pratensis* and *Trifolium* species, often with *Poa pratensis* included. Two fields in the oldest group were seeded with *Dactylis glomerata* and *Bromus inermis*.

The newly reseeded fields showed as expected a very high proportion of the sown species with a dominance of *Phleum pratense*. The proportion of clover was rather low, which is probably due to high application of nitrogen fertilizers.

The 4-7 year old fields showed a declining content of the sown species *Phleum pratense and Festuca pratensis*. However, the content of *Poa pratensis* increased. The content of coach grass (*Elymus repens*) was high, and in five out of ten fields coach grass was the most frequent species in this group.

Table 1. Proportion (%) of different species in cut meadows of different age in the mountain districts of southern Norway

Number of fields	**1-3 yr N = 11**	**4-7 yr N = 10**	**>7 yr N = 9**
Phleum pratense	56	21	3
Festuca pratensis	21	15	2
Poa pratensis	5	14	16
Trifolium repens	5	<1	1
Trifolium pratense	2	1	<1
Elymus repens	3	27	36
Poa annua	2	5	4
Taraxacum officinale	<1	4	2
Dactylis glomerata	<1	2	6
Agrostis capillaris	1	1	8
Deschampsia cespistosa	1	2	6
Alchemilla spp	<1	1	6
Other grasses	<1	1	4
Other herbs	3	7	6
Standard error mean	6.4	8.4	9.7
P value	<0.001	<0.001	<0.001

In the oldest fields, *Elymus repens* had the highest proportion, with *Poa pratensis* on second place. Coach grass was the most frequent species on five out of nine fields. Here, there was a higher diversity between fields in species composition, and typically, the content of herbs was higher than in younger grasslands.

The content of coach grass was high compared with older Norwegian investigations (Nesheim 1986, Lundekvam and Gauslaa 1986), although this species was present under different conditions. In the mountain districts, herbicide treatment with glyphosate against coach grass has not become common practice before renewal. With a continuous grassland production, coach grass is usually not considered as a problem weed. Many farmers think they grow sown grasses although they have a high proportion of coach grass in their meadows. When the proportion of sown species, especially *Phleum pratense* and *Festuca pratensis*, decreases after two-three years, coach grass fills gaps in the sward and is well adapted to fertilization practice, harvest- and grazing regimes in the mountain district.

The yield investigation showed average yields of about 6 tons dry matter per hectare (Table 2). This figure is rather low compared with grassland experiments (e.g. Bakken *et al*. 2009). However, compared with the official yield statistics it is high (Statistisk sentralbyrå 2013). There are big losses in the process between grass cutting and silage feeding. When measuring silage bales, dry matter losses in the field and in the conservation process were included. However, losses during feeding and disposal of badly preserved bales were not considered.

Table 2. Average yields of dry matter (t ha^{-1}) in two cuts in grassland of different age

Number of fields	1-3 yr N = 8	4-7 yr N = 8	>7 yr N = 3
Yield 1st cut	3.2	3.7	2.9
Yield 2nd cut	3.1	2.6	2.6
Total yield	6.3	6.3	5.5
SE (total yield)	1.7	0.6	1.0
Minimum	3.6	5.8	4.4
Maximum	9.0	7.8	6.5

The average total yield did not differ between different grassland age groups (P = 0.54) (Table 2). The 4-7 year old grasslands yielded at the same level as the 1-3 year old ones. However, one should not conclude about this from one year and a small material. Differences in harvest times and elevation might influence the dry matter yield considerably, but the groups were quite similar in this respect. In the permanent meadow group (age >7 years) there were five fields in addition from high altitude fields (about 900 m a.s.l.). Here, only one late cut was taken with average yield 4.1 t DM ha^{-1}.

One goal of the project is to get a better understanding of yield variation between fields. Although the material is yet too small to draw clear conclusions at this point, we could see that some of the lowest yielding fields were poorly drained. The connection between botanical composition and yield still is not clear, and there seems to be no clear effect of the content of *Elymus repens* on dry matter yield. The project continues and hopefully, more clear conclusions may be achieved later. Connections between yields, botanical composition, soil conditions and agronomical practice will be examined. From the first year we conclude that the high content of *Elymus repens* is important. Many grasslands with age above three years have a high content of this species and we need a better understanding of the effects of coach grass. Forage quality will be included in the project in 2014. The methodology of measuring yields by counting and sampling grass bales worked out well and will be continued.

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Agronomic performance of some perennial grass cultivars in Algerian semi arid conditions

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Abstract. Selection of perennial forage grasses is aimed at improving the sustainability of cropping. Tolerance to drought conditions, persistence and high forage yields are the major traits that determine the adaptability of the tested genotypes. This study was conducted at the experimental site of the ITGC institute in Sétif during the cropping season 2008/2009 with the objective of evaluating the performance of 13 varieties of perennial grasses, belonging to two species: *Festuca arundinacea* Schreb. and *Dactylis glomerata* L. in a semi arid region. Cultivar characterization focused on various agronomic traits in order to assess their adaptability to drought prone environments. The results showed the existence of a wide range of variability between cultivars, particularly regarding biomass production, production cycle and persistence. These results showed high potential for the selection of a plant material adapted to the specific conditions of the semi-arid areas of the Algerian high plains. Indeed, this study allowed us to select the most adapted varieties such as Flecha, Fraydo and Kasbah.

Keywords. *Festuca arundinacea – Dactylis glomerata* – Tolerance to drought – Persistence – Adaptability.

Performance agronomique de quelques cultivars de graminées pérennes sous conditions semi-arides en Algérie

Résumé. *La sélection des graminées fourragères pérennes vise à améliorer la durabilité du système de production. La tolérance à la sécheresse, la persistance ainsi que la production de la biomasse sont les principaux caractères qui déterminent la capacité d'adaptation des génotypes. Cette étude a été réalisée dans une région semi-aride, au niveau de ITGC de Sétif durant la campagne 2008/2009 avec l'objectif d'évaluer la performance de 13 variétés de graminées pérennes appartenant à deux espèces :* Festuca arundinacea Schreb. *et* Dactylis glomerata *L. La caractérisation a porté sur différents traits agronomiques afin d'évaluer la capacité d'adaptation des différents cultivars aux conditions de stress hydrique. Les résultats ont montré l'existence d'une grande variabilité entre les variétés évaluées, en particulier en ce qui concerne la production de biomasse, le cycle de production ainsi que la persistance. Ces résultats suggèrent l'existence d'un potentiel génétique pour la sélection d'un matériel végétal adapté aux conditions spécifiques des zones semi-arides algériennes. En effet, cette étude nous a permis de sélectionner les variétés les plus adaptées, à savoir Flecha, Fraydo et Kasbah.*

Mots-clés. Festuca arundinacea – Dactylis glomerata – *Tolérance à la sécheresse – Persistance – Adaptation.*

I – Introduction

Forage and turf grasses are the backbone of sustainable agriculture and contribute extensively to the world economy. They play a major role in providing high quality and economical meat, milk, and fibber products and are important in soil conservation, environmental protection, and outdoor recreation (Wang *et al.,* 2001). In the Mediterranean environment, the possibility of grasses to survive water stress during summer depends on their ability to reduce the vegetative phase to a dormant phase, and become active again under the first autumn rains (Laude, 1953). Stress-tolerant forage resources are increasingly needed for the environmental and economic sustainability of extensive Mediterranean livestock systems. In this context, perennial forages can be a valuable alternative to annuals, if they can survive across successive summer droughts. Poor persistence of sown perennial pasture grasses is a problem in the Mediterranean regions all-over the World where the most stressful, life-threatening season is a summer characterised by long and often severe droughts with high temperatures. Among the perennial grass species of common interest across the Mediterranean basin, tall fescue (*Festuca arundinacea* Schreb.) and orchardgrass (*Dactylis glomerata* L.) are of paramount importance (Ghesquière and Jadas-Hécart, 1995).

The objective of this study was to characterize variation for dry matter yield, forage maturity, plant height, and persistence among cool-season perennial grass varieties evaluated under semi arid conditions of the eastern high plains of Algeria.

II – Materials and methods

Thirteen perennial forage grass varieties were implanted, among which seven varieties of *Festuca arundinacea* Schreb. and six varieties of *Dactylis glomerata* L. (Table 1). The plant material was obtained by PERMED project (INCO-CT-2004-509140). The field study was conducted during the 2008/09 cropping season at Sétif Agricultural Experimental Station (36°12'N, 5°24'E, 1023 m asl). The long term annual mean precipitation of the experimental site is 396.0 mm, occurring mainly in November to March with a winter mean temperature of 6.6°C and a spring mean temperature of 12.5°C. The climate is temperate continental, varying from arid to semi-arid. Season 2008/09 was characterized by a cold rainy winter and a warm spring with a rainfall peak in April, followed by a dry and hot summer. The soil is loamy clay, with a bulk density of 1.35 g cm^{-3}.

Each grass variety was sown on 10 row-plot 2.5 m long and 0.20 m row spacing. The 6 inner rows were harvested in November 2008 and April 2009 by clipping mechanically at a height of 7.0 cm. Fresh plant material samples, of varying size (100-500 g), were dried at 70°C for 48 h at each harvest for dry matter determination. Defoliation was initiated in the autumn before the onset of kill frost and in the spring season when inflorescence emerged in at least 4 varieties. Heading date was recorded, on the outer rows, as the number of Julian days from January 1st to the date when 50% panicles fully emerged. Plant height was determined as an average of three measurements taken per plot from the soil surface to the highest point of the vegetation just before the harvest. Variation in the ground cover was used as a measure of persistence.

All data collected were analysed as a randomized complete block design using GenStat (Discovery Ed.). Differences among the means were tested using the least significant difference (LSD) test at the 0.05 probability level.

III – Results and discussion

Mean plant height, averaged over cultivars, varied from 20.0 cm to 40.2 cm with significant differences between seasons (P <0.001) (Table 1). The *Dactylis* Delta-1 was the shortest variety with a mean of 20 cm and Lutine and Fraydo fescues were the tallest among the evaluated entries with 34.2 cm and 40.2 cm respectively (Table 1). Dry matter yields over cultivars were relatively low during autumn as compared to spring harvests (Table 1), with an average dry matter yield of 0.43 t ha^{-1} for the autumn harvest and 0.84 t ha^{-1} for the spring harvest, which allowed better expression of the yielding ability of the different varieties. The analysis of variance of the autumn dry matter yield indicated that the Kasbah cocksfoot and the tall fescue varieties Fraydo and Centurion were the top yielding with an average dry matter yield of 0.69 t ha^{-1}, while the lowest dry matter yield was recorded with Medly with an average of 0.16 t ha^{-1}. Concerning the spring dry matter yield, Anova showed significant differences (P = 0.014) (Table 1) among treatments, the mean values ranging from 0.47 t ha^{-1} (Lutine) to 1.35 t ha^{-1} (Flecha).

Plant height at the defoliation period was directly correlated to the production level of each variety. The sward elongation was slow at the beginning of the cycle (autumn), when the differences between species were very small. The elongation became higher at the end of the cycle when tall fescue varieties exhibited a better response to the environmental conditions than *Dactylis* varieties. Volaire (1991) suggested the existence of a strong correlation between vegetation height, vigour, and recovery. Concerning the dry matter production, crops were harvested twice, in autumn and spring when significant differences were noted between varieties (Table 1). The poor autumn production could be explained by the low level of soil moisture available for growth; autumn rains usually arrive very late, and in summer there is a complete absence of rain resulting in gradual dormancy of the different varieties, which reduced their dry matter production.

Row cover and the number of days to heading showed significant differences between cultivars (Table 1). Thus, sward persistence as expressed by final row cover ranged from 31.0% (Lutine) to 78.7% (Kasbah) in autumn and from 28.7% (Lutine) to 69.8% (E542) in spring (Table 1). Regarding the number of days to heading, Flecha exhibited the earliest heading date (114.7 and 120.7 days, respectively), while *Dactylis* varieties Delta1 and Jana were the latest to head (133.5 and 135 days, respectively) (Table 1).

Table 1. Description of the studied varieties an d genotypic means during the fourth production year

Name	Origin	PHT	DM1	DM2	Rec1	Rec2	DHE
Cocksfoot							
Jana	Italy X north Africa	25.7	0.3	0.6	54.8	46.5	135.0
Medly	Mediterranean	22.6	0.2	0.6	44.6	38.4	121.3
Kasbah	South Morocco	26.8	0.7	1.2	78.7	59.7	129.7
Delta-1	France	20.0	0.3	0.5	61.6	53.4	133.3
Currie	Algeria	22.7	0.4	0.7	61.2	45.1	127.7
Ottava	Sardinia	25.8	0.4	0.6	51.2	42.9	129.7
Tall fescue							
Tanit	Italia X Morocco	32.2	0.5	1.2	64.0	55.2	125.3
Sisa	Sardinia	31.2	0.4	0.9	47.6	42.3	125.3
E-542†	France X Tunisia	29.7	0.4	0.7	70.7	69.8	122.7
Centurion	Italia X Tunisia	31.4	0.7	1.2	66.7	64.7	124.7
Flecha	France X Tunisia	28.7	0.5	1.3	75.8	65.4	114.7
Lutine	Temperate X Mediterranean types	34.2	0.2	0.5	31.0	28.7	129.0
Fraydo	Israel	40.2	0.7	1.0	56.3	40.7	120.7
LSD (0.05)	–	5.28	0.26	0.53	9.06	13.35	6.74

† E-542 = Flecha tall fescue infected with the non toxic AR5421 strain of *Neotyphodium Coenophyialum.* Plant height (PHT, cm), Autumn dry matter yield (DM1, t ha^{-1}), Spring dry matter yield (DM2, t ha^{-1}), Plant recovery (REC1,2,%), Number of days to heading (DHE, days).

The lower persistence of continental *Dactylis glomerata* cultivars in comparison with the Mediterranean ones can be ascribed to their difficulty in developing a deep root system and extracting water under conditions of limited water availability (Volaire and Lelièvre, 2001). The widespread yield advantage of *Festuca* over *Dactylis* may largely derive from greater growth across autumn and winter (Lelièvre *et al.*, 2011). Kasbah maximized the drought tolerance and persistence through its complete dormancy trait. The high level of persistence attained by Flecha arose from survival mechanisms other than complete dormancy, such as the deep root system (Lelièvre *et al*., 2011) and the development of an extensive collar of senescent leaf sheaths around its young tillers in summer which could increase tiller survival by reducing transpiration losses (Norton *et al.*, 2006).

IV – Conclusion

These results showed the possibility to select an adapted material of *Dactylis glomerata* and *Festuca arundinacea* to the specific conditions of the semi-arid areas of the Algerian high plains, where annual rainfalls rarely exceed 400 mm per year. Flecha, Fraydo and Kasbah showed superior adaption for the measured traits. There was some evidence for better drought tolerance of earlier-heading varieties.

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Yielding ability of different annual cereal-legume mixtures

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Abstract. The preliminary results of a trial aimed at optimizing legume-cereal mixtures are reported. The experiment was carried out during the season 2012-2013 in North Sardinia (Italy). Sixteen plots were sown in November 2012 with pea or vetch and oat or triticale in monoculture and mixtures, following a randomized complete block design with 4 replicates. Measurements included dry matter production, botanical composition and phenology. The dry matter production of sown species ranged between 5.0 and 7.3 t ha^{-1}. Both vetches cultivars showed a very competitive behaviour against unsown species. These preliminary results allowed to identify some mixtures with correct dry matter yield combined with a favourable forage composition and a satisfactory control of unsown species.

Keywords. Annual forage crops – Pea-based mixtures – Binary mixtures – Grass pea – Common vetch.

Capacité de production de divers mélanges annuels de céréales et de légumineuses

Resumé. *Les premiers résultats d'une expérimentation dont l'objectif était d'optimiser des mélanges de céréales et de légumineuses sont présentés. Seize parcelles ont été semées en Novembre 2012 avec pois ou vesce et avoine ou triticale, en monocultures et en mélanges, selon un plan expérimental randomisé avec 3 répétitions. Des mesures ont été effectuées sur la biomasse : mesure de la production de matière sèche, analyse de la composition botanique et de la phénologie. La production de matière sèche des espèces cultivées variait entre 5,0 et 7,3 t ha*$^{-1}$. *Les deux cultivars de vesce ont montré un haut niveau de compétitivité par rapport aux espèces non semées. Ces résultats préliminaires ont permis d'identifier des mélanges avec un bon rendement combiné à une composition favorable du fourrage et un contrôle satisfaisant des espèces sauvages.*

Mots-clés. *Cultures fourragères annuelles – Mélanges à base de pois – Mélanges binaires – Vesce de Narbonne – Vesce commune.*

I – Introduction

Crop-livestock systems are threatened by the overexploitation of forage resources, the marked insufficiency of high-protein feedstuff, the increasing costs of agricultural inputs and climate change. Enhancing forage productivity by exploiting synergies among different functional groups of plants as an alternative to high artificial inputs is one of the challenges faced by agricultural research (Finn *et al.,* 2013). Legumes and cereals mixtures are of particular interest to boost fodder protein content especially in organic farming systems, where the self-sufficiency in protein production allows a higher economic profitability. Nonetheless, the success of the mixtures relies on the right choice of species and varieties, as they could have a facilitative effect one each other, produce maximum yield at the same harvest time, and have the same sowing date (Eskandari *et al*., 2009).

The objective of our experiment was to optimize the composition of annual pea-based mixtures according to the associated cereal (oat or triticale) and the pea plant type (semi-dwarf semi-leafless, or tall semi-leafless), and to compare their yielding ability with other legume-based mixtures (i.e. common and Narbon vetch).

II – Materials and methods

The trial was carried out at the CNR-ISPAAM experimental field 'Leccari', North Sardinia, Italy (40°45'15''N, 8°25'13''E; altitude 24 m a.s.l.). The climate is Mediterranean, with dry and hot summer and mild winter. Average annual rainfall is 550 mm, concentrated from October to May. The site is characterized by a deep alluvial soil, with pH 7.8. *Pisum sativum* L. (pea), semi-dwarf and semi-leafless type (cv Attika, P1) and tall size and semi-leafless type (line 1/27b, P2), *Vicia narbonensis* L. (Narbon vetch, cv Bozdag, N) and *V. sativa* L. (common vetch, cv Barril, V), *Avena sativa* L. (oat, cv Bionda, O) and *x triticosecale* Wittm. (triticale, cv Amarillo, T) were evaluated. A total of 16 treatments were compared: six pure stands (P1, P2, N, V, O, T), eight binary mixtures (P1-T, P1-O, P2-T, P2-O, N-T, N-O, V-T, V-O) and two 4-species mixtures (P1-P2-O-T, V-N-O-T). Fertilizers were applied as 45 kg P_2O_5 ha^{-1} in all plots plus 30 kg N ha^{-1} in cereals monoculture and 15 kg nitrogen ha^{-1} in legumes and legume-based mixtures before sowing. Nitrogen fertilization was repeated at the end of winter. Broadcasting seeding of plots was done in mid-November 2012 following a randomized complete block design with four replicates. Plot size was 12 m^2 (3 m x 4 m). Germinable seed rate (no. m^{-2}) was 70 for P1, P2, and N, 140 for V and 280 for O and T. In binary mixtures and 4-species mixtures, seed rates were halved or reduced to a fourth, respectively. Plots were entirely rainfed. Harvesting was carried out when cereals were at flowering stage, on May, 9^{th} 2013. Plants were cut at 2 cm above the soil from a 1 m^2 sampling area at the centre of each plot. Each mixture component and unsown species were separated from the resulting sample and weighted. A subsample was dried in ventilated oven at 65 °C up to constant weight and re-weighted, in order to estimate the aboveground dry matter yield (DMY) of both sown and unsown species. Phenological stages were observed weekly from germination to harvesting and assigned when at least 50% of plants of the whole plot showed a specific stage. Meteorological conditions were registered during the trial.

One-way ANOVA was carried out using the software Statgraphics Centurion xv. Homoscedasticy of data was assessed by Bartlett's test. Mean differences among treatments were separated by LSD test at 0.05 probability level.

III – Results and discussion

Meteorological pattern. Total rainfall from seeding to harvest was 495.9 mm. A small amount of rain fell after sowing in autumn, but winter was unusually wet. Monthly mean temperatures showed slightly higher values than annual average mean temperatures in January (+1°C) and lower values in February (-1.3°C).

***Phenology*.** For all species and treatments, seedling emergence occurred eleven days after sowing. Both pea varieties flowered 57 days before the flowering stage of oat and 51 days before for triticale (Table 1). Nevertheless, P1 showed ripe brown pods and dry seeds when O was at booting stage and T showed the first awns. P2 showed some dry pods and seeds at the base of plant only at harvesting, when cereals were at flowering stage. P1 was too early maturing in binary mixtures compared to oat and triticale. Conversely, harvesting stages of vetches and cereals matched, as V and N flowered when O and T were at heading stage. Consociation did not affect phenology of species in the cereal-legume mixtures.

***DMY of sown and unsown species*.** DMY of sown species ranged between 5.0 and 7.3 t ha^{-1} with significant differences among treatments (Fig. 1). The average DMY was 6.1, 6.4 and 6.3 t ha^{-1} in monocultures, 2- and 4-species mixtures, respectively. DMY of V-N-O-T (7.3 t ha^{-1}) and V-O (7.1 t ha^{-1}) differed significantly from DMY of P1-O (5.2 t ha^{-1}), P1-P2-O-T (5.3 t ha^{-1}) and P2 (5.0 t ha^{-1}). The other 2-species mixtures showed intermediate DMYs. In general terms, this output indicates an absence of strong interactions between species observed in other trials (Dhima *et al*., 2007), probably due to the lower seeding rate of legumes used in this experiment. DMY of unsown species (DMY_W) was less than 1 t ha^{-1}. DMY_W was significantly higher in P1, P2 and T than in V, N and O (data not shown).

Both vetches showed a very competitive behaviour against unsown species, thanks to their ability to cover soil with a dense canopy. A slight trend towards a higher efficiency in controlling unsown species was shown in binary mixtures where oat was a component. Finally, V-N-O-T showed a better control than P1-P2-O-T mixture.

Botanical composition. The cultivars used in the legume-based mixture showed a good amount of legume biomass on the basis of weight. The percentage of legumes in mixtures (DMY*100/total DMY) ranged between 37% (P2-O) and 87% (V-T) (Fig. 2). In binary mixtures, the contribution of vetches (57.5%) was higher than that of peas (34.9%), especially common vetch (72%). This could be explained not only with the better control of unsown species by vetches compared to peas but also with the higher competitive behaviour of vetches against the other sown species.

Table 1. Phenological stages of legumes and cereals used in mixtures. The phenological stage is expressed as number of days elapsed from sowing. Sowing was carried out on November 15th 2012. Phenological observations ended at day 175 (harvesting)

	Legumes					Cereals	
Phenological stage	**P1**	**P2**	**N**	**V**	**Phenological stage**	**O**	**T**
Stem elongation	97	97	97	97	Tillering	97	97
First flower	110	105	135	143	Stem elongation	127	127
50% flowering	118	118	155	155	Booting	151	148
1st pod	127	127	151	162	Heading	159	155
Pods with green seeds	141	169	169	169	Full flowering	175	169
Pods with dry seeds	151	175	–	–	End of flowering	–	175

P1 = *P. sativum* cv Attika, P2 = *P. sativum* line 1/27b; N = *V. narbonensis* cv Bozdag; N = *V. sativa* cv Barril; O = *A. sativa* cv Bionda; T = *x triticosecale* cv Amarillo.

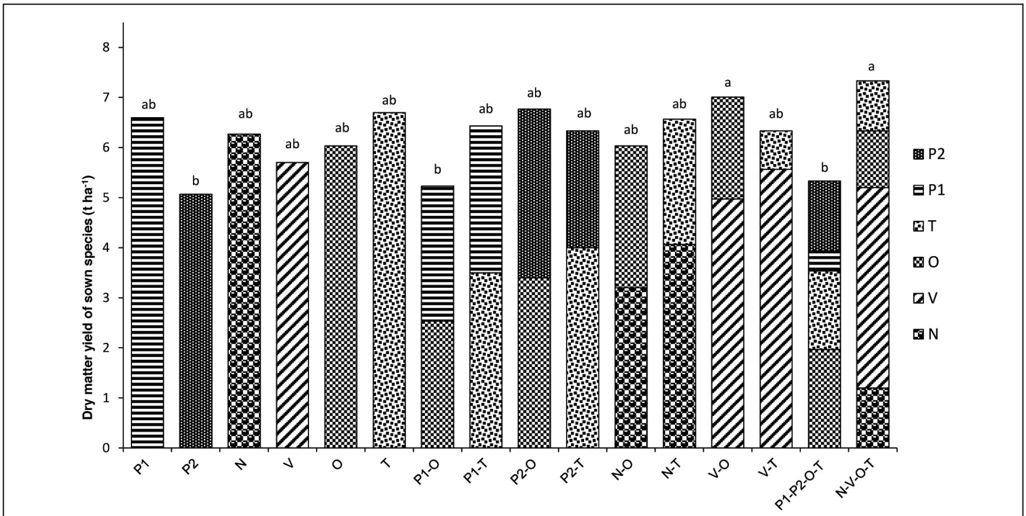

Fig. 1. Dry matter yield (t ha^{-1}) of pea cv Attika (P1), pea line 1/27b (P2), Narbon vetch cv Bozdag (N), common vetch cv Barril (V), oat cv Bionda (O) and triticale cv Amarillo (T) monocultures and their 2- and 4-component mixtures. Different letters show significant differences (P<0.05).

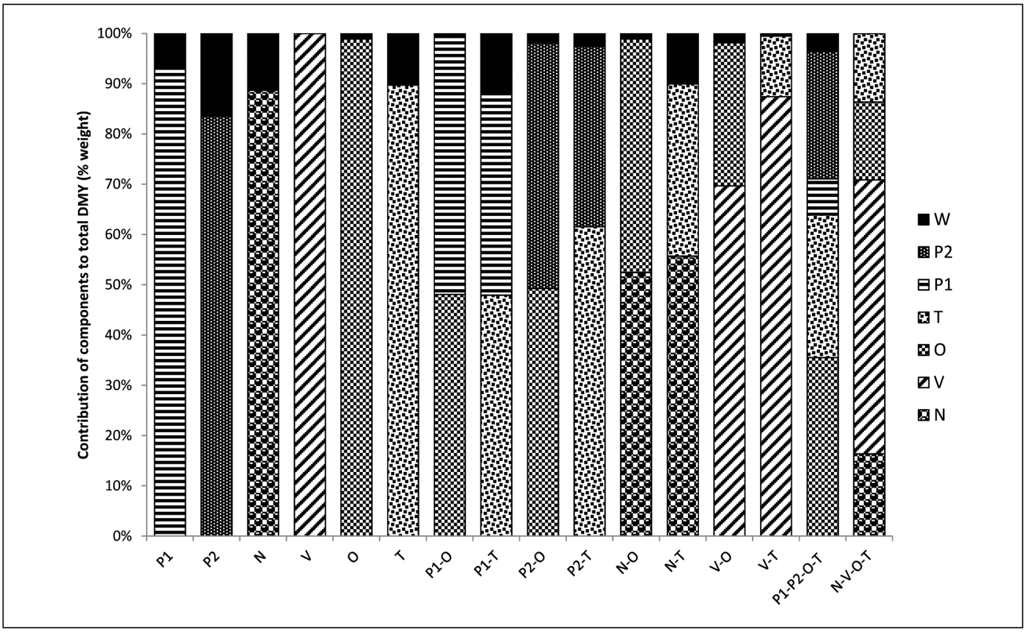

Fig. 2. Contribution (%) to total DMY of DMYs of unsown species (W), pea cv Attika (P1), pea line 1/27b (P2), Narbon vetch cv Bozdag (N), common vetch cv Barril (V), oat cv Bionda (O) and triticale cv Amarillo (T) in monocultures, binary and 4-component mixtures.

IV – Conclusions

These preliminary results allowed identifying some mixtures with a good DMY and a favourable botanical composition, i.e. V-O and N-V-O-T. Moreover, some species and varieties in our trial matched for phenology and showed a great ability in controlling unsown species. Integrative chemical analyses are needed to assess what are the mixtures with the highest forage quality.

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Dairy cow's pastures quality in Jura Mountains and Comté cheese area: maintenance with draught horses

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Abstract. In PDO Comté cheese area, especially in the Jura Mountains, grass from pastures is the main feed of dairy cows during the grazing season. To maintain the high nutritive value of grass, farmers have to cut grass refusals after the exit of cows from the paddock. An alternative is to use horses to eat these grass refusals, thanks to complementary feeding behaviours between these 2 herbivorous species. Thus, some farmers associate draught horses to dairy cattle on pastures. The aim of our study is to analyse the farmers' practices about grazing management when they associate horses and dairy cows on the same pastures. A survey was performed in 14 mixed (draught horses + dairy cattle) farms producing PDO Comté cheese. The results highlighted three types of associations between horses and lactating cows on pastures: (i) successive grazing, (ii) simultaneous grazing, (iii) winter grazing of horses. Moreover, three managements of grass refusals by cows were identified: (i) horses only, (ii) mowing only, (iii) both horses and mowing. In view of these 14 farms, the use of horse grazing to manage grass refusals could depend on the type of horse grazing, the equine stocking rate and the value of horses/cows ratio.

Keywords. Dairy cows – Grazing – Draught Horses – Mountain pastures.

Qualité des pâtures des vaches laitières présentes en zone AOP Comté dans le massif du Jura: Entretien des parcelles par les chevaux de trait

Résumé. *Dans le massif du Jura, en zone AOP Comté, l'herbe pâturée est la principale ressource alimentaire des vaches laitières durant la saison de pâturage. Pour maintenir la valeur nutritive des pâtures, les éleveurs doivent éliminer régulièrement les refus des vaches laitières. Une solution alternative à la gestion mécanique de ces refus est l'utilisation des chevaux, grâce à la complémentarité alimentaire entre ces deux espèces. Ainsi, certains éleveurs associent les deux espèces sur les pâtures. Notre étude avait pour objectif d'étudier les pratiques des éleveurs concernant la gestion du pâturage lorsqu'ils associent des chevaux de trait et des vaches laitières sur les mêmes parcelles. L'enquête menée dans 14 exploitations (chevaux de trait + vaches laitières) a mis en évidence trois types d'associations de chevaux et de vaches au pâturage: (i) le pâturage alternatif, (ii) le pâturage simultané, (iii) le pâturage hivernal des chevaux. De plus, trois gestions différentes des refus ont été identifiées: (i) l'utilisation que des chevaux, (ii) la fauche des refus, (iii) la fauche en plus du pâturage par les chevaux. Au vu de ces 14 élevages, le choix des chevaux dans la gestion des refus des vaches dépendrait des modalités de pâturage des chevaux, du chargement équin et du ratio chevaux/vache sur les pâtures.*

Mots-clés. *Vaches laitières – Pâturage – Chevaux de trait – Montagne.*

I – Introduction

In the Jura Mountains (located in Franche Comté region), the Protected Designation of Origin (PDO) Comté cheese production is based on grazing farming systems and grass has to be the main component of the dairy cows diet. Thus, it is essential to manage the quantity and quality of grass. To maintain a high nutritive value of pastures during grazing period, farmers have to remove grass refusals of dairy cows. Some farmers replace mechanical mowing of grass refusals by associating draught horses and dairy cows grazing as the feeding behaviours of both species are complementary (Menard *et al.*, 2002; Orth, 2011). The aim of this study is to analyse the farmers' practices about grazing management when they associate draught horses and dairy cows on the same pastures.

II – Materials and methods

Some surveys have been carried out in 14 farms located in the Jura Mountains (from 700 meters to 1000 meters above the sea level) and producing PDO Comté cheese. The farms were chosen because they had both dairy cattle and draught horses (at least 3 mares). The questionnaire focused on grazing management on cows' paddocks, especially concerning the use of horses to remove grass refusals after cow grazing on each paddock. The horses/cow ratio (expressed in percentage) was calculated as the number of equine Livestock Unit (LU) divided by the number of LU of lactating cows * 100. The equine stocking rate on cows' pastures (expressed in LU/ha) was calculated as the number of LU per hectare of paddocks grazed by lactating cows. One lactating cow is equal to 1.00 LU, one suckling mare (2 years old at least) is equal to 0.93 LU and one growing horse is equal to 0.74 or 0.90 LU, depending on its age from 1 to 2 years old (INRA, 2012). As regard as the few numbers of farms, qualitative analyses were performed.

III – Results and discussion

1. Farms characteristics

The total area of farms was on average 101 ± 8 ha (means ± standard of error of the mean); n = 14 farms; ranged from 54 to 160 ha). Grasslands represented 96% of this total area. One farm had 15 ha of crops and one farm cultivated 1 ha of forage maize. Permanent grasslands represented 94% of the grassland area. Lactating cows grazed from April to November. Horses pastured during the grazing period and also in winter, except in 3 farms. The herds' size was on average 81 ± 7 cattle LU and 10 ± 2 horses LU (means ± SEM; n = 14 farms). On average, farms had 12 horses per 100 head of cattle (19 horses per 100 lactating cows). The global stocking rate was 0.94 ± 0.03 LU/ha (means ± SEM; n = 14 farms; ranged from 0.68 to 1.20 LU/ha). The milk production was on average 7.345 kilogrammes per cow per year. The milk productivity per grasslands hectare was on average 3.296 kilogrammes per hectare. These farms had a grazing system which was more or less extensive. These global characteristics were representative of the dairy systems located in the Jura Mountains (Cassez *et al.*, 2012).

2. Grazing management of cows' pastures

In all farms, horses grazed at least once the paddocks which were grazed by lactating cows. Three modes of association between cows and horses on pastures can be described. The first mode (in 6/14 farms) consisted in a simultaneous grazing: cows and horses grazed together in the same paddocks. The second mode (in 8/14) was a successive grazing, with cows first and then horses. The third mode (in 8/14) was a winter grazing of horses: horses grazed alone during winter on the paddocks used by cows during the grazing period. In this last mode, farmers wanted to keep horses near the stable, so they used dairy cows' paddocks. These modes of horses – cows association were also observed in Auvergne (Bigot *et al.,* 2013). They can be combined on the same farm (Table 1).

Table 1. Six groups of farms having the same mode of horses/cattle association on cows' pastures

Groups of farmers	I	II	III	IV	V	VI
Association of horses and cows on the cows' pastures	Simultaneous grazing	Simultaneous and winter grazing	Simultaneous then successive grazing	Successive grazing	Successive and winter grazing	Winter grazing
Number of farms	1	3	2	3	3	2

The equine stocking rates on the cows' pastures were lower in the simultaneous grazing (0.18 ± 0.04 LU/ha; means ± SEM; n = 6 farms) than in the successive grazing (0.51 ± 0.18 LU/ha; means ± SEM; n = 8 farms). In addition, the horses/cow ratios were lower in the simultaneous grazing (9% ± 1%; means ± SEM; n = 6 farms) than in the successive grazing (28% ± 7%; means ± SEM; n = 8 farms). These results suggested that when the equine stocking rate and the horses/cow ratio were higher, farmers chose a successive rather than a simultaneous grazing mode. As milk production is the major production of these farms, farmers preferred to keep pasture first for lactating cows. Farmers revealed that they managed the grazing of horses in order to maintain the quality of the cows' pastures which was essential for the feeding of cows. An experimental study showed that the animal performances could vary with the horses/cattle ratio and the annual pasture productivity (Martin-Rosset and Trillaud-Geyl, 2011). Thus, the horses/cow ratio and the equine stocking rate seemed to determine the mode of horses-cows association on pastures. Further study would be necessary to evaluate the horses/cow ratio and equine stocking rate thresholds in the different horses-cows associations in order to avoid degradation of animal performances and pastures quality.

3. Use of draught horses in the management of grass refusals

In relation with the previous global grazing management, two ways to remove grass refusals on the paddocks after being grazed by dairy cows can be observed: the grass refusals were either (i) consumed by horses or (ii) mechanically mowed. The first modality can be observed in most of the farms (11/14). However, three groups of farmers were identified.

The first group of farmers (7/14) didn't use the mechanical mowing to remove grass refusals. According to these farmers, the horses-cows association on paddocks was sufficient to remove grass refusals or avoid their occurrence. In these farms, draught horses grazed with or after lactating cows on paddocks, several times during the grazing period.

The second group of farmers (4/14) removed the grass refusals using the horses and the mechanical mowing. In these farms, horses grazed either a part of area grazed by cows or all the pastures with or after cows only during a short period at spring or autumn. Thus, these farmers used horses to remove only a part of grass refusals.

The third group of farmers (3/14) preferred to use the mechanical mowing in order to remove grass refusals. In this group, horses grazed alone only during winter or after cows grazing during a short period at autumn. These farmers considered that horse grazing was not sufficient to remove grass refusals.

The modes of horse grazing (number of times, period of grazing) rather than the mode of horses-cows association on the cows' pastures seemed to influence the efficiency of horses grazing to remove grass refusals or avoid their occurrence.

The grassland area, the global LU and the global stocking rate were not different between the three groups of farms (Table 2). However, the horses/cow ratio on pastures tended to be lower in the groups II and III than the group I (Table 2). A survey performed in Auvergne highlighted that when the horses/cattle ratio was low (around 10%), the mixed grazing had no influence on the forage estimate compared to only cattle grazing (Bigot *et al.,* 2010). Thus, the horses/cow ratio could determine the success of the removal of grasses refused by cows using horses grazing. Moreover, the equine stocking rate on cows' pastures tended to be lower in the groups II and III than the group I (Table 2). Thus, the stocking rate and the number of times where horses grazed the cows' pastures could be also the key factor in the maintenance of cows' pastures with draught horses.

Table 2. Main features of the 3 groups of famers, depending on the type of management of grasses refused by cows (means +/- SEM†)

Group of farms	**I**	**II**	**III**
Management of grasses refused by cows	**Horse grazing**	**Horse and mowing**	**Mowing**
Number of farms	7	4	3
Grassland area (ha††)	89 ± 11	108 ± 20	113 ± 21
Global livestock unit	80 ± 7	102 ± 16	100 ± 15
Global stocking rate (LU/ha†††)	0.9 ± 0.1	1.0 ± 0.1	0.91 ± 0.05
Equine stocking rate on cows' pastures (LU/ha†††)	0.55 ± 0.23	0.22 ± 0.07	0.18 ± 0.03
Horse/cow ratio on cows' pastures (%)	31 ± 10	8 ± 2	12 ± 4

† SEM: Standard Error of the Mean; †† ha: hectare; ††† LU/ha: Livestock Unit/hectare.

IV – Conclusions

In the Jura Mountains, herds of draught horses were involved in cows' pastures management in dairy farming systems in similar ratio than in Auvergne (Bigot *et al.,* 2013). It appeared that the horse grazing could be an alternative solution to remove grasses refused by cattle if the grazing pressure of horses was sufficient. Further studies would be performed to evaluate the best conditions of mixed grazing on the maintenance of cows' pastures (biodiversity, productivity) and to assess the economic and environmental advantages of horse grazing to remove grass refusals.

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Evaluation and characterization of perennial ryegrass (*Lolium perenne* L.) genotypes collected from natural flora

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Abstract. This study was conducted to characterize perennial ryegrass genotypes collected from Yozgat's flora and evaluate regarding yield, quality and site adaptation. Plant materials were collected from 53 locations and, each location included several genotypes. Seeds firstly were sown in plastic trays on October 2010 and then transplanted to field with 50x50 distance on the following month of march. In the first year, there was no observation but plants were cut frequently to avoid seed formation. Observation began the second year and concerned: plant height, main stem diameter, node number, flag leaf length and leaf ratio, plant dry weight, protein, ADF, NDF ratios, and minerals (P, K, Ca, Mg) contents. In 462 genotypes collected from 53 locations, the data ranged between 46.2 - 71.2 cm for plant height, 1.09 - 6.67 mm for main stem diameter, 2.0 - 5.0 for node number, 5.50 - 35.00 cm / 1.00 - 5.00 mm for flag leaf length/width, 5.41 - 91.03% for leaf ratio, 4.21 - 285.86 g for plant dry weight, 8.64 - 17.95% for protein ratio, 21.34 - 41.14% for ADF, 45.13 - 70.41% for NDF, and 0.32 - 0.52%, 2.65 - 5.34%, 0.02 - 0.69%, 0.06 - 0.33% for P, K, Ca, Mg content respectively. The study highlighted the existence of variability between the populations. The investigated features in this study must be repeated one more year, and then in the light of the two year data, selection will be made to use turfgrass and forage cultivation.

Keywords. *Lolium perenne* L. – Perennial ryegrass – ADF – NDF – Protein.

Evaluation et caractérisation de génotypes de ray-grass anglais (**Lolium perenne*** ***L.) collectés dans la flore naturelle***

Résumé. *Cette étude a été conduite pour caractériser des génotypes de ray-grass anglais (*Lolium perenne. *L.) collectés dans la flore du Yozgat et évaluer leur production, leur qualité et leur adaptation au site. Le matériel végétal a été collecté en 53 lieux différents, chaque lieu comportant plusieurs génotypes. Les graines ont été d'abord semées dans des bacs plastiques en Octobre 2010, puis ils ont été transplantés au champ avec des intervalles de 50x50 cm en mars suivant. Durant la première année, il n'y a pas eu d'observations, mais les plantes ont été coupées régulièrement pour éviter la formation de graines. Les observations ont commencé la deuxième année et la hauteur des plantes, le diamètre de la tige, le nombre de nœuds, la longueur du limbe, la proportion de feuilles, le poids sec, les teneurs en protéines, ADF, NDF et en minéraux (P, K, Ca, Mg) on été mesurés. Parmi les 462 génotypes collectés en 53 lieux, les données ont varié entre 46,2-71,2 cm pour la hauteur, 1,09-6,67 pour le diamètre de la tige, 2,0-5,0 pour le nombre de nœuds, 5,50-35,00 cm / 1,00-5,00 mm pour la longueur/largeur du limbe, 5,41-91,03 % pour la proportion de feuilles, 4,21-285,86 g pour le poids sec, 8,64-17,95% pour la teneur en protéines, 21,34-41,14% pour l'ADF, 45,13-70,41% pour la NDF, et 0,32-0,52, 2,65-5,34, 0,02-0,69, 0,06-0,33% pour les teneurs en P, K, Ca et Mg respectivement. L'étude montre l'existence d'une variabilité entre populations. L'étude doit être répétée une deuxième année pour sélectionner des populations destinées à être cultivées.*

Mots-clés. Lolium perenne *L.* – ray-grass anglais – ADF – NDF – Protéine.

I – Introduction

The aim of the plant breeder is to produce new cultivar, improved in one or more important characteristics, in the most efficient manner possible. New phenotypes created by the plant breeder are a function of changes in genotype associated with selection and the environmental conditions under which the new cultivar will be utilized and which the breeder has replicated to the greatest extent possible (Conaghan and Casler, 2011).

Perennial ryegrass also named English ryegrass (*Lolium perenne* L.) is a cool-season grass sown over a wide area Europe. As a turf grass, it is especially adapted to the mild winter and cool moist summer conditions prevailing in western and north-western Europe. In these conditions, perennial ryegrass offers the most rapid turf establishment among cool-season turf grasses, and it provides the best wear tolerance and the best recovery after wear sequences (Sampaux *et al*., 2012).

The quality of the grass intake affects both animal production and nitrogen (N) utilization (Rearte, 2005). The neutral detergent fibre (NDF) and acid detergent fibre (ADF) are important parameters of herbage quality as they affect dry matter intake and digestibility. Protein is an essential nutrient, but the N mass fraction of temperate pasture grazed at an immature stage is usually exceeding the animal requirements (Hoekstra *et al.*, 2007).

The objectives of this study were to characterize perennial ryegrass (*Lolium perenne* L.) genotypes collected from Yozgat's flora and to evaluate them regarding yield, quality and site adaptation. The usage potentialities of these materials will be set up for improvement of turfgrass and forage agriculture in the region.

II – Material and methods

In this study, perennial ryegrass populations collected from 53 different locations in Yozgat/Türkiye were used as material. The experiment was established in Yozgat-Turkey ecological conditions. The soil at the experimental site taken 30 cm depth is classified as clay-loam with pH: 7.34, low organic matter (1.82%), medium P_2O_5 (24.28 ppm) and high K_2O (807.08 ppm) contents. Annual rainfall, average temperature and moisture are 330 mm, 11.8 °C and 54.8 %, respectively in the experimental site. *Lolium perenne* seeds were collected from 53 different locations, and in total 462 genotypes were studied. Seeds collected from each genotype were sown in viol in October 2010. The seedlings in viol were planted at 50X50 cm in observation plots in March 2011. Before planting, the land was fertilizer with 10 kg N da^{-1} and 10 kg P_2O_5 da^{-1}. N fertilizer was applied both at the establishment year and the second year. The first year, plants were harvested not being allowed to produce seeds. Observations and measurement were taken in second year. Investigated characters were plant height, main stem thickness, number of nodes, flag leaf length and width, leaf ratio, dry weight per plant, crude protein ratio, ADF, NDF, P, K, Ca and Mg. These measurements were applied on the basis of Tosun (1992), Sagsoz *et al.* (1996), Mut (2003), and Tamkoc *et al.* (2009). To determine dry weight per plant, plant samples were dried at 60°C until constant weight. Dry weight was calculated through the values of green forage production and dry-weight percentage. After cooling and weighing, the samples were ground to pass through 1 mm screen for quality analyses. Crude protein (CP), Acid detergent fiber (ADF), Neutral detergent fiber (NDF), Ca, P, Mg and K contents were determined by using Near Reflectance Spectroscopy (NIRS, 'Foss XDS') with software package program 'IC-0904FE'. The measurements taken on each genotype were analyzed using SPSS 10.0 statistical software package program; mean and coefficient of variation were calculated.

III – Results and discussion

Average plant height, main stem diameter and nodes number of the 462 ryegrass plants were measured as 59.20 cm, 2.26 mm and 3.85, respectively. It is also noteworthy to mention that the average of the flag leaf blade length and width of the samples were 14.33 cm and 2.66 mm. Regarding this characters, which is very important for yield and quality, high variation (25.62 and 28.74%, respectively) may give an alternative to select better samples for breeding.

Average dry weight per plant was determined as 72.85 g. The CV for this character, which is an important character for hay yield, was 57.16% (Table 1). The aim of plant breeding is to successfully select for the best genotypes leading to the development of improved cultivars. Genetic variation within population is very high in this study, thus offering significant scope for genetic improvement.

Table 1. Definitions of statistical values and results obtained from the experiment

Features	N	Mean	Minimum	Maximum	CV (%)
Plant height (cm)	462	59.20	46.19	71.17	16.59
Main stem diameter (mm)	462	2.26	1.09	6.67	19.85
Node number	462	3.85	2.00	5.00	16.13
Flag leaf blade length (cm)	462	14.33	5.50	35.00	25.62
Flag leaf blade width (mm)	462	2.66	1.00	5.00	28.74
Dry weight per plant (g)	462	72.85	4.21	285.86	57.16
Leaf ratio (%)	462	43.95	5.41	91.03	31.16
Crude protein (%)	462	15.19	8.64	17.95	13.11
Acid detergent fibre (%)	462	31.16	21.34	41.14	12.03
Nötr detergent fibre (%)	462	60.76	45.13	70.41	8.55
Phosphorus (%)	462	0.42	0.32	0.52	6.71
Potassium (%)	462	4.18	2.65	5.34	8.99
Calcium (%)	462	0.29	0.02	0.69	35.27
Magnesium (%)	462	0.16	0.06	0.33	25.77

The average leaf ratio, crude protein, ADF, NDF, P, K, Ca and Mg figured out 43.95%, 15.19%, 31.16% and 60.76%, 0.42%, 4.18%, 0.29% and 0.16%, respectively (Table 1). These characters are very important for hay quality. Digestibility is the most important selection criterion for improving the nutritional value of grasses (Conaghan and Casler, 2011). The variation for these characters in our study is very high. It is the notion among the breeders that the high level of genetic diversity in a gene pool contributes to variation, demonstrating the significance of selection (Acar *et al.*, 2010).

Previous studies showed the similar variation among the examined characters on perennial ryegrass samples (Elgersma, 1990; Tamkoc *et al.*, 2009; Acar *et al.*, 2010; Hammond *et al.*, 2011; Sampaux *et al.*, 2012; Sun *et al.*, 2012).

IV – Conclusions

The study highlighted the existence of variability between the populations. The investigated features in this study must be repeated one more year, and then in the light of the two year data, selection will be made for turf grass and forage cultivation.

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Changes in forage quality of an upland permanent grassland under climate change including a summer extreme drought combined with a heat wave

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Abstract. An experiment was conducted to predict the response of an upland permanent grassland to future climate change including a summer extreme event. Treatments combined current and future atmospheric CO_2 concentrations (380 and 520 ppm, respectively) with or without an extreme event consisting of a two-week heat wave (+6°C) associated with severe drought during the three summer months, followed by a recovery period in autumn. During the experiment, air temperature was regulated 2°C above the current temperature for all four treatments. Forage quality was measured four times: once in spring the year before the extreme climatic event, twice in spring just before the extreme event, and once in autumn when plants have been rehydrated after the event. Elevated CO_2 resulted in a decrease in plant nitrogen (N) and cell wall contents (NDF), while the extreme event increased N and decreased NDF. Changes in plant chemical composition impacted rumen fermentation as the extreme event consistently increased *in vitro* dry matter digestibility. Extreme climatic events may thus be most likely to modify plant tissue chemistry and improve forage quality than changes in atmospheric CO_2 concentration.

Keywords. Climate change – Grassland – Forage quality – *In vitro* rumen fermentation.

Changements de la qualité fourragère d'une prairie permanente de moyenne montagne sous l'effet du changement climatique incluant une sécheresse estivale extrême combinée à une canicule

Résumé. *Une expérimentation a été conduite pour évaluer la réponse d'une prairie permanente de moyenne montagne au changement climatique avec ou sans évènement extrême. Quatre traitements ont été appliqués : deux niveaux de concentrations de CO_2 atmosphérique (actuelle et future, soit 380 et 520 ppm, respectivement) avec ou sans un évènement extrême estival consistant en une vague de chaleur de deux semaines (+ 6°C) associée à une sécheresse sévère de trois mois, suivie d'une période de récupération en automne. Pour tous les traitements, la température était régulée 2°C au-dessus de la température actuelle. La qualité du fourrage a été mesurée quatre fois : une fois au printemps l'année précédant l'évènement extrême, deux fois au printemps juste avant l'évènement, et une fois en automne après réhydratation des plantes. L'augmentation de la concentration en CO_2 atmosphérique a diminué la teneur en azote et en constituants pariétaux (NDF) des plantes, tandis que l'évènement extrême augmentait la teneur en azote du couvert et diminuait sa teneur en NDF. Ces modifications de composition chimique ont impacté les fermentations ruminales* in vitro *avec une augmentation de la digestibilité de la matière sèche en réponse à l'évènement extrême. Ces résultats suggèrent que les évènements extrêmes pourraient avoir plus d'effet que la concentration de CO_2 atmosphérique sur la valeur des fourrages.*

Mots-clés. *Changement climatique – Prairie – Qualité fourragère – Fermentation ruminale* in vitro.

I – Introduction

There is increasing evidence that climate change due to human activities is expected to result in warmer temperatures, elevated atmospheric CO_2, changes of rainfall patterns, and increased frequency of extreme climatic events (Seneviratne *et al*., 2012). The botanical and ecophysiological changes in plants in response to climate change can affect the chemical composition of forages and their digestive use by domestic herbivores.

The objective of this study was to measure changes in forage chemical composition and *in vitro* rumen fermentation parameters when an upland grassland was exposed to elevated atmospheric CO_2 concentration combined with a summer extreme event in semi-controlled conditions.

II – Materials and methods

In May 2010, monoliths of a permanent grassland were extracted from a site located at Saint Genès-Champanelle in the upland area of central France (45°43'N, 03°01'E, 800 m a.s.l.) and transferred into the Ecotron (Montferrier-sur-Lez, 43°40'N, 03°52'E, 90 m a.s.l., France), a large infrastructure dedicated to the simulation of climatic changes. Twelve macrocosms were allocated to four treatments: current and 2050-atmospheric CO_2 concentrations, 380 and 520 ppm, respectively, combined with an extreme event consisting of a two-week heat wave (+6°C) associated with a severe drought during the three summer months of 2011 (including two weeks of water withheld). After the extreme event, plants were rehydrated to assess their recovery in autumn. In all treatments, air temperature of the macrocosms was regulated 2°C above the current temperature of the upland site.

Samples were collected four times to assess the forage quality: once in May 2010, just before monoliths entered into the macrocosms, in April 2011 and June 2011 just before the extreme event, and once in November 2011 when plants have been rehydrated after the event. Representative samples of plants were taken in each macrocosm, and subsamples were either oven-dried at 60°C for 72h or freeze dried. Nitrogen (N), Neutral Detergent Fiber (NDF), total water-soluble carbohydrates (WSC), as well as glucose, sucrose, fructose and fructans of forage were analysed. To assess the digestive use of forage by ruminants, an *in vitro* rumen fermentation assay was carried out. Freeze-dried plants were ground to pass through a 1 mm sieve and incubated in anaerobic conditions at 39°C during 24h in culture bottles containing 40 mL of buffered rumen juice from sheep (Niderkorn *et al*., 2011). At the end of the incubation period, acidification (dpH), total gas production and composition including methane (CH_4), *in vitro* dry matter digestibility (IVDMD) and concentration of volatile fatty acids (VFA) were measured. Values were adjusted by subtracting at each collection point the values from blanks without plant substrate.

Data were submitted to analysis of variance using the mixed procedure of the SAS software package (version 9, SAS Institute Inc., Cary, NC, USA) with CO_2, extreme event and sampling date as fixed effects, and the macrocosm considered as random effect. Data from the first sampling date in May 2010 were used as a covariate, and the first order autoregressive covariate structure was used for the repeated term. All non-significant interactions were removed from the model.

III – Results and discussion

Increasing atmospheric CO_2 concentration decreased forage N content by 13% ($P<0.001$) and its NDF content by 3% ($P<0.05$) (Tables 1 and 2). The change in availability of N under elevated CO_2 has been well documented (Reich *et al.*, 2006; Wang *et al*., 2012). The reduction of plant cell wall content was consistent with results obtained by Picon-Cochard *et al.* (2004) when an upland community was subjected to an atmospheric CO_2 enrichment owing to the Mini-FACE system. However, the amplitude of CO_2 effect on NDF content remained generally small (Dumont *et al.*, 2014). This could explain that no impact of elevated CO_2 was observed on the extent of *in vitro* rumen fermentation, excepted for acidification which increased (P<0.05), likely due to a lower ammonia production in response to the lower N content (Tables 3 and 4). Contrary to expectation, we did not observe any increase in WSC content induced by elevated CO_2 (Wang *et al.*, 2012). However, air warming may reduce carbohydrate content, thus counterbalancing positive effect of elevated CO_2 on WSC (Casella and Soussana, 1997). In addition, WSC may be subjected to particularly high variability due to time of harvest, speed of sample conditioning, and analytical methods in the different studies (Dumont *et al.*, 2014).

Table 1. Chemical composition (g/kg dry matter) of forage community subjected to two CO_2 concentrations (380 and 520 ppm) with or without extreme event

	Sampling 2 (April)		Sampling 3 (June)		Sampling 4 (November)				SEM
					Control		Extreme		
CO_2 (ppm)	380	520	380	520	380	520	380	520	
N	23.1	20.5	18.2	16.6	17.7	14.4	27.6	21.6	0.83
NDF	515	514	586	569	550	546	533	490	11.7
WSC	263	236	187	192	147	194	166	195	21.3
Glucose	19.8	17.4	20.3	16.9	10.1	7.7	11.1	10.7	1.76
Sucrose	39.7	40.1	29.4	30.5	17.7	20.1	24.0	27.4	3.34
Fructose	21.7	18.5	20.6	17.9	12.8	12.6	15.4	16.6	1.91
Fructans	182	160	117	127	105	155	117	139	17.9

N: nitrogen, NDF: neutral detergent fiber, WSC: water-soluble carbohydrates, SEM: standard error of the mean.

Table 2. Effect of fixed effects on chemical composition parameters of forage community subjected to two CO_2 concentrations (380 and 520 ppm) with or without extreme event

Effect	CO_2 effect	Ext effect	Sampling effect	CO_2 × ext effect	CO_2 × sampling effect	Ext × sampling effect	CO_2 × ext × sampling effect
N	*** (380>520)	*** (E>C)	*** (2,4>3)	NS	NS	***	NS
NDF	* (380>520)	* (C>E)	*** (3>2,4)	NS	NS	NS	NS
WSC	NS	NS	*** (2>3,4)	NS	NS	NS	NS
Glucose	* (380>520)	NS	*** (2,3>4)	NS	NS	NS	NS
Sucrose	NS	NS	*** (2>3>4)	NS	NS	NS	NS
Fructose	NS	NS	*** (2,3>4)	NS	NS	NS	NS
Fructans	NS	NS	*** (2>3,4)	NS	NS	NS	NS

N: nitrogen, NDF: neutral detergent fiber, WSC: water-soluble carbohydrates, E or ext: extreme, C: control.
* P<0.05, ** P<0.01, *** P<0.001, NS : non significant.

The application of the extreme event in summer resulted in an increase in forage N content by 35% (P<0.001) and a decrease in NDF content by 7% (P<0.05) for sampling date 4 (Tables 1 and 2). Consistently, it led to an increase in IVDMD by 8% (P<0.05) (Tables 3 and 4) as plants contained more digestible tissues. In terms of herbivore nutrition, more digestible plants have a better energetic value.

Table 3. **_In vitro_ rumen fermentation parameters of forage community subjected to two CO_2 concentrations (380 and 520 ppm) with or without extreme event**

	Sampling 2 (April)		Sampling 3 (June)		Sampling 4 (November)				SEM
					Control		Extreme		
CO_2 (ppm)	380	520	380	520	380	520	380	520	
N	23.1	20.5	18.2	16.6	17.7	14.4	27.6	21.6	0.83
NAcidification (dpH)	0.91	0.95	0.83	0.84	0.70	0.77	0.66	0.72	0.023
IVDMD (%)	60.3	58.3	52.7	51.5	51.7	51.5	54.0	57.9	1.07
Total VFA (mmol/g DM)	122	126	114	113	108	111	110	116	3.0
C2:C3 (mol/mol)	2.70	2.79	2.82	2.89	2.96	2.91	2.83	2.76	0.052
Total gas (mmol/g DM)	7.12	7.10	6.48	6.37	6.11	6.06	6.29	6.47	0.159
CH_4	1.26	1.25	1.12	1.10	1.08	1.06	1.14	1.12	0.030
CO_2	5.87	5.82	5.32	5.27	5.04	5.02	5.16	5.35	0.120
$CO_{2:}CH_4$ (mol/mol)	4.66	4.67	4.79	4.82	4.69	4.74	4.54	4.80	0.083

IVDMD: *in vitro* dry matter digestibility, VFA: volatile fatty acids, C2: acetate, C3: propionate.

Table 4. **Effect of fixed effects on _in vitro_ rumen fermentation parameters of forage community subjected to two CO_2 concentrations (380 and 520 ppm) with or without extreme event**

Effect	CO_2 effect	Ext effect	Sampling effect	CO_2 × ext effect	CO_2 × sampling effect	Ext × sampling effect	CO_2 × ext × sampling effect
Acidification	* (520>380)	NS	*** (2>3>4)	NS	NS	NS	NS
IVDMD	NS	* (E>C)	*** (2>3,4)	NS	*	*	NS
Total VFA	NS	NS	*** (2>3,4)	NS	NS	NS	NS
C2:C3	NS	NS	** (4,3>2)	NS	NS	**	NS
Total gas	NS	NS	** (2>3,4)	NS	NS	NS	NS
CH_4	NS	NS	*** (2>3,4)	NS	NS	NS	NS
CO_2	NS	NS	*** (2>3,4)	NS	NS	NS	NS
$CO_{2:}CH_4$	NS	NS	NS	NS	NS	NS	NS

IVDMD: *in vitro* dry matter digestibility, VFA: volatile fatty acids, C2: acetate, C3: propionate, E or ext: extreme, C: control. *: P<0.05, **: P<0.01, ***: P<0.001, NS: non-significant.

Strong effects of sampling date were detected on all parameters of both chemical composition and *in vitro* rumen fermentation, except for the CO_2:CH_4 ratio in fermentation gas. Overall, forages harvested in April were richer in rapidly fermentable substrates than forages harvested in June and November, which can be explained by changes in plant phenological stage.

IV – Conclusions

Our results suggest that forage quality of an upland grassland may be impacted by future climate change in different ways. While elevated CO_2 combined with warming decreased both N and fiber contents in plants without leading to an effect on forage digestibility, extreme summer drought increased plant content in digestible tissues after their recovery. Extreme climatic events may thus be most likely to modify plant tissue chemistry and improve forage quality than changes in atmospheric CO_2 concentration.

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Effect of grass height and species on nutritive value of winter stockpiled forage

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Abstract. The necessity of reconciling control of production costs, improvement of food autonomy and work efficiency on livestock farms generates new questions today. An answer to this issue seems to be a better valuation of grass by increasing the share of grazing in the ration. The implementation of this practice requires the knowledge of grassland evolution along winter in terms of quality and quantity. To answer this issue, two forage collections have been established in two sites with different soil and climatic conditions in France. Two levels of stockpiling were studied on five grass covers (*Lolium perenne, Dactylis glomerata, Festuca rubra, F. arundinacea,* permanent grassland). Biomass and nutritional values were studied over winters of 2010/2011 and 2011/2012. An effect of grass species and height at the beginning of winter can be observed on dry-matter yield and pepsin-cellulase dry-matter digestibility. *L. perenne* and *F. rubra* maintain good nutritional values along winter but the accumulation is limited as compared to *D. glomerata*. A good compromise is obtained with *F. arundinacea*. Stockpiling with a younger grass allows to maintain correct nutritional values at the end of winter.

Keywords. Grassland – Winter – Nutritional values – Stockpiling.

Effets de la hauteur et de l'espèce végétale sur la valeur nutritive de l'herbe en hiver

Résumé. *La nécessité de concilier maîtrise des coûts de production, amélioration de l'autonomie alimentaire et efficacité du travail sur des exploitations d'élevage génère aujourd'hui de nouveaux questionnements. Une réponse à cette problématique semble être une meilleure valorisation de l'herbe en augmentant la part du pâturage dans la ration. La mise en œuvre de cette pratique et son insertion dans un système de production nécessite de connaitre l'évolution de la prairie au cours de l'hiver, en valeur et en quantité. Pour y répondre, deux collections fourragères ont été mises en place dans des contextes climatiques différents en France. Deux niveaux de stock d'herbe en début d'hiver ont été étudiés sur cinq types de couverts végétaux (ray grass, dactyle, fétuque élevée, fétuque rouge, prairie permanente). L'évolution de la biomasse et des valeurs nutritives a été étudiée sur deux hivers : 2010/2011 et 2011/2012. Des effets « espèce » et « hauteur » ont pu être observés sur la digestibilité à la pepsine cellulase.* Lolium perenne *et* Festuca rubra *maintiennent de bonnes valeurs nutritives tout au long des hivers mais l'accumulation de biomasse reste limitée contrairement au dactyle.* Festuca arundinacea *semble être une espèce qui offre un bon compromis entre valeur nutritive et accumulation. Des stocks sur pied avec une herbe plus jeune ont permis de garder des valeurs nutritives correctes à la fin de l'hiver.*

Mots-clés. *Prairie – Hiver – Valeurs nutritives – Stock sur pied.*

I – Introduction

The increase of suckling cow herd size, the necessity of reducing the feeding costs, and the improvement of the work efficiency raise the problem of practices simplification. Many studies focus on outdoor wintering either with daily hay or silage feeding (Pottier *et al.*, 2001) or with an extended grazing season (D'Hour *et al.*, 2000). Can stockpiled forage grass be an alternative to animals during the winter season that could extend the grazing season? And can this technique decrease the area of harvested surfaces and quantities resulting in winter work simplification? This practice is not yet common in France but it has been used in North America for several years during winter and summer (Taylor and Templeton, 1976; Baron *et al*., 2005). An experiment on stockpiled forage grass utilization by grazing animals carried out at Laqueuille, France (1000 m a.s.l.) over two winters (Note *et al*., 2010) showed a mitigated fodder balance depending on climatic conditions. In order to optimize this practice, questions regarding the evolution of green grass quality and quantity (which are dependent on botanical composition of the grassland and climatic conditions) in winter season need to be answered. At the beginning of winter grazing, what grass height would enable a better utilization and enhancement of the grass? In summary, the goal is to study the behaviour of different grass species during winter in terms of quantity and quality according to the level of stockpiled forage.

II – Materials and methods

The study was carried out on two sites with different soil and climatic conditions in France: (i) Mourier (45°39'N, 01°17'E, 360 m a.s.l. – continental with oceanic influence – mean temperature 4.4°C and mean rainfall of 245 mm during the two studied winters from November to March, with 12 days of snow in February 2012); and (ii) Laqueuille (45°38'N, 02°44'E, 1000 m a.s.l. – mountain conditions – mean temperature 1,9°C and mean rainfall 339 mm – 35 days of snow between November 2010 and January 2011, 8 and 33 days of snow in December 2011, and between February and March 2012 respectively).

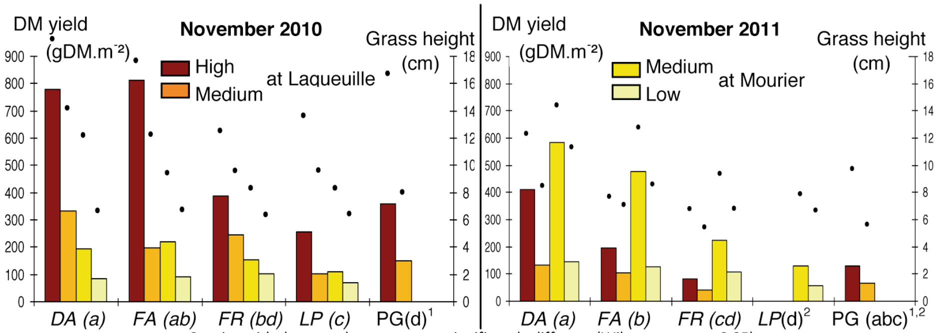
Two forage collections with the same design were implanted in May 2008 at Laqueuille and in October 2009 at Mourier. On three blocks (repetitions), we studied two factors with a randomized design: grass species and grass heights obtained in winter. Four commercial grassland species monocultures were studied on 9 m² plots: *Lolium perenne (LP), Dactylis glomerata (DA), Festuca rubra (FR)*, and *F. arundinacea (FA).* The Laqueuille site comprised a supplemental variant known as the local permanent grassland. At the beginning of both winters 2010/2011 and 2011/2012, two levels of stockpiled forage were constituted at each site: high (H) and medium (M) grass height at Laqueuille and medium (M) and low (L) grass height at Mourier. Stockpile initiation dates were: at Laqueuille, June 22 and July 29, 2010 and June 28 and August 2, 2011; at Mourier, July 16 and Septemer 20, 2010 and May 25 and September 14, 2011. Both experiments received a non-limiting N-P-K fertilisation.

The fresh harvested biomass was collected once a month from September/October to March then dried at 60°C for 72 h and weighed to calculate the DM yield of each plot (g DM m^{-2}) at each date. 744 samples were collected for DM yield at all cutting dates. These samples were ground using a 1 mm screen-mill. Each sample was analysed using near-infrared reflectance spectroscopy (NIRS) to determine its nutritive value. The calibration set was analysed, among other things, for pepsin-cellulase DM digestibility (Aufrère and Demarquilly, 1989). The statistical parameters of the calibration models obtained for pepsin-cellulase DM digestibility of the grass were: number of samples, 269; ranges, 20.7-90.4%; standard errors of cross-validation, 2.52%. The R^2 of cross-validation was 0.98.

A Shapiro-Wilk test was performed on residuals of studied model using R software. It showed that our data were not normally distributed. As a consequence, two non-parametric tests using R software were performed: a Wilcoxon test for linked data within each site (same date, block, site, specie or height modality) and a Mann-Whitney test in order to compare data between sites.

III – Results and discussion

On both winters, we observed a gradient of grass height and accumulation between sites which is coherent with our objectives (Fig. 1). In winter 2011/2012, the levels of biomass accumulation were clearly less important on Laqueuille because of a proliferation of voles which reduced by half the stock compared with winter 2010/2011. With the same stockpile initiation dates, we noticed that grass species showed different capacity of accumulation: *Dactylis glomerata* and *Festuca arundinacea* presented a stock approximately twice as large as other covers.



Species with the same letter are not significantly different (Wilcoxon test, p<0.05)

[1] PG is just compared with other cover at Laqueuille

[2] On winter 2011/2012, *LP* is just compared with other cover at Mourier because of its disappearance at Laqueuille this winter

Fig. 1. Grass availability at the beginning of two winters in November at Laqueuille and Mourier (histogramm = DM yield, point = grass height).

The percentage of biomass disappearance during winter due to natural plant mortality (no grazing on forage collection) was calculated (Table 1). This variable was not studied on the second winter because of rodent impact. Depending on sites, we noticed a different relation between the modalities of grass height. At Mourier, low modality presented a low rate of disappearance and even a growth for *Festuca rubra* ($p<0.05$), whereas at Laqueuille, high modality seemed to be more "conservative" ($p<0.01$). Climate seemed to play an important role: under more frigid climate (e.g. Laqueuille), unlike short grass, important biomass would tend to protect grass from degradation. But under more moderated climates (Mourier), the grass age seemed to be the main factor of degradation. At Laqueuille, *Lolium perenne* distinguished itself from *Festuca rubra* and *Dactylis glomerata* ($p<0,05$). At Mourier, *Festuca rubra* distinguished itself from other species ($p<0.05$) but not from *Lolium perenne*.

Table 1. Average percentage of biomass disappearance on winter 2010/2011 on two sites (= [November biomass – February biomass]*100 / November biomass)

Site	Grass height	*DA*	*FA*	*FR*	*LP*	PG
Laqueuille	High	58.7	62.4	54.4	73.6	46.6
	Medium	65.7	75.1	80.1	100.0	97.3
Mourier	Medium	56.1	69.9	-38.8	27.9	–
	Low	37.2	4.2	-27.7	22.5	–

The lowest grass heights presented the highest pepsin-cellulase DM digestibility along winter: on average +9% at Laqueuille and +14% at Mourier (Wilcoxon test with same cut date, species and block: $p<0.01$). The same relation was found in November (the beginning of winter) and February (the end of winter) (Tables 2 and 3). Between November and February, digestibility decreased as expected (Tables 2 and 3) by 10% on average, but the evolution of digestibility was not statistically significant depending on height modalities. Between sites during both winters (Mann-Whitney test, $p<0.01$), the low height at Mourier presented the highest digestibility (mean: 67%) as compared to the medium height at Mourier, which showed 53% against 46% for the medium height at Laqueuille.

Along the winter on both sites, the species could be ranked as follows according to digestibility (Wilcoxon test with same cut date, height modality and block: $p <0.05$): *Lolium perenne* > *Festuca rubra* > *Festuca arundinacea* > permanent grassland> *Dactylis glomerata*. But at the end of winter, *Lolium perenne* and *Festuca rubra* didn't show any difference and the permanent grassland was not different from *Dactylis glomerata* and *Festuca arundinacea* (Table 2).

Table 2. Means of pepsin-cellulase dry-matter digestibility for five grass covers at Laqueuille and at Mourier at the beginning (November), middle (January) and end (February/March) of each winter

Grass height	High						Medium						
Species	*DA*	*FA*	*FR*	*LP*	PG	Means	*DA*	*FA*	*FR*	*LP*	PG	Means	Means
Laqueuille (2010/2011)													
Nov.	31.5	46.6	44.0	38.0	37.1	**39.5**	44.3	57.9	56.0	57.4	48.1	**52.7**	**46.1**
Jan.	24.6	29.3	32.8	27.8	26.4	**28.2**	33.6	34.0	39.5	37.8	30.9	**35.2**	**31.7**
Feb.	23.3	29.3	35.6	28.3	25.4	**28.4**	26.9	34.0	37.7	–	24.2	**32.0**	**29.8**
(2011/2012)													
Nov.	35.2	46.0	58.6	68.7	47.5	**49.9**	49.6	57.6	61.3	69.3	44.0	**56.3**	**53.3**
Jan.	25.6	32.5	47.5	59.8	34.7	**38.6**	35.1	41.8	50.7	57.4	47.6	**45.6**	**42.0**
Mar.†	24.8	40.3	51.6	–	32.4	**36.0**	40.7	44.9	52.6	59.7	41.0	**46.3**	**41.4**
Means	**27.5**	**37.3**	**44.6**	**41.5**	**33.9**	**36.6**	**38.4**	**45.0**	**49.6**	**55.6**	**40.7**	**45.4**	**40.9**
Mourier (2010/2011)													
Nov.	55.5	45.9	58.7	60.0	–	**55.0**	58.9	66.2	61.6	71.8	–	**64.7**	**59.8**
Jan.	49.5	44.1	65.1	69.0	–	**56.9**	61.7	63.2	69.2	73.5	–	**66.9**	**61.9**
Feb.	45.7	45.0	65.5	70.4	–	**56.7**	54.8	66.1	69.1	74.2	–	**65.3**	**60.8**
(2011/2012)													
Nov.	46.0	54.7	61.9	62.3	–	**56.2**	76.5	74.8	69.6	76.7	–	**74.4**	**65.3**
Jan.	30.0	36.0	54.4	66.7	–	**46.8**	62.7	59.8	65.0	68.6	–	**64.0**	**55.4**
Feb.	26.3	29.9	49.1	–	–	**35.1**	53.8	57.2	60.8	74.1	–	**59.0**	**47.7**
Means	**42.2**	**42.6**	**59.1**	**65.7**	–	**51.8**	**61.4**	**64.5**	**65.9**	**73.0**	–	**65.9**	**58.9**

† No measures in February 2012 at Laqueuille because of snow cover for the whole period.

IV – Conclusions

Stockpiling a younger grass allows to maintain correct nutritional values at the end of winter. It is thus necessary to have a low stocking rate (around 10 cm of grass height at the beginning of winter, but it depends on species) on large area to offer cattle or sheep a good grass quality over the winter period. Some species as *Festuca arundinacea* or *Festuca rubra* seem to be a good compromise between nutritional values and biomass accumulation.

Acknowledgments

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Setaria pumila (Poir.) Roem. e Schult affects grassland botanical composition and forage nutritive value

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Abstract. Meadows and pastures are increasingly threatened by invasive grasses (especially *Setaria pumila* (Poir.) Roem. e Schult) as a consequence of human actions and climate change. In the surveys performed by Agridea (PRAMIG project) in Canton Ticino (CH) an anomalous production peak was observed on lowland pastures during summer. In 2012 a study was carried out to better understand the phenomenon. We measured: (i) biomass; (ii) botanical composition; and (iii) chemical composition. To test the hypothesis that *S. pumila* development during summer is related to specific climate conditions, meteorological data (temperature, precipitation) were collected. We assessed the relative effect of climatic variables and of *S. pumila* competition by Generalized Linear Mixed Model (GLMM). We found that *S. pumila* abundance is inversely correlated with rainfall and with the presence of other species, and it is positively correlated with temperature increase. The summer peak of the seasonal growth curve could be attributed to *S. pumila*, when other species are less competitive because of drought conditions. Beside the high *S. pumila* biomass production a reduction of forage quality was observed.

Keywords. *Setaria pumila* (Poir.) – Generalized Linear Mixed Model – Meadows – Forage quality – Drought.

Setaria sp. ***affecte la composition botanique des prairies et la valeur nutritive du fourrage***

Résumé. *Les prairies et les pâturages sont de plus en plus menacés par des espèces envahissantes (surtout* Setaria pumila *(Poir.) Roem. e Schult) comme une conséquence des actions humaines et des changements climatiques. Dans les relevés réalisés par Agridea (projet PRAMIG) dans le canton du Tessin (Suisse), un pic de production anormal a été observé en été sur les pâturages de plaine. En 2012, une étude a été réalisée pour comprendre ce phénomène. On a mesuré: (i) la biomasse; (ii) la composition botanique; (iii) la composition chimique des prairies. Pour tester l'hypothèse que* S. pumila *se développe pendant l'été en lien avec les conditions climatiques, des données de température et de précipitations ont été collectées. On a évalué l'effet des variables climatiques sur la présence de* S. pumila *avec un Modèle Mixte Linéaire Généralisé (MMLG). On a constaté que* S. pumila *est inversement corrélée à la pluviométrie et à la présence d'autres espèces, mais qu'elle est positivement corrélée avec l'augmentation de la température. Le pic d'été de la courbe de croissance est attribué à* S. pumila*, quand d'autres espèces sont moins compétitives en raison de la sécheresse. La grande production de biomasse de* S. pumila *était en revanche accompagnée d'une réduction de la qualité de fourrage.*

Mots-clés. *Setaria pumila* (Poir.) – Generalized Linear Mixed Model – Prairies – Qualité de fourrage – Sécheresse.

I – Introduction

In the last decades grassland are increasingly threatened by C4 summer-grass weeds as a consequence of human action and climate change (Tozer *et al*. 2008). In the Southern side of the Alps a rapid increase of *Setaria pumila* (Poir.) Roem. e Schult. was observed in terms of presence and biomass.

The interest of ecologists and experts in the biological invasion of these herbaceous species has recently incremented with the aim of gaining further insight on patterns of invasion and mechanisms driving them along the elevation gradient (Alexander *et al*. 2011). In the summer period, characterized by increasing temperature, high light intensity, and drought, the more efficient carbon fixation by C4 plants would provide competitive advantages over the less efficient C3 ones, with consequences on botanical composition and probably also on forage nutrient value. For an adequate conservation of natural forage resources, so important for pastoral activities in the plain and at the bottom of valleys, it is necessary to implement the knowledge about the phenomenon of invasion of meadows and pastures by summer grass weeds.

II – Materials and methods

The study was conducted between May 2012 and December 2012 in Canton Ticino (Italian Switzerland), on the Southern side of Alps, at two different sites: Cadenazzo (203 m a.s.l.), in the plain of Ticino river, and Semione (370 m a.s.l.), at the bottom of the Blenio Valley.

In summer and autumn 2012, surveys were carried out, to assess the biomass and the forage production, with a modified Corral Fenlon method (Corral and Fenlon, 1978) revised as regard the number of plots (two instead of four) and as regard the time interval between two cuts (14 days instead of one week), in three different parcels: two located in Cadenazzo (hereinafter referred to as Cad. meteo and Cad. stallone) and one in Semione. At each site the experimental design consisted in two plots of 6.6 m^2 (6 m X 1.10 m) mowed alternatively every 14 days, from mid-April until mid-October. Beside biomass forage production, the botanical composition was also identified in the plot before each mowing, according to linear point quadrat method (Daget and Poissonet, 1969) along a transect of 6 m, 25 intercept were collected. Moreover 53 mown grass samples were collected to verify the nutrient variation along growing season analysing the grassland nutritive value, expressed in NEL (Net Energy for Lactation) with a NIRs instrument.

To test the hypothesis that *S. pumila* development during summer is related to specific climate conditions, meteorological data (temperature, precipitation, and evapotranspiration) were collected at the end of the 2012 from two stations nearby the study sites, one located in Cadenazzo and one in Malvaglia, near Semione.

With the aim of quantifying the amount of *S. pumila*. in terms of production, the total biomass was divided into *S. pumila* and other species, considering *S. pumila* specific contribution (CS%), calculated for each botanical survey, multiplied to the biomass measured in the plot. To analyse the effects of climate and the presence of the other species on the abundance of *S. pumila* in terms of biomass, we chose a Generalized Linear Mixed Model (GLMM) with temperature, precipitation and other species biomass as independent variables. Thermal time (Tt, °C*day), Total precipitations (TP, mm*day) and Evapotranspiration (ET, mm*day) were calculated for each time interval between two cuts, from the beginning of the growing season. Evapotranspiration was excluded from the analysis because of its correlation to thermal time. In the model a gamma distribution was specified for the continuous dependent variable *S. pumila* abundance, as normality assumption was not met (normality tested with Kolmogorov-Smirnoff test).

GLMM was preferred to GLM to check, in addition, for non-independence of each survey value given by the location of the plot (the site), considered in the model as normally distributed random factor. Analyses were performed with R software, version 2.15.3 (R Foundation for Statistical Computing, 2013) with the "glmmADMB" package (SVN revision 231).

III – Results and discussion

Examining data on forage production during the growing season an anomalous production peak was observed in summer 2012, especially in Cadenazzo (Fig. 1), when the growth should be lower than in spring.

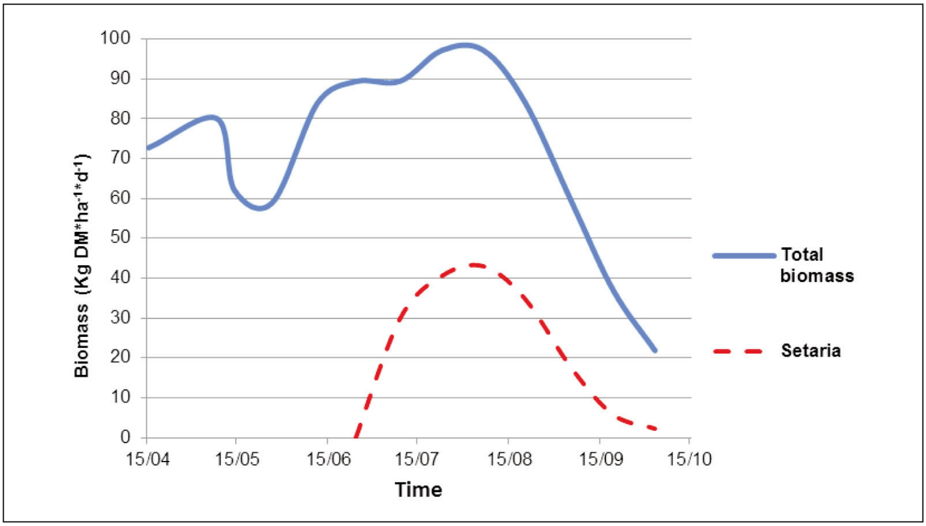

Fig. 1. Total biomass and *Setaria*'s growth curve in the parcel Cad. meteo in summer 2012.

In the study sites the abundance of *S. pumila* was thoroughly quantified by botanical surveys. They show the evolution of the botanical composition in the plots during the growing season. The maximum presence of *S. pumila*, expressed in percentage on total botanical composition (46% in Cad. meteo, 44% in Cad. stallone, 24% in Semione), occurred in all plots at the beginning of August, in correspondence of the summer production peak of the seasonal growth curve (97 kg DM*ha^{-1}*d^{-1} for Cad. meteo, 103 kg DM*ha^{-1}*d^{-1} for Cad. stallone, 71 kg DM*ha^{-1}*d^{-1} for Semione).

Table 1. GLMM summary with *S. pumila* abundance related to other species biomass, thermal time and total precipitation

GLMM parameters	Estimate	*p* value	Std. error	Signif.†
Intercept	5.201	< 2^{e-16}	0.136	***
Biomass (kg DM)	-0.802	4.0^{e-05}	0.195	***
Thermal time (°C*day)	2.060	5.9^{e-16}	0.255	***
Total precipitations (mm*day)	-0.592	0.0014	0.185	**

† *** P<0.001, **P<0.01, *P<0.05, .P<0.1.

The GLMM results showed that the abundance of *S. pumila* was inversely correlated with rainfall and with the presence of other species, but it was positively correlated with temperature increase. Beside the high *S. pumila* biomass production, a reduction in forage quality was observed. In fact, in correspondence of the maximum quantity of C4 plants the net energy for lactation (NEL, MJ/kg DM) decreased considerably (Fig. 2).

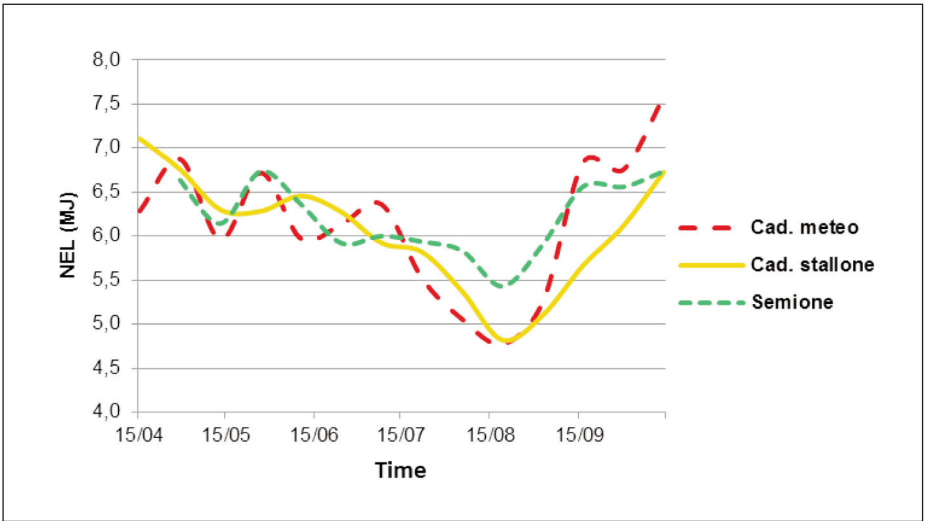

Fig. 2. Grass energy content (NEL – Net Energy for Lactation) during the growing season.

IV – Conclusions

Results show a correspondence between *S. pumila* presence and the summer production peak of the seasonal growth curve. This species is probably more competitive because of climate conditions than other species with regard to drought and to high temperatures, thanks to its C4 carbon fixation cycle. Thus, during *S. pumila* increase we could observe an increase of the sward biomass, which, however, corresponded to a strong reduction of the nutritive value.

The result of this research raises the concern about upward spread of invasive plants, consequence of climate warming and human pressure in mountain systems. Monitoring existing population is important but preventing the introduction of pre-adapted species is a more urgent goal. Special attention should be given to herbaceous species (as *Setaria* sp.) which can flower over a short time period and later in the season (Barni *et al*. 2012). The results allow the adaptation of the grassland management to limit *Setaria* sp. development in meadows and pastures, to enhance competition of desirable pastures species (Tozer *et al*. 2008).

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Impact of maturation on extractable polyphenols in leguminous fodder species

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Abstract. Legume trees and shrubs are valuable feed sources for small ruminants although their antiquality factors. The aim of the present study was to investigate differences in total phenols (TPH), total tannins (TT) and condensed tannins (CT) content in leaves and stems of three legume ligneous species (*Amorpha fruticosa, Robinia pseudoacacia* and *Colutea arborescens*) at two different stages of maturity: (i) during the season of rapid growth (May) when the leaves were young, and (ii) in September (mature) when growth had ceased and the woody parts had been hardened. Samples were analysed for their TPH, TT and CT content. According to the results, *R. pseudoacacia* had significantly higher content of TPH, TT, CT in leaves in May, compared to the other two species. Inversely, *A. fruticosa* had significantly higher TPH and TT content in the stems, while *C. arborescens* had the lowest one in both leaves and stems for the same period. In September, there was no significant difference in the content of TPH and TT in the leaves among species, except for *C. arborescens* which had significantly lower concentration. From the tested species, *C. arborescens* had the lowest content of all extractable polyphenols, without significant differences to leaves and stems in May and September respectively.

Keywords. Condensed tannins – Phenological stage – Leaves – Phenols – Forage quality.

Impact de la maturité sur les polyphénols extractibles chez les espèces de légumineuses arborescentes

Résumé*. Les légumineuses arborescentes ou arbustives sont une source d'alimentation précieuse pour les petits ruminants, malgré certains facteurs antinutritionnels. Le but de cette étude était d'étudier les différences de concentrations en phénols totaux (TPH), tanins totaux (TT) et tanins condensés (CT) dans les feuilles et les tiges de trois espèces ligneuses de légumineuses à différents stades de maturité:* Amorpha fruticosa, Robinia pseudoacacia *et* Colutea arborescens*. Trois plantes de chaque espèce ont été sélectionnées au hasard à deux périodes distinctes (stades de maturité) : jeunes feuilles pendant la saison de croissance rapide (Mai) et début Septembre (maturité) alors que la croissance avait cessé et les parties ligneuses avaient durci. Les échantillons ont été analysés pour leurs teneurs en TPH, TT et CT. Selon les résultats,* R. pseudoacacia *avait des teneurs significativement plus élevées en TPH, TT, TC dans les feuilles en Mai, par rapport aux deux autres espèces. Inversement,* A. fruticosa *avait des teneurs nettement plus élevées de TPH et TT dans les tiges, tandis que* C. arborescens *avait la teneur la plus faible à la fois dans les feuilles et les tiges à cette même période. En Septembre, il n'y avait pas de différence significative des teneurs en TPH et TT dans des feuilles de* R. pseudoacacia *et* A. fruticosa*, à la différence de* C. arborescens *qui avait des concentrations significativement plus faibles. Des espèces testées,* C. arborescens *avait les teneurs les plus faibles en polyphénols extractibles, en Mai comme en Septembre et quel que soit la partie de la plante.*

Mots-clés. *Tanins condensés – Stade phénologique – Feuilles – Phénols – Qualité du fourrage.*

I – Introduction

Browse species can provide green forage for grazing animals throughout the year (evergreen species) or during critical periods (deciduous ones) (Kokten *et al.,* 2012). Despite their potential use as feed resources for ruminants and wild animals, most ligneous species contain anti-nutritive components such as phenolic compounds and especially tannins (Sallam *et al.,* 2010). Due to their nature and depending on their concentration, tannins have differential effects (Rana *et al.*, 2006) on animals ranging from beneficial to toxicity and even death (Makkar, 2003a).

Leaves contain more than 40% of the total nitrogen contained in a woody species (Kramer and Kozlowski, 1979) and their nutritive value is higher than the stems (Cordesse *et al.*, 1991). However, the intake of leaves from ligneous species by herbivores is often restricted by defending or deterring mechanisms related to high tannin content (Provenza, 1995). Maturity stage, leaf age and season (Rogler and Sell, 1984; Schultz *et al.,* 1982), are some of the factors affecting the concentration of tannins.

The objective of this research was to investigate the impact of maturity stage in the concentration of phenols, tannins, and condensed tannins separately in leaves and stems of three ligneous species.

II – Materials and methods

The experiment was carried out at the Aristotle University's farm (40° 34' E, 23° 43' N, at sea level) in northern Greece. The climate of the area could be characterized as Mediterranean semi-arid with cold winters. The mean annual temperature and precipitation are 15.5 °C and 443 mm, respectively.

Three broadleaved deciduous leguminous fodder species *Robinia pseudoacacia* var. monophylla (L.), *Amorpha fruticosa* L. and *Colutea arborescens* L. were investigated. For each species, samples were hand-plucked (i.e., leaves and twigs with diameter <3mm) from three individual plants at two discrete periods and stages of maturity: (i) during the season of rapid growth (immature: May, IM) when the leaves were young, and (ii) in September (mature: September, M) when growth had ceased and the woody parts had been hardened.

Upon collection, each plant was divided into leaves and stems and oven-dried at 50 °C for 48 h. All the samples were ground through a 1 mm sieve and were analysed for total phenols (TPH), total tannins (TT) and condensed tannins (CT) in three replicates according to Makkar (2003b). Total phenols (TPH) and total tannins (TT) in the extract were determined by a modification of the Folin-Ciocalteu method using polyvinylpolypyrrolidone (PVPP) to separate tannin phenols from non-tannin phenols. Both TPH and TT were expressed as tannic acid equivalent (mg/g TAE) (Makkar *et al*., 1993). Condensed tannins (CT) were determined according to the method of Porter *et al*. (1986), using purified quebracho CT as the reference standard and therefore expressed as quebracho equivalent.

Two-way ANOVA of the data was performed using SPSS® statistical software v. 18.0 (SPSS Inc., Chicago, IL, USA), in order to determine differences among the three species in the two stage of maturity in leaves and stems separately. The LSD at the 0.05 probability level was used to detect the differences among means (Steel and Torrie, 1980).

III – Results and discussion

In immature stage, *R. pseudoacacia* had higher concentration of TPH, TT and CT in the leaves compared to that of the other species, followed by *A. fruticosa*. *C. arborescens* had the lowest concentration in all measured components. In mature stage, *R. pseudoacacia* had higher CT concentration than the other species, while *R. pseudoacacia* and *A. fruticosa* had significant higher TPH and TT concentration in the leaves than *C. arborescens*. There was a significant interaction between season x species for TPH TT and CT (Table 1). The TPH and TT concentration in leaves of *R. pseudoacacia* was significantly higher in immature stage than in mature, while stage of maturity did affect the concentration of other two species. Moreover, maturity significantly reduced the CT concentration in leaves of *R. pseudoacacia* and *A. fruticosa,* but did not affected *C. arborescens*.

Table 1. TPH (mg/g DM TAE), TT (mg/g DM TAE), CT (mg/g DM QE) concentration of leaves from leguminous browse plants at immature (IM) and mature stage (M)

Species/Leaves	TPH (mg/g d.w. T.A.E)		TT (mg/g d.w. T.A.E)		CT (mg/g d.w. Q.E)	
	(IM)	(M)	(IM)	(M)	(IM)	(M)
Robinia pseudoacacia	26.5a†	20.1b	26.0a	20.0b	101a	82.5b
Amorpha fruticosa	16.5c	18.3bc	16.2.b	18.0b	68.0c	40.0d
Colutea arborescens	7.3d	7.6d	7.0c	7.2c	1.3e	1.0e

† Means for the same component with different letters are significantly different (P ≤ 0.05).

Concerning the stems, *A. fruticosa* had the highest concentration of TPH, TT compared to the other two species in both stage of maturity. However, *A. fruticosa* had significantly higher CT concentration than the other species in mature stage, but only than *C. arborescens* in immature stage (Table 2). There was a significant interaction between season x species for TPH, TT and CT concentration of stems. Both *R. pseudoacacia* and *A. fruticosa decreased significant* the TPH and TT concentration from immature to mature stage, but not *C. arborescens.* The CT concentration significantly decreased with maturity only of *R. pseudoacacia.* Generally, leaves had higher concentration of TPH, TT and CT than stems in both maturity stages (Tables 1, 2). Similarly, Salawu *et al.* (1997) reported that the leguminous species *Calliandra calothyrsus* had more CT in leaves than in stems.

Table 2. TPH (mg/g DM TAE), TT (mg/g DM TAE), CT (mg/g DM QE) concentration of stems from leguminous browse plants at immature (IM) and mature stage (M)

Species/Leaves	TPH (mg/g d.w. T.A.E)		TT (mg/g d.w. T.A.E)		CT (mg/g d.w. Q.E)	
	(IM)	(M)	(IM)	(M)	(IM)	(M)
Robinia pseudoacacia	5.7c†	3.8d	5.6c	3.8d	17.0a	9.2b
Amorpha fruticosa	9.7a	7.7b	9.4a	7.4b	16.3a	19.5a
Colutea arborescens	2.6d	4.5cd	2.4e	4.4cd	0.4c	0.4c

† Means for the same component with different letters are significantly different (P ≤ 0.05).

Contrasting results have been reported regarding the concentration of phenols in relation to the maturity stage. Glyphis and Puttick (1988) found that the concentration of phenols increased or remained stable as leaves became more mature. In contrast, Waterman and McKey (1989) reported that leaves had higher concentration of phenols in spring than in autumn. The results of the present study provide evidence than the concentration of phenols through maturity is species depended. There is a decrease in leaves CT concentration from spring to autumn for *R. pseudoacacia* and *A. fruticosa*. Several factors may affect the concentration and the solubility of CT in leaves. The quantity of CT to the foliage could vary according to the genotype (Baldwin *et al.,* 1987) and their concentration and extractability changes with season (Hagerman, 1998; Salem, 2005).

IV – Conclusions

R. pseudoacacia had the highest concentration among the tested species for all the measured components in leaves in spring and for CT in autumn, while *C. arborescens* the lowest ones. Concentrations in stems were generally lower compared to these in the leaves. The results of the present study indicate that the impact of maturation on the type and the concentration of phenols and tannins is species depended.

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The effects of P fertilization on spontaneous annual self-reseeding legume species of Mediterranean pastures

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Abstract. Natural and improved pastures represent an important component for forage systems, biodiversity, human activities, and rural countryside in Sardinia (Italy). However, research dealing with agronomic methods to increase the performances of spontaneous legumes in natural pastures, as an alternative to the introduction of the corresponding commercial varieties to improve pasture productivity, is still limited. A three-year trial was carried out to study the effects of phosphorus (P) fertilization in a natural pasture containing spontaneous legumes. Annual forage yields of grasses, legumes and others families and its quality and legume seed production have been monitored. Annual forage dry matter yield increased from 1 to 2 t ha^{-1} in P fertilized pasture compared to the unfertilized treatment. Legume contribution to the total DM yield increased from 4 to 40%. Moreover, forage quality and annual legume input to the soil seed bank significantly improved.

Keywords. Rangelands – Dry matter yield – Forage quality – Seed bank.

Les effets de la fertilisation phosphatée dans un pâturage naturel contenant des légumineuses spontanées

Résumé. *En Sardaigne (Italie) les pâturages naturels représentent un élément important non seulement comme source de fourrage, mais également en termes de biodiversité, ainsi que pour le maintien des activités humaines et du paysage rural. Cependant, les recherches qui concernent des méthodes agronomiques pour augmenter les performances des légumineuses spontanées dans les pâturages naturels restent encore limitées. Cela représente pourtant une alternative à l'introduction de variétés commerciales (pâturages semés) afin d'améliorer la productivité des pâturages. Un essai de trois ans a été réalisé pour étudier les effets de la fertilisation phosphatée dans un pâturage naturel contenant des légumineuses spontanées. La production fourragère annuelle (en quantité et qualité) des principaux groupes d'espèces (graminées, légumineuses et autres familles) ainsi que la production de semences de légumineuses ont été suivies. La production de matière sèche est passée de 1 à 2 t ha^{-1} dans les pâturages ayant reçu une fertilisation P par rapport au traitement non fertilisé. La contribution des légumineuses à la matière sèche totale est passée de 4 à 40%. En outre, la qualité du fourrage et la contribution de légumineuse annuelle à la banque de semences du sol a augmenté de façon significative.*

Mots-clés. *Pâturage – Production fourragère – Qualité du fourrage – Banque de semences.*

I – Introduction

Natural and improved pastures cover more than 1 million hectares in Sardinia, where they represent an important component, not only as forage source but also in terms of biodiversity, traditional human activities, and rural countryside. The low productivity of Sardinian rangelands is basically due to pedological and climatic factors (Bullitta *et al.*, 1993), which impose short growth periods on the prevalent annual plant communities. Spontaneous self-reseeding legumes are an important biological element of Mediterranean pastures (Sulas, 2005). In fact, starting from germplasm collections carried out in Mediterranean basin, several pasture and forage varieties have been released in Australia (Loi *et al.*, 2005) and widely used to improve pasture productivity. However, research dealing with agronomic methods to increase the performances of spontaneous legumes *in situ*, as an alternative to the introduction of the corresponding commercial varieties (sowed pastures), is still limited. On the other hand, low persistence and re-establishment have been recorded in 2^{nd} generation legumes grown in Sardinia (Porqueddu *et al.*, 2010). Chemical fertilization can be a cheap agronomic technique to improve pasture productivity and its quality (Bullitta *et al.*, 1993; Martiniello and Berardo, 2007). In addition, chemical fertilization may affect the botanical composition of sward and the size and the type of seed bank of pasture species. We supposed that phosphorus (P) fertilization could maximize the performances of spontaneous annual self-reseeding legume species. This research aimed at studying the effects of the P fertilization of natural pastures containing spontaneous legumes in terms of annual forage yield, its quality and legume seed production, and in comparison with unfertilized pastures.

II – Materials and methods

A three-year trial was carried out during 2010-13 in Bolotana, Sardinia (Italy). The soil of the trial is shallow, waterlogged in winter and characterized by low fertility (Table 1). Within traditional agro-pastoral private farms, natural pasture areas were identified and plots were arranged in a randomized complete block design with three replicates. The size of each experimental unit was 50 m^2.

Table 1. Main pedo-climatic characteristics of the trial location (Bolotana, Nu)

Latitude/longitude	40°16'N / 8° 58'E	Assimilable P (mg kg^{-1})	3.5
Altitude (m.a.s.l.)	200	Exchangeable K (mg kg^{-1})	141.6
Sand/Silt/Clay (%)	68 / 12/ 20	Avg. rainfall	580
Soil series (Fao, 1988)	Eutric, Calcaric e Mollic Fluvisols	Avg. temperature (°C)	16.6
pH	6.3	Total rainfall 2011/12/'3	740/640/860

Each autumn, all plots were fertilized with 100 kg ha^{-1} of P_2O_5 using triple superphosphate. No additional fertilizer or herbicide was applied. At the end of each spring, dry matter (DM) yields for all plots were determined by cutting the aerial biomass at 5 cm above ground level on sampling areas, and by drying the cut material at 65 °C in a forced-air oven until a constant weight is obtained. Botanical composition was determined on subsamples by separating the main species groups: grasses, legumes and other dicotyledonous species. The dry biomass was ground finely for forage quality determination. Neutral, acid detergent fibre and lignin were determined according to Van Soest (1994). Crude protein (CP) was calculated by multiplying the N content (Kjeldahl method, 1965) by 6.25. In summer, legume seeds were taken from plots by digging up to 4 cm soil depth and legume seed bank size was determined. On collected data a one-way ANOVA was performed. Duncan test was applied to compare the treatments every year. Tests of significance were made at a 95% confidence level. Analyses were processed using SAS for Windows (SAS Institute, 1999).

III – Results and discussion

During the three years, annual rainfall exceeded the mean long-term value by 20%, on average. The total DM yield of the unfertilized natural pasture ranged from 0.7 to 1 t ha^{-1} (Fig. 1). The total DM production in the fertilized natural pasture was always higher than in unfertilized during the three years. In the third year, the total DM significantly decreased in the unfertilized plots. The botanical composition, as percentage of total DM, was almost stable but different between treatments. In the unfertilized pasture it was: 56% grasses, 4% legumes, 40% others species. In the fertilized pasture (43% grasses, 42% legumes, 15% others) the legume content was 10 times higher compared to the unfertilized one. The most important legume species were: *Trifolium subterraneum, T. campestre, T. strictum, Medicago murex* and *Ornithopus compressus.*

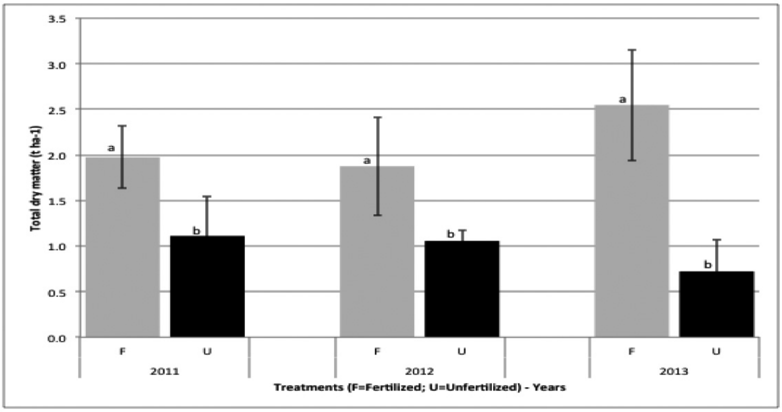

Fig. 1. Total dry matter (t ha^{-1}) in fertilized (F) and unfertilized (U) pastures (different letters within year indicate statistical differences at P<0.05).

The forage DM yields were representative of Mediterranean extensive pastures. The contribution of the native legumes remained very stable during the three years. On the contrary, a previous experiment in the same area pointed out that there was a remarkable presence of sowed commercial legume varieties in the sowing year only (Porqueddu *et al*., 2010).

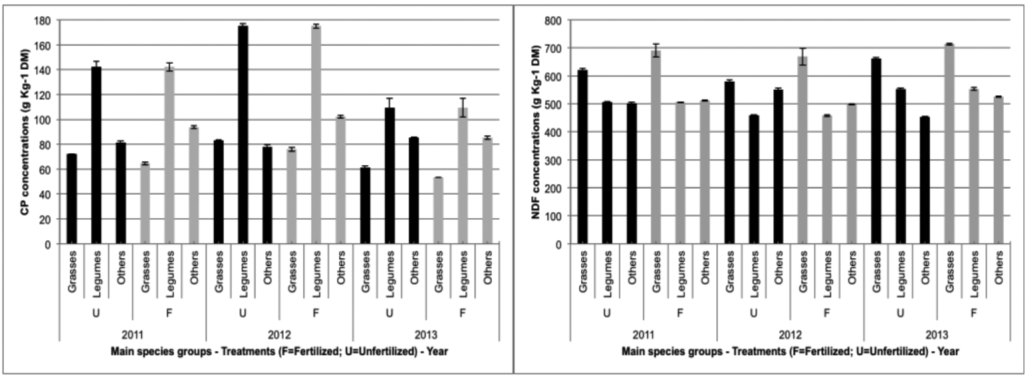

Fig. 2. Concentrations of a) crude protein b) neutral detergent fibre (NDF), in fertilized and unfertilized pastures.

The forage crude protein concentrations (Fig. 2a) ranged from 110 to 180 g kg^{-1} DM and was significantly higher in legumes. In fact, CP content never exceeded 80 and 100 g kg^{-1} DM in grasses and other species, respectively. The neutral detergent fibre concentration of grasses (Fig. 2b) showed higher values than legumes and other species (on average 700 *vs* 500 g kg^{-1} DM, in the fertilized pasture).

Total crude protein yields (Table 2) exceeded 200 kg ha^{-1} in the fertilized pasture. These contents were twice the unfertilized pasture, as a result of the concurrent remarkable legume contribution and their high CP content in fertilized pasture. On the contrary, even if present, native legumes were not so effective in the unfertilized pasture. NDF yields ranged from 1,000 to more than 2,500 kg ha^{-1} in the fertilized pasture, and they were two to four times higher than those in the unfertilized one. Seed production was markedly affected by the different legume contribution recorded into pasture treatments. In the unfertilized pasture, legume seed yield ranged from 100 to about 700 seeds m^{-2}. In the fertilized pasture, it ranged from 6,000 to more than 10,000 seeds m^{-2} depending also on different single species contribution. Consequently, P fertilization strongly affected annual input to the legume soil seed bank.

Table 2. Total crude protein (CP) and neutral detergent fibre (NDF) in the main species groups

Treatments and species groups	CP (kg ha^{-1})			NDF (kg ha^{-1})		
	2011	2012	2013	2011	2012	2013
Fertilized-grasses	55.0	54.6	62.9	588.8	480.3	845.4
Fertilized-legumes	127.7	125.0	112.3	1862.3	327.7	568.4
Fertilized-others	17.6	45.4	28.7	96.1	220.7	176.4
Unfertilized-grasses	65.0	19.8	28.7	557.6	138.0	309.4
Unfertilized-others	13.5	61.9	17.6	83.3	437.4	93.1
Fertilized-Total	200.4a	224.9a	203.9a	2547.2a	1028.7a	1590.2a
Unfertilized-Total	78.5b	81.7b	46.3b	640.9b	575.5b	402.5b

Different letters within columns indicate statistical differences at $P<0.05$.

The native legume annual input to the seed bank was lower than that recorded in pure sward of commercial cultivar of pasture legumes (Salis *et al*., 2012) just in the year of sowing. Native legumes were able to guarantee an effective and remarkable contribution to the pasture production during all the three-year experiment.

IV – Conclusions

The three-year research point out that P fertilization has relevant effects on pasture productivity, forage quality and legume soil seed bank. Phosphorus fertilization can enhance the role of native legumes in rangelands and assure stable effects from year to year, contributing to improve the sustainability of the forage systems. Therefore, the exploitation of native pasture legumes should be carefully taken into account and regarded as a complementary option to the introduction of imported commercial varieties.

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Characterization of Algerians populations of *Medicago* for cold tolerance by morphological traits and molecular markers

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Abstract. The study was carried on 16 accessions of annual *Medicago* species (*M. truncatula* Gaertn. *M. ciliaris* Krocker., *M. aculeata* Wild. and *M. polymorpha* L.). Seedlings of different accessions of *Medicago* collected from sites of contrasting altitudes (10 to 1170 m) were subjected to different durations of low temperature regimes. Root to shoot ratios of acclimated and non acclimated plants was compared. 12 accessions among 16 studied were used to assess the degree of genetic polymorphism by SSR microsatellites. Results show that accessions originated from high altitude have a better root to shoot ratios (higher ability to cold acclimation) than accessions originated from low altitude (lower ability to cold acclimation).Tests differentiation between species by Fisher pair show that all species are different from each other. Results show the high level of homozygosity for all species (> 80%). There are differences between populations of the same species of cold acclimation, which is encouraging for a study of association between cold acclimation and molecular polymorphism.

Keywords. Cold acclimation – Root:shoot ratios – Molecular polymorphism – Annuals populations – *Medicago.*

Caractérisation des populations algériennes de* Medicago *pour la tolérance au froid à partir de traits morphologiques et de marqueurs moléculaires

Résumé. *L'étude a porté sur 16 accessions de différentes espèces de* Medicago *(*M. truncatula *Gaertn*., M. ciliaris *Krocker*., M. aculeata *Wild. et* M. polymorpha *L.), appartenant à des altitudes contrastées. Des plantules de différentes accessions de* Medicago *ont été soumises à différentes durées de régimes de basse température. Les ratios racines/tiges des plantes acclimatées et non acclimatées (control) ont été comparés.12 accessions parmi les 16 étudiées ont fait l'objet d'une caractérisation moléculaire à l'aide de marqueurs de type SSR. Les résultats montrent que les accessions tolérantes affichent des ratios plus importants par rapport aux sensibles. Le test de Fisher de différentiation entre les espèces montre que les espèces sont différentes les unes des autres. Les résultats montrent aussi le haut niveau d'homozygotie pour toutes les espèces (> 80%). Le fait qu'il existe des différences entre les différentes populations étudiées pour la tolérance au froid est encourageant pour une étude d'association entre l'acclimatation au froid et le polymorphisme moléculaire.*

Mots-clés. *Acclimatation au froid – Ratios racine/tiges – Polymorphisme moléculaire – Populations annuelles –* Medicago.

I – Introduction

The production of a crop is challenged by abiotic and biotic stresses. Temperature is one of the most important environmental factors controlling seed germination, development of seedlings growth and limiting crop distribution. During crop establishment, extreme temperatures can decrease plant emergence and lead to drastic losses in crop yield and quality (Dias *et al*., 2010; Avia *et al*., 2013). Acclimation also is known as cold hardening or cold tolerance (Baruah *et al*., 2011; Pirzadah *et al*., 2014). Many morphological changes have been documented during the acquisition of cold tolerance in different species (Thapa *et al*., 2008; Baruah *et al*., 2011). Cold tolerance can be evaluated by changes in morphological indices such as root/shoot ratios (Hekneby *et al*., 2001; Thapa *et al*., 2008; Hund *et al*., 2008). In natural environments, the spatial distribution of individual plants within populations often depends on environmental factors that affect seedling establishment, such as temperature. Phenotypic assessment can provide a direct an easy estimation of variability for cold stress adaptations. Microsatellite markers, freeing this constraint, are often used in combination with phenological traits to characterize populations and their adaptation to constraint environments (Avia *et al*., 2013). It would be useful to develop morphological and genetic markers to detect genotypes with best degree of acclimation at low temperatures and consequently freezing tolerance using a screening tests in controlled conditions to avoid interference with other limiting factors. The major objective of this study was to develop a laboratory screening procedure to quantify cold acclimation (CA). CA was quantified by measuring morphological cold tolerance indices such as root to shoot ratio treated at different duration in comparison with the control, estimating the genetic diversity of natural *Medicago* accessions using SSR markers and answering the question is there a relationship between the classification of populations through cold tolerance indices as well as their site of origin (low or high altitude) and SSR markers used?

II – Materials and methods

The study was carried on four annual *Medicago* species. A set of 16 accessions (Table 1) was tested for degree of cold acclimation. Ten seeds for each accession were germinated, after scarification, at temperature room in Petri dishes containing universal compost imbibed with distiller water. At three days growth stage, seedlings were divided into two lots. Cold acclimation (CA) lot at 4 °C for three durations 5, 8 and 11 days (T1, T2 and T3) and control lot non-acclimated (NA) lot kept at 23 °C (T01, T02 and T03). CA was quantified by measuring root to shoot ratios at different durations in order to compare with the control.

Table 1. Accessions analyzed for cold tolerance with their origin and ecological description

Species	Accessions	Origin	Latitude	Longitude	Altitude (m)
M. aculeata Willd.	cv. Ac 15678	Australia	–	–	–
	cv. Ac 15679	Australia	–	–	–
	cv. Ac 14821	Australia	–	–	–
	cv. Ac 80	Syria	–	–	–
M. ciliaris Krocker.	Cil 123	Algeria	36°46’02’’N	8° 18’ 9.57’’ E	16
	Cil 124	Algeria	36°17’15’’ N	7° 57’ 14.77’’ E	565
	Cil 125	Algeria	36°17’15’’N	7° 57’ 14.77’’ E	565
	Cil 126	Algeria	36° 28’ 0’’ N	7° 26’ 0’’ E	290
M. polymorpha L.	Poly 57	Algeria	36°17’15’’N	7° 57’ 14.77’’ E	565
	Poly 54	Algeria	36°17’15’’N	7° 57’ 14.77’’ E	565
	Poly 136	Algeria	36°49’0’’ N	5° 46’ 0’’ E	10
	Poly 213	Algeria	35°23’17’’N	1° 19’ 22’’ E	1170
	Poly 42	Algeria	36°54’15’’N	7°45’07’’E	200
M. truncatula Gaertn.	Tru 210	Algeria	34°6’ 50’’ N	2° 5’ 50.14’’ E	1150
	Tru 216	Algeria	34° 6’ 50’’ N	2° 5’ 50.14’’ E	1150
	Tru 62	Algeria	36° 28’ 0’’ N	7° 26’ 0’’ E	290
	Tru 26	Algeria	35° 23’ 17’’ N	1° 19’ 22.16’’ E	1170

Among 16 accessions studied, 12 populations have been characterized using 14 SSR microsatellites. DNA is extracted from 200 mg samples of fresh young leaves material, in the presence of liquid nitrogen and 3 ml of CTAB buffer (Doyle and Doyle, 1990). PCR amplification was performed with fourteen SSR microsatellites. Extraction was carried out at INRA Lusignan France. PCR products were separated using polyacrylamide gel 6.5% in the LI-COR IR2 automated DNA sequencer (LI-COR Inc.). The different parameters are calculated using the Genetix software (version 5.0.4).

III – Results and discussion

1. Ability of cold acclimation

During cold treatment of 4 °C, cold-acclimated plants had reduced stem length and root length (data not shown). This reduction differs from one accession to one another. The values of root to shoot ratios are also different from one accession to another. Differences in root to shoot ratios between acclimated and non acclimated lots were significant at the tree durations of treatment time (Figs 1, 2 and 3). Tolerant accessions have better ratios (root to shoot) than the sensitive one. Ac 80, Ac and 15678 of *M. aculeata,* two populations of *M. polymorpha* Poly 136 and Poly 57, Cil 125 and Cil 126 of *Medicago ciliaris* and Tru 62 and Tru 216 of *M. truncatula* have been found that their degree of acclimation is more efficient for tree durations of treatment. Janska *et al.* (2010) showed that cold tolerant species –herbs, grasses and ground shrubs– have a low leaf surface area and a high root:shoot ratio and cold-adapted plants tend to be slow growing. Thapa *et al*. (2008), observed that growing of *M. truncatula* under low temperature regimes comparatively to control conditions, resulted in an increase of the root:shoot ratio.

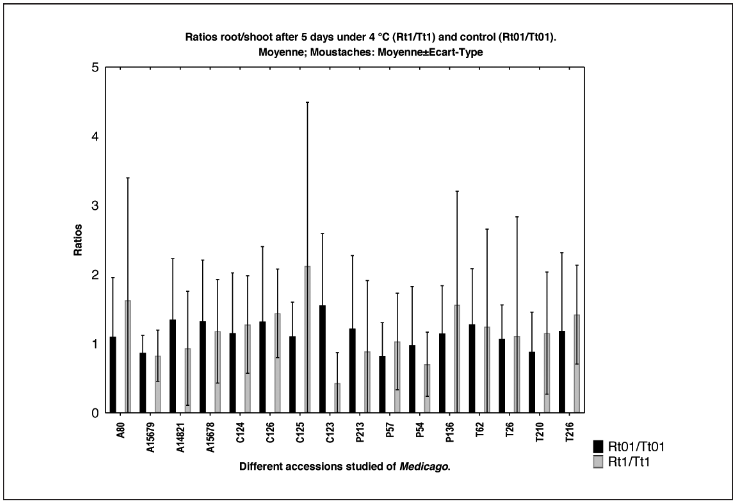

Fig. 1. Ratios root to shoot after 5 days under 4 °C (Rt1/Tt1) and control (Rt01/Tt01), for different accessions studied of *Medicago*.

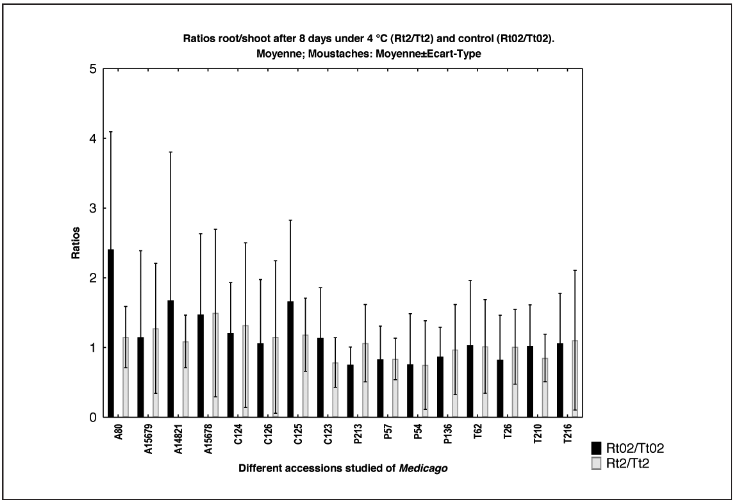

Fig. 2. Ratios root to shoot after 8 days under 4 °C (Rt2/Tt2) and control (Rt02/Tt02), for different accessions studied of *Medicago*.

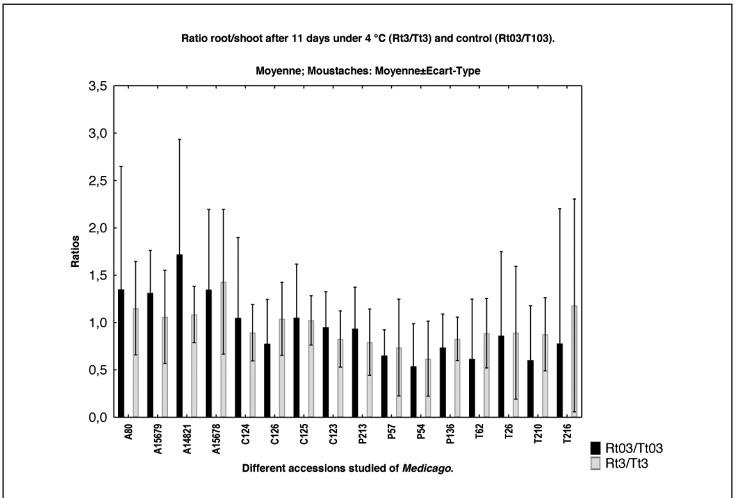

Fig. 3. Ratios root to shoot after 11 days under 4 °C (Rt3/Tt3) and control (Rt03/Tt03), for different accessions studied of *Medicago*.

2. SSR Marker

On 14 SSR markers used, nine were selected (not missing data, Table 2). Differentiation tests between species by Fisher pair; show that all species are different from each other. Results show the high level of homozygosity for all species (> 80%). The overall level of polymorphism, of *M. ciliaris* is lower *than M. polymorpha* and *M. aculeata*. So it is possible to differentiate between four species with nine microsatellite markers. It is possible to differentiate between populations for *M. aculeata* and differences between populations *M. aculeata* are similar to those between species. Some alleles detected at marker loci MTIC-131-432 and MTIC-079 seem to have a relationship with cold tolerance and the geographical origin of accessions (data not shown).

Table 2. Number of alleles and percentage of homozygosity

Loci	*M. ciliaris*	*M. truncatula*	*M. aculeata*	*M. polymorpha*	All species
ATPase456	1 (100%)[†]	1(100%)	5 (77%)	3 (50%)	6 (79%)
Mtic338	3 (85%)	1 (100%)	4 (92%)	5 (100%)	7(93%)
Mtic082	1 (100%)	1 (100%)	2 (100%)	4 (67%)	7 (91%)
mtic451	5 (100%)	3 (100%)	5 (85%)	2 (75%)	12 (88%)
B14B03	1 (100%)	1 (100%)	3 (100%)	5 (92%)	10 (98%)
mtic135	3 (92%)	2 (100%)	3 (100%)	2 (100%)	8 (98%)
mtic343	2 (100%)	2 (100%)	6 (92%)	6 (83%)	12 (93%)
mtic131	2 (92%)	2 (100%)	4 (100%)	4 (83%)	06 (93%)
Mtic432	1 (100%)	2 (80%)	2 (100%)	6 (83%)	13 (93%)
Total	19 (97%)	15 (98%)	34 (94%)	37 (81%)	81 (92%)

[†] The percentage of homozygosity is indicated in parenthesis.

IV – Conclusion

The effect of cold treatment was investigated in different populations of annual *Medicago*, and revealed a high genetic variability for cold tolerance. The degree of cold acclimation increased with the duration of treatment. It appears that it does not seem to be structuring between populations for *M. polymorpha* and *M. ciliaris* (to be confirmed with more individuals and markers) while there are differences between populations of the same species of cold acclimation. This is encouraging for a study of association between cold acclimation and molecular polymorphism.

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Phenology and grain yield of some common vetch (*Vicia sativa* L.) accessions in Tunisia

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Abstract. The phenology and agronomic characteristics of seven accessions of common vetch (*Vicia sativa* L.) were assessed over two years and contrasting sites through making the following notations and measurements: flowering and maturing dates, seed and biological yield, pod number per plant, seed number per pod, seed weight, and percent of shattering. Analysis of variance showed a significant effect of the environment (sites, year and site x year interaction) on all the agronomic and phenologic traits except the number of pods/plant. Significant variation was found between accessions for earliness, seed weight and number, and seed yield. All accessions flowered earlier in the sub-humid site while seed yield, seed number and weight were higher in the semi arid site. Positive and significant correlations were found between seed yield and seed number ($r=0.47$, $P<0.04$, $n=19$), flower number and seed weight ($r=0.88$; $P<0.001$) and flower number and seed yield ($r=0.93$; $P<0.0001$). The highest average seed yield was recorded for INRAT 303, a local variety (1232 kg ha^{-1}), while the lowest value was recorded for accession VS7 from Syria (888 kg ha^{-1}). Based on their earliness and lower shattering rate, accessions VS8 and VS15 originating from Cyprus and Afghanistan respectively, were selected as promising grain yielding lines.

Keywords. *Vicia sativa* L. – Semi arid – Sub humid – Seed yield – Shattering.

Phénologie et rendement en graines de quelques accessions de vesce commune (*Vicia sativa *L.) en Tunisie

Résumé. *La phénologie et les caractéristiques agronomiques de 7 accessions de vesce commune (*Vicia sativa *L.) ont été évaluées sur deux années et deux sites contrastés à travers les notations et les mesures suivantes: date de floraison et de maturité, rendement en graines et rendement total, nombre de gousses/plante, nombre de graines/gousse, poids des graines et pourcentage d'égrainage. L'analyse de variance montre un effet significatif de l'environnement (site x année) sur tous les caractères agronomiques et phénologiques sauf sur le nombre de gousses/plante. Toutes les accessions fleurissent précocement dans le site subhumide alors que le rendement en graines, le nombre et le poids des graines sont plus élevés dans le site semi-aride. Des corrélations significatives ont été trouvées entre le rendement en graines et le nombre de graines/gousse ($r=0,47$, $P<0,04$, $n=19$), entre le nombre de fleurs et le poids des graines ($r=0,88$; $P<0,001$) et entre le nombre de fleurs et le rendement en graines ($r=0,93$; $P<0,0001$). Le rendement en graines moyen le plus élevé a été enregistré chez la variété locale INRAT 303 (1232 kg ha^{-1}), alors que le plus faible a été observé chez l'accession VS7 en provenance de Syrie (888 kg ha^{-1}). En se basant sur la précocité et le faible taux d'égrainage, les accessions VS8 et VS15 provenant respectivement de Chypre et d'Afghanistan, ont été retenues comme étant des lignées prometteuses à bon rendement en graines.*

Mots-clés. *Vicia sativa* L. *– Semi-aride – Sub-humide – Rendement en graines – Égrainage.*

I – Introduction

In Tunisia, the current situation is marked by an increase in consumption and prices of basic products (cereals for human consumption and concentrates for animals). The use of productive and well adapted forages and cereals varieties in association with appropriate management techniques and practices is likely to reduce production costs and provide economical solutions to farmers. Nowadays, several registered varieties of forage legumes (e.g. vetch and pea) and grasses (e.g. oats, barley, tall fescue) selected from local or introduced genetic resources may contribute positively to these requirements. Beside their large adaptation and high nutritional values, these varieties are able to provide a rich and balanced diet for animal husbandry. Among them, vetch grains present high crude protein content (about 30%) and are candidates to potentially replace soybean in the formulation of concentrate for ruminants (Ben Salem, pers. comm.). In previous studies, it has been proven that grazing vetch by dairy sheep resulted in a substantial reduction of soybean meal incorporation level in the daily diet (Atti and Hassen, data not published). In the purpose of searching alternatives to soybean meal, the aim of the present study is to test introduced and local accessions of common vetch for earliness and grain yield potential under Tunisian environments.

II – Materials and methods

1. Trials management

The trials were conducted under rain fed conditions in two contrasting sites (Oued Béja and Oued Mliz) during two cropping years (2009/2010 and 2010/2011). Oued Beja site (OB) has a sub humid Mediterranean climate with 600 mm average annual rainfall, cold winter and hot summer. Oued Mliz site (OM) has a semi arid environment with 460 mm rainfall, cold winter and hot dry summer. The total amount of rainfall recorded in Oued Béja was 362 mm and 498 mm in 2010 and 2011, respectively, and that recorded in Oued Mliz was 498 mm and 593 mm in 2010 and 2011, respectively. The two experiment years were dryer in Oued Béja and wetter in Oued Mliz compared to their corresponding average rainfall.

2. Plant material

In 2010-2011, four accessions originated from different Mediterranean countries were received from ICARDA in the frame of germoplasm exchange and, evaluated in comparison with two local checks (var. Mghila and var. INRAT 303). For each year and site, a complete block design with three replications was used. Each accession was sown in a plot of four rows of 4 m long and 30 cm apart.

3. Measurements

Agronomic traits were determined during the first and the second year in both sites through measuring seed yield, seed yield components such as seed weight and number, pod number and weight, number of flowers per plant, biological yield, percentage of shattering and empty pods. The four latest parameters were evaluated at Oued Béja only during one year and that was made on 20 individual plants randomly taken from each plot. The remaining plants were cut for seed yield. Phenologic traits such as days to flowering and days to maturity were recorded in both sites.

4. Statistics

Analysis of variance was performed on seed yield with year and site as random effects and accession as fixed effect. For the other agronomic traits, ANOVA was performed with the year random effect. Analyses were performed using SAS (SAS Institute, 1998-2000).

III – Results and discussion

There is a significant effect of site, year and site x year interaction on all agronomic and phenologic traits except the number of pods per plant (Table 1). Significant variation was found between accessions for earliness, seed weight and number and seed yield. Pod number and seed weight were two times higher in the semi arid site of Oued Mliz than in the sub humid site of Oued Béja (Table 1).

On average, accessions flowered and matured earlier in Oued Béja than in Oued Mliz (107.5 days *vs* 125.5 days and 145.6 days *vs* 163 days, respectively) (Table 1). The average biological yield ranged from 438 kg ha^{-1} for var. INRAT303 to 2867 kg ha^{-1} for accession VS7. These results are consistent with those obtained by Larbi *et al*. (2010) in North West Syria (3.3 and 2.2 t ha^{-1} in wet and dry environments, respectively). Shattering rate varied between accessions from 20 to 32% in var. Mghila and accession VS11, respectively. INRAT303 was the most shattering variety.

Table 1. Means of all accessions of common vetch (*V. sativa* L.) for phenologic and agronomic traits

Accession name	Days to flowering	Days to pod maturity	Number of flowers†	Biological yield (kg ha^{-1})†	Shattering† (%)	Seed number pod^{-1}	1000 seed weight (g)	Pod number $plant^{-1}$
VS 15	110.2^{c}	145.7^{c}	29.13^{b}	800^{bc}	28.0^{b}	5.2^{a}	54.8^{bc}	58.3^{a}
VS 8	107.4^{c}	145.4^{c}	38.20^{b}	1620^{bac}	21.9^{b}	5.0^{a}	59.2^{bc}	60.5^{a}
VS 11	110.9^{c}	148.5^{c}	37.67^{b}	1283^{bac}	31.7^{b}	5.1^{a}	59.0^{ba}	52.0^{a}
VS 7	121.7^{a}	162.8^{a}	32.80^{b}	2867^{a}	31.0^{b}	$4.7b^{a}$	59.4^{ba}	57.5^{a}
INRAT 303	121.7^{a}	162.5^{a}	94.90^{a}	438^{c}	50.0^{a}	3.9^{b}	52.9^{c}	61.7^{a}
Mghila	113.5^{b}	152.1^{b}	17.50^{b}	2575^{ba}	20.0^{b}	4.8^{ba}	63.6^{a}	44.2^{a}
Total mean	*114.5*	*152.3*	*37.8*	*1512*	*27.8*	*4.8*	*58.7*	*54.5*
SE	*2.6*	*2.4*	*26.6*	*954.1*	*7.3*	*0.9*	*4.8*	*18.7*
Mean OB	*107.5*	*145.6*	–	–	–	3.9^{b}	52.2^{b}	55.6^{a}
Mean OM	*125.5*	*163.0*	–	–	–	6.3^{a}	68.9^{a}	52.8^{a}

† Recorded at one site and for one year only (Oued Béja 2010). Numbers with the same letter in a same column are not significantly different at P<0.05 level. OB: Oued Béja site, OM: Oued Mliz site.

Seed yield was two times higher in the semi arid site than in the sub humid one (Table 2). This proves that common vetch is more adapted to dry and cold conditions.

Table 2. Seed yield (kg ha^{-1}) of *Vicia sativa* accessions evaluated in two sites and over two years

	Oued Béja site				Oued Mliz site				
	2010		2011		2010		2011		
Accessions	Mean	Sd	Mean	SD	Mean	SD	Mean	SD	Accession average
VS 7	206.8	98.5	–	–	1570.1	138.4	–	–	888.5^{b}
VS 8	308.0	125.8	1218.0	172.8	1754.7	300.8	323.3	134.3	901.0^{b}
VS 11	380.4	171.2	1023.3	538.4	1604.1	309.8	373.3	66.6	845.3^{b}
VS 12	245.5	173.7	–	–	1553.8	285.4	–	–	899.7^{b}
VS 15	154.2	69.7	1328.0	176.5	1860.6	224.9	406.7	32.1	937.4^{b}
INRAT303	342.9	380.4	–	–	2122.6	126.3	–	–	1232.7^{a}
Mghila	708.8	116.9	719.3	267.0	1639.6	493.6	380.0	249.8	861.9^{b}
Year average									
2010	1032.3^{a}								
2011	721.5^{b}								
Site average									
Oued Béja	303.0^{b}								
Oued Mliz	1235.3^{a}								

–: not included in the trial; values with the same letter are not significantly significant at P<0.05. SD: standard deviation.

Compared to other countries, the average total seed yield recorded in our experiments (0.9 t ha-^{1}) is higher than that obtained by Berger *et al.* (2002) in north Syria (0.4 t ha^{-1}) and lower than that obtained by Benyoussef *et al*. (data not published) (1.7 t ha^{-1} for both Mghila and INRAT303 under 356 mm in Tunis), and that of Larbi *et a*l., (2010) in wet conditions of north Syria (1.2 t ha^{-1}). A highest grain yield of 2.2 t ha^{-1} was obtained by Miki *et al.* (2013) in one accession of Serbia. Under more favourable climate in Tunisia (> 600mm rainfall), Hassen and Atti (data not published) obtained a biological seed yield of 3 t ha^{-1} for the variety Mghila grown in a mixture with spring triticale used as tutor.

Significant correlations were found between flower number and seed weight (r=0.88. p<0.0001) and flower number and seed number per pod (r=0.93. P<0.001) which themselves are correlated to seed yield (r=0.54, P<0.02, n=19; r=0.47, P<0.04, n=19).

IV – Conclusion

The evaluation of common vetch under contrasting environments has demonstrated interesting grain yields for the semi arid conditions. High seed weight, low shattering rate and earliness are important criteria for selecting promising lines of common vetch. Based on these criteria, VS8 and VS15 were retained for registration as commercial cultivars for grain purpose.

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Effects of temperature, drought and salinity on seed germination of Fabaceous species (*Anthyllis henoniana*)

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Abstract. This study was conducted at germination stage on *Anthyllis henoniana,* a Fabaceae species, which grows under arid lands in Tunisia. The effects of temperature, salt and drought stresses at the same water potentials induced by NaCl and polyethylene glycol (PEG 6000), were investigated on seed germination. Results indicated that a temperature between 15 and 25°C was the most favorable at germination stage. An increase in PEG and NaCl potentials progressively decreased both the percentage and the mean germination time. Germination under salt and water stresses showed the differences occurred; salt stress had less inhibitory effect on germination than drought stress. The germination behavior of this species would therefore imply adaptive mechanisms to colonize the arid lands threatened by desertification in Tunisia.

Keywords. Arid lands – *Anthyllis henoniana* – Germination – Temperature – Water stress – Salt stress.

Effet de la température, du stress hydrique et du stress salin sur la germination des graines d'une espèce de* fabaceae *(*Anthyllis henoniana*)

Résumé. *Cette étude concerne le comportement germinatif d'*Anthyllis henoniana *de la famille des Fabaceae, collectée dans des zones arides de la Tunisie. Les effets de température, du sel et du stress hydrique aux mêmes potentiels hydrique induits par NaCl ou le PEG 6000, ont été examinés sur la germination des graines. Les résultats indiquent qu'une température entre 15 et 25°C était la plus favorable à la germination des graines. Une augmentation du PEG et des potentiels du NaCl diminuent progressivement le pourcentage et le temps moyen de germination. La germination sous l'effet du sel et du stress hydrique a montré des différences entre les traitements. L'effet inhibiteur du stress salin sur la germination est moins marqué que celui du stress hydrique. Le comportement germinatif de cette espèce impliquerait donc des mécanismes adaptatifs pour coloniser des zones menacées par la désertification en Tunisie.*

Mots-clés. *Zones arides –* Anthyllis henoniana *– Germination – Température – Stress hydrique – Stress salin.*

I – Introduction

Desertification is a serious threat to arid and semiarid environments that cover 40% of the global land surface. Tunisia is one of the most affected countries. On account of desertification problems and soil erosion affecting large areas of the Mediterranean region, it's necessary to create programs leading to revegetation, to improve arid ecosystems and also to preserve natural resources.

Several species of *Fabaceae* family have a high interest due to their high adaptation to arid and semi-arid environments, nitrogen fixing capacity and ability to grow in poor soils (Ibanez and Passera, 1997). They are of great importance worldwide, especially in countries under Mediterranean climate like Tunisia. They contribute to soil fertility and to the prevention of soil erosion. A successful germination is a crucial stage in the life cycle of plants and tends to be highly unpredictable over space and time as it determines whether or not the populations will successfully establish (Tlig *et al.*, 2008). The germination is adversely affected by unfavorable moisture conditions due to lack of rain. Seed germination rates generally decrease with decreases in soil water potential, which is always associated with failure of plant emergence (Willenborg *et al*., 2005).

Salinity is another major constraint to seed germination. Tolerance to salinity during germination is critical for the establishment of plants growing in saline soil of arid regions. Because of the increase of expanded saline areas throughout the world, that makes a dangerous trend of 10% per year, many studies were carried out to determe salt effects on this stage (Abari *et al*., 2011). Severe drought and high salinity are rapidly increasing and could promote the desertification and salination of lands. In this regard understanding seed germination under various levels of water stress, salt stress, and temperatures is essential for successful plant establishment and revegetation.

The aim of this study was to evaluate, during germination, the adverse effects of temperature, salinity, and drought on *Anthyllis henoniana,* an endemic species of East Algeria, south of Tunisia, and west Libya, grown under conditions of the arid environments of Tunisia.

II – Materials and methods

This experimental study was carried out under laboratory conditions. Seeds of *Anthyllis henoniana*, collected by Arid Land Institute Medenine, were used without any type of pretreatment. Seeds were then surface sterilized in aqueous solution of 0.1% mercuric chloride for 60s to prevent fungal attack and rinsed in several changes of sterile distilled water. Germination experiments were conducted in incubators set at 5, 10, 15, 20, 25, 30, and 35°C in complete darkness (four repetitions of 25 seeds). The effect of drought and salt stress were conducted at the optimal temperature, according to the temperature experiment. It was investigated on seeds placed in Petri dishes with 5 ml of aqueous solutions of polyethylene glycol (PEG 6000) or NaCl to create water stress or salt stress, respectively, with iso-osmotic potentials: 0 (distilled water), -0.1, -0.2, -0.4, -0.6, -0.8 and -1.0 MPa.

Final germination percentage (FGP) and median germination time (MGT) or the time to 50% germination were calculated. Final germination percentage was calculated as the cumulative number of germinated seeds at termination of the experiment:

$$FGP = \frac{\sum n}{Nt}.100$$

where *n* is the number of germinated seed at each enumeration interval, and *Nt* is the number of seeds in each experiment;

$$MGT = \frac{\sum ni, ti}{N}$$

where *ni* is the number of seeds germinated at day *i*, *ti* is the incubation period in days and *N* the total number of germinated seeds in the treatment.

Statistical analyses were performed using SAS software (version 8.2, USA). A one-way analysis of variance (ANOVA) was performed on all results.

III – Results

ANOVA showed significant effects ($p < 0.001$) of temperature on mean germination time and final germination percentage (Fig. 1).

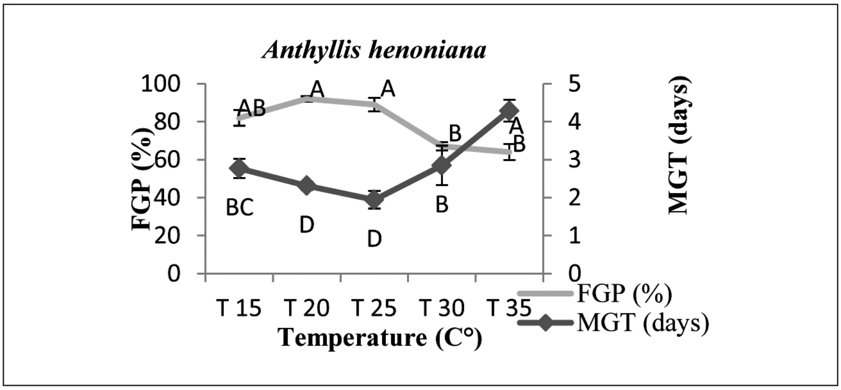

Fig. 1. Variation of the final germination percentages (FGP) and the mean germination time (MGT, days) of *Anthyllis heoniana* seeds at different temperatures. Values of each parameter (mean ± 95% confidence limits, n = 4), having the same letter are not significantly different (P>0.05) each other (Duncan test).

Optimal germination occurred at 20°C in *Anthyllis heoniana* seeds. This species showed relatively higher records of germination percentages at the treatments between 15° and 25°C, but it showed a reduction at the highest temperature regime (T35).

The effects of water stress (PEG treatment) on seed germination are reported in Table 1.

Table 1. Effect of PEG 6000 on final germination percentage (FGP) and mean germination time (MGT) of *Anthyllis heoniana* at the optimal temperature (T = 20°C)

	Water stress (PEG 6000, MPa)					
	0	-0,2	-0,4	-0,6	-0,8	-1
FGP	89 ± 1,49^{A}	91 ± 1,10^{A}	83 ± 1,49^{AB}	70 ± 1,32^{B}	57 ± 1,79^{DC}	51 ± 1,49^{D}
MGT	2,74 ± 0,22^{D}	3,05 ± 0,16^{D}	4,13 ± 0,25^{C}	4,76 ± 0,18^{B}	5,03 ± 0,19^{B}	5,77 ± 0,22^{A}

Means (± s.e.: n = 4) with the same letter across rows and columns were not significantly different (P > 0.05).

Water stress induced by PEG had a significant effect (P < 0.001) on final germination percentage (FGP) and mean germination time (MGT) of the species. Final germination percentage and speed decreased with a decrease of water potential, this decrease was most significant at lower PEG level (-1MPa). The potential of -0.2MPa indicated the highest records among all treatments (91%). Also, germination percentage exceeded 50 % at -1 MPa.

The results of ANOVA showed that salt stress (NaCl treatments) had a significant effect (P < 0,001) on germination percentage and mean germination time (Table 2). The germination was significantly reduced by high NaCl levels and there were no great differences in final germination percentage between 0 and -0,4 MPa, so germination percentage was reduced with increasing NaCl to levels above -0,4 MPa (Duncan test, 1%).

The germination speed, expressed by MGT, decreased with the decrease in NaCl potentials.

Table 2. Effect of NaCl on final germination percentage (FGP) and mean germination time (MGT) of *Anthyllis heoniana* at the optimal temperature (T°20)

	Salt stress: NaCl (MPa)					
	0	-0,2	-0,4	-0,6	-0,8	-1
FGP	90 ± 3,06^{A}	87 ± 1,54^{A}	89 ± 1,03^{A}	74 ± 0,95^{AB}	63 ± 0,85^{BC}	53 ± 1,10^{C}
MGT	1,65 ± 3,06^{C}	2,18 ± 0,08^{C}	2,35 ± 0,96^{BC}	3,13 ± 0,09^{B}	4,32 ± 0,27^{A}	4,27 ± 0,62^{A}

Means (± s.e.: n = 4) with the same letter across rows and columns were not significantly different ($P > 0.05$).

IV – Discussion

Seed germination behavior in relation to thermal stress is very important to determine the colonization capacity of species (Ungar, 1982). In the present study germination was significantly (P < 0.001) inhibited by either an increase or decrease in temperature from thermal optimum (Fig. 1). Seeds of this species germinate better at temperatures between 15 and 25°C. The behavior of the species is a typical strategy of Mediterranean plants with optimal temperatures ranging between 15 and 25°C (Baskin and Baskin, 1998). In the present study, 51% of *Anthyllis heoniana* seeds germinated at the lowest water potential (-1 MPa). This suggested that this species easily grows under low water availability. Other study demonstrated that even desert species like *Ziziphus lotus* presented less than 5% of germinated seeds at -1 MPa (Maraghni *et a*l., 2010). Ibanez and Passera (1997) found that *Anthyllis cystoides* seeds were able to germinate at -1,12 MPa (48%). Also at growth stage, Ourcival and Berger (1995) confirmed the high resistance of *Anthyllis heoniana* plants which continued at -1,9 MPa in May. Similar results were reported for other *Fabaceae* species like *Acacia tortilis* which had no germinated seeds at -0,8 MPa (Jaouadi *et al*., 2010). This limit of tolerance (-0,8 MPa) was also observed in other *Fabaceae* and desert species like *Retama raetam* (Youssef, 2009).

The results of this study showed that increases in salinity caused a decrease in germination percentage and speed, it also delayed germination in all studied species. Generally, salt stress affected the germination capacity and speed of *Anthyllis heoniana* seeds. These results were confirmed by several other research (Lachiheb *et al*., 2004).

In our study, the seed germination was higher in NaCl than in PEG at the same water potential. In this regard some studies have demonstrated that NaCl and PEG adversely affected germination but NaCl had a less inhibitory effect on seed germination than an iso-osmotic of PEG (He *et al*., 2009). In contrast, Katembe *et al.* (1998) found that higher concentrations of NaCl (-1MPa) were more inhibitory to germination of two *Atriplex* species than iso-osmotic PEG solutions.

Considering the percentage of seeds that germinated in the -1 MPa, we can conclude that this *Fabaceae* species is well adapted to germinate under conditions of water and salt stresses. These features are typical of the environments where it grows and lives. Arid lands of Tunisia are widely affected by desertification which is caused particularly by the degradation of vegetation cover, deforestation, and drought. The high ability of *Anthyllis heoniana* to germinate over a wide range of environmental conditions provides an opportunity to contribute to future reforestation programs.

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Session 1

Forage services for animal production and product quality

Posters articles – Forage utilisation, animal performances and products

Mediterranean forage resources and Pélardon cheese content of terpenes and fatty acids

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Abstract. Pélardon is a goats' milk PDO cheese produced in a Mediterranean area of southern France requiring a minimal use of rangelands. The aim of this work was to characterise the dominant strategies used by farmers to combine the use of natural resources provided by the region in order to feed the dairy goats and to define the links between these strategies and fatty acid and terpene composition of the cheeses. Thirty five cheeses were collected in spring and summer 2011 from 22 different farmhouse cheese-makers recruited to cover the diversity of farmers' feeding practices. The cheeses were analysed after 2 days' ripening and the farmers' feeding practices during the days prior to cheese-making were collected through an interview. Five main feeding strategies were defined according to the relative importance of rangeland and grassland grazing and the amount of hay and concentrates fed. These feeding strategies did not affect the cheese terpene content and composition whose main drivers are related to the botanical diversity of the rangelands and the grazing management of the goats by the shepherd. Cheese fatty acid composition varied mainly according to the importance of the grassland grazing and the supplementation with hay and concentrates. These results may help the farmer exploiting in an optimal way the diversity of the resources so that cheese characteristics reflect the richness of the "terroir" where they originate.

Keywords. Goat cheese – Terpenes – Fatty acids – Mediterranean forage resources.

Ressources fourragères Méditéranéennes et composition des fromages Pélardon

Résumé. *Le Pélardon est un fromage de chèvre AOP produit dans une zone Méditerranéenne du sud de la France. L'objectif de ce travail était de décrire comment les éleveurs combinent l'utilisation des ressources naturelles du territoire pour nourrir leur troupeau et étudier les liens entre ces combinaisons de pratiques et la composition de leurs fromages en acides gras et terpènes. Trente-cinq fromages fermiers ont été collectés au cours du printemps et de l'été 2011 dans 22 élevages sélectionnés pour couvrir la diversité des pratiques d'alimentation de la zone. Les fromages âgés de 2 jours ont fait l'objet des analyses et les principales pratiques d'alimentation des troupeaux au cours des jours précédant la fabrication des fromages ont été relevées lors d'une enquête. Les pratiques d'alimentation des éleveurs ont été classées en 5 stratégies variables selon l'importance relative du pâturage sur prairies et sur parcours, et selon les quantités de foin et d'aliments concentrés distribuées au troupeau. Ces stratégies d'alimentation n'ont pas eu d'impact significatif sur la teneur et la composition des fromages en terpènes qui dépendent principalement de la biodiversité des parcours et des pratiques de garde des éleveurs. La composition des fromages en acides gras a varié principalement selon l'importance du pâturage sur prairies et les quantités de foin et de concentrés offerts. Ces résultats pourraient aider les éleveurs à exploiter de façon optimale la diversité des ressources naturelles de leur territoire de façon à ce que les fromages reflètent au mieux la richesse du terroir où ils sont produits.*

Mots-clés. *Fromage de chèvre – Terpènes – Acides gras – Ressources fourragères Méditerranéennes.*

I – Introduction

For cheeses labelled with a protected designation of origin (PDO), understanding how the "terroir" influences the characteristics of the cheeses is an important issue. The natural resources provided by the region and the way the farmers combine their use to feed the animals is part of the definition of the "terroir". In the case of mountain cows' milk cheeses, some feeding practices like the use of permanent pastures have been shown to exert an important influence on cheese chemical composition and sensory properties (Martin *et al.,* 2005). In Mediterranean areas, a wide diversity of spontaneous and sown vegetation coexists. In those areas, the characterisation of the linkage between the natural resources and the characteristics of the cheeses may be particularly complex (Napoléone *et al*., 2012). This is the case for Pélardon, a small (100 g) goats' raw milk soft cheese produced in a Mediterranean area of southern France by 2 small dairies and 62 farmhouse cheese-makers. The aim of this work was: (i) to characterise the main strategies used by the farmers to feed the goats; and (ii) define the links between these strategies and the composition of the cheeses. We focussed on cheese fatty acids and terpenes, two families of compounds shown to depend little on cheese processing and to vary mainly according to animal feeding (Tornambé *et al*., 2006; Chilliard *et al*., 2007).

II – Materials and methods

Thirty five cheeses were collected in spring and summer 2011 from 22 different farmhouse cheese-makers recruited to cover the diversity of farmers' feeding practices. During a visit to the farm, the farmers were interviewed in order to describe the feeding management of the goats the day's prior cheese sampling. The focus was on the quantities and nature of the dry forages and concentrates given to the dairy goats, the time the goats spent grazing on grasslands and rangelands. Rangelands are made of very diverse wooden and herbaceous Mediterranean spontaneous vegetation. Its botanical diversity was classified as low, medium or high and the type of management of the goats on rangelands (free grazing or active shepherd management). Two 2-day-old cheeses were collected, frozen and sent to the laboratories for the analyses of volatile compounds by headspace gas chromatography coupled with mass spectrometry and fatty acids (FA) by gas chromatography. The data collected on-farm were used to classify the goats' diets in 5 feeding strategies identified by a graphical treatment of the data as described by Bertin (1977). The terpene and FA composition of the corresponding cheeses was then compared by an Anova (SAS software). A Principal Component Analysis was made using the 21 individual terpenes and 48 FA as active variables (SPAD Software). The data related to two additional "control" cheeses not PDO granted because goats were only fed indoors are reported but not included in the statistical analyses.

III – Results and discussion

A total of 21 monoterpenes were identified in the cheeses. As already reported by Napoleone *et al.* (2012), the most abundant terpenes was α-pinene followed by limonene, β-pinene, p-cymene, 3,7-dimethyl-1,6-octadiene and camphene. The variability and the amount of terpenes in the cheese were particularly important but variable according to the compounds; from 92 to 22 000 fold higher in the richest cheeses compared to the poorest. The variability of the FA was also very high; saturated FA (SFA) ranged from 62 to 77, monounsaturated FA (MUFA) from 18 to 32 and polyunsaturated FA (PUFA) from 4 to 6 g/100 g Total FA (TFA). Linolenic acid and CLA ranged from 0.7 to 1.4 and 0.3 to 1.1 g/100 g TFA respectively.

The practices of the farmers were also very diverse: the quantities of hay and concentrates ranged from 0 to 2.5 and 0.1 to 1.2 kg/d/goat respectively. The daily duration of grazing on grasslands and rangelands ranged from 0 to 10 h/d and from 0 to 12 h/d respectively. Five distinct feeding strategies were identified according to the amount of hay and concentrates fed to goats and the duration of grazing on grasslands or rangelands (Table 1). Two feeding strategies were characterised by a long grazing on rangelands without grasslands and differed according to the amount of hay fed. In two other feeding strategies, the grazing on grasslands and rangelands was equivalent and differed according to the amount of hay and concentrate. The last strategy was based on pasture on grassland supplemented by hay and concentrates.

Table 1. Description of the feeding strategies and associated cheese FA and terpenes composition

Type of pasture	Rangelands		Rangelands & grasslands		Grasslands	S*	RSD	*Control*
Hay & concentrate	-	+	-	+	+			*+*
Number of cheeses	7	11	7	6	4			*2*
Rangelands h/d	6.0b	5.0b	3.5ab	3.4ab	0.1a	*	2.69	*0*
Grasslands h/d	0.1a	0.1a	4.2b	3.7b	4.9b	***	1.69	*0*
Hay kg/d	0.5a	1.8b	0.4a	1.5b	1.3b	***	0.40	*2.5*
Concentrate kg/d	0.6a	0.7ab	0.6a	1.0b	0.7ab	*	0.23	*0.8*
α-pinene	6.6	6.3	6.4	6.3	5.7	NS	0.65	*5.5*
Camphene	5.3	5.2	5.3	5.2	4.6	NS	0.63	*4.6*
β-pinene	5.7	5.5	5.5	5.5	5.0	NS	0.50	*4.6*
p-cymene	5.3	5.4	5.3	5.3	5.0	NS	0.42	*4.6*
Limonene	5.8	5.8	5.6	5.6	5.4	NS	0.45	*5.3*
α-thujene	4.3	4.7	4.8	4.6	3.5	NS	0.87	*3.1*
γ-terpinene	4.6	4.9	4.9	4.7	4.1	NS	0.68	*3.2*
∑ Saturated FA	70.23	70.44	70.21	67.70	68.66	NS	3.34	*76.68*
6:0	2.75b	2.77b	2.70ab	2.47a	2.46a	*	0.23	*2.73*
8:0	2.97	3.00	2.84	2.56	2.59	+	0.36	*3.03*
16:0	24.88	24.31	24.27	24.56	24.93	NS	1.86	*29.92*
18:0	11.19	11.52	12.50	11.69	11.47	NS	1.55	*6.98*
20:0	0.33b	0.29ab	0.32b	0.27ab	0.24a	*	0.05	*0.21*
22:0	0.14d	0.11bc	0.13cd	0.10ab	0.08a	***	0.02	*0.09*
∑ Monounsat. FA	23.73	23.99	24.08	26.53	25.74	NS	3.14	*18.50*
*c*9-16:1	0.46ab	0.48ab	0.42a	0.53b	0.52b	*	0.06	*0.60*
*c*9-18:1	18.69	19.17	18.88	21.15	20.46	NS	2.44	*15.00*
*c*15-18:1	0.22ab	0.20ab	0.23b	0.20ab	0.19a	+	0.03	*0.16*
*c*11-18:1	0.44ab	0.54bc	0.41a	0.58c	0.56bc	**	0.09	*0.44*
*t*11-18:1	1.34	1.10	1.61	1.40	1.56	NS	0.45	*0.47*
∑ Polyunsat. FA	5.41	4.94	5.08	5.15	4.95	NS	0.44	*4.03*
*t*11*c*15-18:2	0.15ab	0.08a	0.16b	0.11ab	0.15ab	**	0.05	*0.08*
20:4n6	0.15	0.14	0.12	0.12	0.11	+	0.02	*0.12*

* S = statistical significance; +P<0.10. *P<0.05. **P<0.01. ***P<0.001. NS: non-significant.
Data within the same row not sharing a common superscript are different (P<0.05).
Terpenes are expressed in log (arbitrary units) and FA in g/100gTFA.

None of the cheese terpenes differed significantly according to the feeding strategies because of the very high variability in the data. Nevertheless, 17 terpenes were numerically higher (from 2 to 18-fold) in the 4 feeding strategies including rangeland grazing in comparison to those that did not (grassland and control). Within the feeding strategies including rangelands, the amount of terpenes was comparable, regardless of the duration of the grazing on rangelands or the amount of hay and concentrates fed, certainly because grazing goats are very plant selective.

The concentrations of 6:0 and 8:0 were decreased by increasing grazing on grasslands with the same amount of hay distributed. This result, in accordance with Chilliard *et al.* (2007), is linked to a putative inhibitory effect of 18:3n-3 against mammary *de novo* synthesis of FA. The *c*9-16:1 concentration was the highest in the feeding strategies including grasslands pasture and high amounts of hay and concentrate in the diet. The highest *c*11-18:1 concentration was observed with high amounts of hay and concentrates. The *t*11*c*15-18:2 concentration was numerically lower in feeding strategies including high amount of hay and concentrate in the diet, suggesting that 18:2n-6 from concentrate could limit the ruminal biohydrogenation (RBH) of 18:3n-3 (Chilliard *et al.,* 2007). The 20:0 and 22:0 were the highest when goats grazed rangelands and when hay supplementation was low. The 20:4n-6 concentration tended to increase with the duration of rangeland grazing rich in aromatic plants. We can suppose that secondary metabolites of these plants could limit the RBH of this FA.

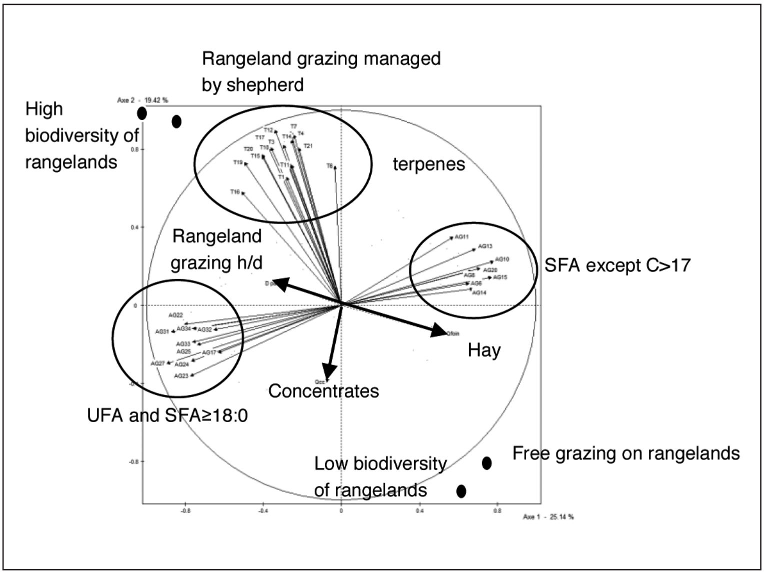

Fig. 1. PCA on cheese FA and terpene composition and projection of the farmers' practices.

The first plot of the PCA (Fig. 1) shows the independence between the FA, mainly correlated with PC1 (most SFA on the positive side of the PC and most UFA on the negative side) and the terpenes mainly correlated with PC2. Cheese terpenes, that reveal the ingestion of aromatic plants rich in secondary metabolites (Tornambe *et al.,* 2006), were the highest when rangelands were the most diverse and when rangeland grazing was managed by the shepherd.

IV – Conclusions

The results of this trial showed that the main drivers of the Pélardon cheese composition of FA are the grazing on grasslands and the amount of hay and concentrates fed. The feeding strategies we defined didn't reveal the ingestion of plants rich in terpenes as those commonly found in Mediterranean rangelands. When grazing on rangelands, the drivers of this ingestion seem to be mainly the shepherd's management of goats and the rangeland biodiversity and in a lesser extent, the quantitative duration of the grazing and the amount of hay and concentrates fed. These results may help the farmers to exploit in an optimal way the diversity of the local resources so that cheeses' characteristics reflect the richness of the "terroir".

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In vitro anthelmintic activity of *Thymus capitatus* from southern Tunisia on gastrointestinal nematodes of sheep

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Abstract. *Thymus capitatus* (Lamiaceae) is used traditionally by people as spices and was reported to possess some biological effects. The objective of this study was to evaluate the anthelmintic efficacy of *T. capitatus* in comparison to albendazole against the gastrointestinal (GI) nematodes of sheep. To fulfil the objectives, In vitro anthelmintic activities of crude aqueous (CAE) and ethanolic extracts (CEE) of aerial parts of *T. capitatus* were investigated on the egg and adult nematode parasite *Haemonchus contortus*. Both extract types of *T. capitatus* inhibited hatching of eggs completely at a concentration close to 2mg/ml. LC50 of ethanolic extract of *T. capitatus* was 0.368 mg/ml while that of aqueous extract was 6.344 mg/ml. There was statistically significant difference between aqueous and ethanolic extracts ($p < 0.05$). The ethanolic extract showed better in vitro activity against adult parasites than the aqueous one in terms of the paralysis and/or death of the worms at different hours post-treatment (PT). Dose dependent activity was also observed for both extract. As far as the literature could be ascertained, there is no published report on anthelmintic activity of *T. capitatus.* The results of the present study suggest that *T. capitatus* extracts are a promising alternative to the commercially available anthelmintics for the treatment of GI nematodes of small ruminants.

Keywords. *Thymus capitatus* – Anthelmintic – Haemonchus contortus – Tunisia.

Activité anthelminthique* in vitro *du* Thymus capitatus *du sud de la Tunisie sur les parasites gastro-intestinaux du mouton

Résumé. Thymus capitatus (Lamiaceae) *est traditionnellement utilisée comme épice et a été signalée posséder des effets biologiques. L'objectif de cette étude était d'évaluer l'efficacité anthelminthique de* T. capitatus *par rapport à l'albendazole contre les nématodes gastro-intestinaux (GI) des ovins. Pour atteindre ces objectifs, les activités* in vitro *des extraits bruts aqueux et éthanoliques des parties aériennes de la plante ont été testées sur les œufs et les vers adultes d'*Haemonchus contortus*. Les deux types d'extraits ont inhibé totalement l'éclosion des œufs à une concentration proche de 2 mg/ml. Les DL50 de l'extrait éthanolique et de l'extrait aqueux de* T. capitatus *étaient 0,368 mg/ml et 6,344 mg/ml respectivement. Il y avait une différence statistiquement significative entre les extraits aqueux et éthanoliques (p < 0,05). En outre, l'extrait éthanolique a montré une meilleure activité* in vitro *contre les parasites adultes que l'extrait aqueux en termes de paralysie et / ou de mort des vers à différentes heures post-traitement. Cet effet dose dépendant a également été observé pour les deux l'extraits. Les résultats de cette étude révèlent que les extraits de* T. capitatus *peuvent représenter une alternative prometteuse aux anthelminthiques purement chimiques pour le traitement des nématodes gastro-intestinaux des petits ruminants.*

Mots-clés. Thymus capitatus – *Anthelminthique* – Haemonchus contortus – *Tunisie*.

I – Introduction

The genus *Thymus* (Lamiaceae), which comprises about 215 species, is particularly prevalent in the Mediterranean area (Hazzit *et al*., 2009). *Thymus capitatus* is known in Tunisia as ‘‘Zaâtr’’ and was commonly used as spices and was reported to possess some biological effects such as antibacterial (Essawi and Srour, 2000), antiviral, and antioxidant activities (Miura and Nakatani, 1989; Ines *et al.*, 2012).

As far as the literature could be ascertained, there is no published report on anthelmintic activity of *T. capitatus.* In the present study, an experiment was performed to test in vitro anthelmintic efficacy of crude aqueous and ethanolic extracts of aerial parts of *T. capitatus* when compared to a reference drug albendazole against *Haemonchus contortus*.

II – Material and methods

Plant material, collection and preparation. Fresh plants were collected in June 2011 from a local farm at Matmata, local government area of Gabes, Tunisia. Leaves, stems and flowers were separated and thoroughly rinsed in running tap water. The stems were cut into chunks, and all of the plant material was air dried at room temperature for a period of 14 days and pulverized. The aerial parts of the plant (leaves, stems and flowers) were air-dried and finally ground to a fine powder.

Preparation of extracts. Both crude aqueous and ethanolic extracts were used. Thus, dried and finely powdered aerial parts of *T. capitatus* (100 g) were sequentially extracted by maceration with distilled water at room temperature (20-25°C, 3 × 500 ml). The aqueous extract was collected and filtered by Whatman No.1 filter paper and then lyophilized (Alawa *et al*., 2003). For the ethanolic extract, 200 g of powdered plant were added to 500 ml of 95° ethanol. The resulting mixture was incubated for 16 hours at room temperature and frequently agitated before being filtered through Whatman No. 4 filter paper. The process is repeated 3 times. Then, all the solvent was evaporated in Rotavapor. All extracts were concentrated, dried and kept in the dark at 4°C until tested.

***In vitro* anthelmintic assays – Egg hatch assay.** Eggs used in the present assay were collected from donor sheep according to World Association for the Advancement of Veterinary Parasitology (WAAVP) guidelines (Coles *et al*., 1992). Fresh eggs were then washed repeatedly with distilled water. Aqueous and ethanolic extracts of the leaves of *T. capitatus* were used as the test treatment. Albendazole (99.8% pure standard reference) was used as the reference drug (positive control) while untreated eggs in PBS (Phosphate Buffered Saline) with DMSO (Dimethyl sulfoxide) (0.5%) were used as negative control. In the assay, approximately 200 eggs in 1.5 ml of PBS were placed in each test tube. Aqueous and ethanolic extracts of *T. capitatus* at concentrations of 2.0, 1.0, 0.5, 0.25, 0.125 and 0.0625 mg/ml in a total volume of 0.5 ml in PBS and ethanolic extracts at same concentrations in a total volume of 0.5 ml in PBS with DMSO (0.5%) were used. Albendazole was dissolved in DMSO and diluted at the concentrations of 1 µg/ml. The test tubes were then covered and kept in incubator at 27°C for 48 h. The experiment was replicated four times for each concentration. Hatched larvae (dead or alive) and un-hatched eggs were then counted under dissecting microscope with 40× magnification.

***In vitro* anthelmintic assays – Adult worms motility assay.** This test was performed according to Hounzangbe-Adote *et al*. (2005). Adult worms were collected from an experimentally infected lamb, 6 weeks after infection. Immediately after slaughtering, the abomasum was removed, opened and placed in 37° C saline. The collected parasites were then washed and kept in PBS. Five to ten actively moving worms were placed in petridishes filled with 2.0, 1.0, and 0.5 mg/ml of the aqueous and ethanolic extracts of *T. capitatus* respectively in PBS and in PBS with DMSO (0.5%) in a total volume of 4 ml. PBS with DMSO (0.5%) was used as a negative control. Albendazole dissolved in DMSO and diluted in PBS at the concentrations of 0.5 mg/ml was used as a positive control. Three replicates were performed for each treatment. Inhibition of worm motility was the rationale for anthelmintic activity. The time required for paralysis or complete inactivity and mortality was recorded at 0, 2, 4 and 8 h intervals. After 8h the extracts and albendazole were washed away and parasites resuspended in luke warm PBS for 30 min to test the revival of the worm motility. The number of motile (alive) and immotile (dead) worms were counted under dissecting microscope, and recorded for each concentration. Death of worms was ascertained by absence of motility for observation period of 5-6 s. A mortality index was calculated as the number of dead worms divided by the total number of worms per petridish.

Statistical analysis. The statistical analysis was performed using the SPSS-10.0 software package for Windows. LC_{50} for egg hatch inhibition was calculated by probit analysis. Regression was used for evaluation of dose-response relationship using Minitab® Release 14. The result of the worm motility inhibition was expressed as mean ± standard error of mean (S.E.M). Means of anthelmintic efficacy were compared by student's t test. A probability of 0.05 was used as a threshold for statistical significance.

III – Results and discussion

1. Egg hatch assay

The results of *H. contortus* egg hatching inhibition by aqueous and ethanolic extracts of *T. capitatus* are presented in Figure 1. In PBS less than 2% eggs did not hatch. With the albendazole concentration used, 92.05% eggs incubated did not hatch. Both extracts showed ovicidal activity in all tested concentrations and the histogram evolution showed dose dependency ($P<0.05$). Statistical differences ($P<0.05$) were also observed among two types of extracts.

Crude ethanolic extract (LC50 = 0.368 mg ml^{-1}) was found to have higher inhibitory effects compared with that of aqueous extract (LC50 = 6.344 mg ml^{-1}) on egg hatching.

Both extracts of *T. capitatus* inhibited egg hatching at lower concentration compared to some medicinal plants studied previously, for instance, 7.1 mg/ml of aqueous extract of *Annona senegalensis* inhibited only 11.5% eggs (Alawa *et al*., 2003) and methanol extract of *Spigelia anthelmia* induced 97.4% egg hatch inhibition at concentration of 50 mg/ml (Assis *et al*., 2003).

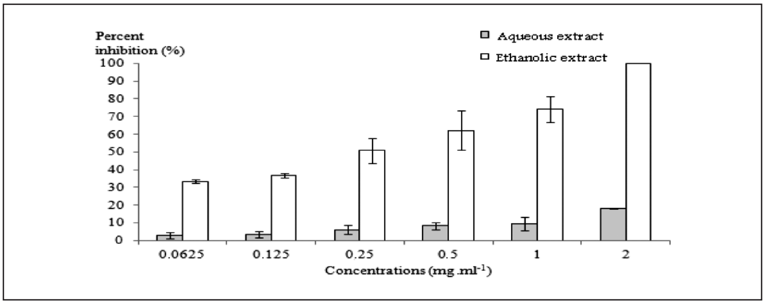

Fig. 1. Dose-dependent profile of the percent hatching egg of *Haemonchus contortus* submitted to the six increasing concentrations of plant extracts (0.0625, 0.125, 0.25, 0.5, 1 and 2 mg/ml).

2. Adult worm motility

The ethanolic extract of *T. capitatus* killed more worms than the aqueous extract in all tested concentrations. Dose dependent activity was also observed for both extract. The ethanolic extract induced 100% mortality at the highest concentration tested while the aqueous extract induced

85.71% at the same concentration (Table 1). There was 78.04% mortality of worms in albendazole (used as a reference drug) within 8 h post-exposition. There was 13.63% mortality of worms kept in PBS with DMSO 0.5% observed 8 h post-exposition.

Table 1. In vitro anthelmintic efficacy of crude aqueous and ethanolic extracts of *Thymus capitatus* on *Haemonchus contortus* of sheep

Treatment	Concentrations mg/ml	Percent of *Haemonchus contortus* worms showing mortality post-exposure to various treatments (Mean ± SEM)			
		0 h	2 h	4 h	8 h
Crude aqueous extract	0.5	0 ± 0.00	0 ± 0.00	3.57 ± 0.036	21.42 ± 0.089
	1	0 ± 0.00	9.09 ± 0.06	31.83 ± 0.099	68.21 ± 0.087
	2	0 ± 0.00	37.01 ± 0.105	45.71 ± 0.084	85.71 ± 0.128
Crude ethanolic extract	0.5	0 ± 0.00	0 ± 0.00	16.66 ± 0.089	33.33 ± 0.108
	1	0 ± 0.00	33.33 ± 0.125	50 ± 0.136	66.66 ± 0.177
	2	0 ± 0.00	76.92 ± 0.102	84.61 ± 0.25	100 ± 0.00
Albendazole	0.5	0 ± 0.00	0 ± 0.00	12.5 ± 0.051	78.04 ± 0.061
PBS with DMSO 0.5%	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00	

Several studies have revealed that the effect of plant extracts on adult worms can occur only at the highest concentration, for example: methanolic extract of *Euphorbia helioscopia L* induce highest nematode mortality (98%) at 50 mg/ml (Bashir *et al.*, 2012). The greater anthelmintic activity of crude ethanolic extracts than crude aqueous extracts could be due to easier and rapid transcuticular absorption of the ethanolic extract into the body of the worms owing to its lipid soluble nature.

IV – Conclusion

Based on the results of the present study, it can be concluded that *T. capitatus* aerial parts tested in the form of crude aqueous and ethanolic extracts showed significant in vitro anthelmintic activity at concentrations and doses tested against ovine nematodes as determined by worm motility inhibition and egg hatching inhibition of *H. contortus*. These findings suggest that *T. capitatus* could form an alternative to commercially available synthetic anthelmintics. Further investigations are needed to determine the exact active components against helminths and to test it in vivo for a potential commercial development.

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Milk production and quality in Sicilo-sarde ewes drenched with *Artemisia herba alba* or *Rosmarinus officinalis* essential oils

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Abstract. This study aimed to determine the effect of oral administration of essential oils (EOs) extracted from the foliage of *Artemisia herba alba* (ART) and *Rosmarinus officinalis* (ROS) to Sicilo-sarde ewes on milk yield and quality.Thirty ewes were divided into three equivalent groups on the basis of liveweight, lactation rank and litter size, and housed in individual boxes. Each animal received oat hay and barley silage *ad libitum* and 500 g of concentrate for 60 days. The control group did not receive EOs, whereas the ART group was drenched with 200 mg of Artemisia EOs/kg DM intake and those of the ROS group with 200 mg of Rosmarinus EOs/kg DM intake. Neither ART nor ROS essential oils affected the rumen fermentation parameters in ewes. Drenching feeds with ART essential oils increased milk density, fat-free dry matter content, total protein, and polyunsaturated fatty acids. It also increased the concentrations of blood triglycerides and total protein. These results suggest that the administration of ART EOs impacted positively on milk quality of dairy ewes, however, ROS EOs were ineffective. Further studies would be required to define the mechanism explaining such positive effect.

Keywords. Dairy ewe – Essential oils – Rumen fermentation – Milk.

***Qualité et production du lait chez les brebis de race Sicilo-sarde recevant par voie orale les huiles essentielles d'*Artemisia herba alba *et* Rosmarinus officinalis**

Résumé. *L'objectif de cet essai est d'étudier l'effet de l'administration orale de 200 mg/Kg de MS ingérée d'huiles essentielles (HE) d'*Artemisia herba alba *(ART) et* Rosmarinus officinalis *(ROS) à 30 brebis de race Sicilo-sarde sur la qualité du lait. Les brebis ont été divisées en trois groupes égaux et homogènes sur la base du poids vif, du numéro de lactation et de la taille de la portée. Elles ont été logées dans des boxes individuels. Chaque animal a reçu pendant 60 jours du foin d'avoine et de l'ensilage d'orge* ad libitum *et 500 g de concentré. Le groupe témoin n'a pas reçu d'HE, les deux autres groupes ont reçu respectivement les huiles essentielles de ROS et d'ART. L'ajout des huiles essentielles n'a pas affecté les paramètres de fermentation ruminale chez la brebis, par ailleurs, les brebis qui ont reçu les huiles essentielles d'ART ont montré une augmentation de la densité du lait, de la teneur en matière sèche dégraissée, des protéines totales, des acides gras polyinsaturés et d'autres acides gras. Le même effet a été enregistré au niveau des triglycérides sanguins et des protéines totales. Ces résultats suggèrent que, contrairement aux HE de ROS qui se sont avérées inefficaces, l'administration des HE d'ART présente un impact positif sur la qualité du lait de brebis laitières. D'autres études devraient être envisagées pour identifier le mécanisme expliquant cet effet positif.*

Mots-clés. *Brebis – Huiles essentielles – Fermentation ruminale – Lait.*

I – Introduction

The importance of the milk from sheep and goat to human health, and its added value for household livelihoods have been proven. To improve the quality and production of this commodity many feed additives has been investigated. Plant derived essential oils (EO) could be used to improve the efficiency of nutrient utilization and performance in ruminants and to reduce the environmental impact of gases generated from feed digestion. The composition and active compounds in EOs vary among plant species thus animal response to the administration of EOs varies accordingly (Benchaar *et al*., 2008). However, literature data on dairy sheep response to the administration of EOs are scarce and the available data are not conclusive (Chaves *et al*., 2008). The objective of the current study was to determine the effects of drenching Sicilo-sarde dairy ewes with EOs extracted from *Rosmarinus officinalis* (ROS) and *Artemisia herba alba* (ART) on rumen fermentation parameters, blood parameters and milk production and composition.

II – Materials and methods

Thirty Sicilo-sarde ewes were randomly selected and divided into three equivalent groups on the basis of live weight, lactation number and litter size. They were housed in individual boxes and received oat hay and barley silage *ad libitum* and 500 g of concentrate (800 g/kg of ground barely, 175 g/kg of soybean meal and 25 g/kg of commercial mineral and vitamin supplement) for 60 days. Essential oils were extracted from *Rosmarinus officinalis* and *Artemisia herba alba* vegetation by hydrodistillation during 6 hours using an apparatus similar to Clevenger (Moyse and Paris, 1967). The compounds in EOs mainly represented by monoterpenes and sesquiterpens, were analysed using a gas chromatograph coupled to a mass spectrometer. The control group (Clt) did not receive EOs, whereas the ART group was drenched daily with 200 mg of EOs/kg DM intake, while the ROS group was drenched with 200 mg of ROS EOs/ kg DM intake. In day 50 about 20 ml of rumen fluid were collected from all ewes before feeding (0h) and after (3h) post-feeding, using a stomach tube. The pH of the rumen fluid was immediately determined, protozoa number were determined using Malassez chamber. Ammonia nitrogen (NH3-N) was analysed according to Weatherburn (1967). Blood samples were withdrawn, on day 46, before feed distribution, plasma was collected after centrifugation and analyzed for glucose, triglycerides, urea and total proteins using Biomaghreb kits. The milk yield of each ewe was recorded daily, individual milk samples, collected weekly, were analyzed for fat, protein, density, salt and lactose by infrared spectroscopy. The chromatographic analyses of fatty acids (FA) were performed using GC/FID. Data corresponding to ewe response to EOs (Tables 1 and 2) were subjected to analysis of variance using the GLM procedure and differences between means were detected using the LSMEANS procedure.

III – Results and discussion

Supplementation with EOs did not affect ($P>0.05$) rumen pH, protozoa count and NH_3-H concentration in the rumen fluid (Table 1). There was a tendency ($P = 0.07$) towards a decrease of NH_3-H at 3h post-feeding for ewes drenched with ART EOs. EOs are rarely reported to affect NH_3-H concentration in vivo with diets similar to those used in the current study (Giannenas *et al*., 2011; Benchaar *et al*., 2008; Tager and Kraus, 2011). However, our findings are in agreement with the *in vitro* results reported by Newbold *et al.* (2004), which observed a decrease in the rate of NH3-N production when rumen contents of cows or sheep supplemented with EO incubated for 24 to 48 h in strained ruminal fluid. Total protein and triglycerides in blood increased by the supplementation of ART EOs. Little information is available on the effect of EOs and their compounds on blood metabolites. Milk yield was not affected by the addition of EOs. This finding is in line with other studies on dairy cattle and cows (Benchaar *et al*., 2007 and 2008, Tager and Kraus 2011). The lack of effect of EO and their active components on milk performance was consistent with the absence of effects of these plant extracts on feed intake and ruminal fermentation.

The composition of milk is given in Table 2. Fat-free dry matter content, density, protein and medium chain fatty acids (MCFA) increased ($P<0.05$) with ART EOs supplementation, but fat tented to decrease (P = 0.07) and lactose tended to increase (P=0.05). In the contrast, all these parameters were not affected by ROS EOs. These results are in agreement with those of Benchaar *et al*. (2006), who did not note any changes in milk yields, proteins and lactose contents of cows fed up to 2 g/d of EOs. Polyunsaturated fatty acids (PUFA) decreased in ROS ewes, and increased in ART group. Several Gram-positive bacteria are involved in ruminal biohydrogenation of dietary unsaturated FA (Harfoot and Hazlewood, 1988). Therefore, feeding EO could reduce biohydrogenation of FA by reducing the number and the activity of bacteria involved in the biohydrogenation of unsaturated FA. Benchaar *et al.* (2007) concluded that the supplementation of cows with 750 mg of EOs daily had no effect on milk FA profile. However, supplementing the same mixture at a higher dose (2 g/day) increased the proportion of conjugated linoleic acid. The increase of PUFA indicates that ART EOs could be used as a natural additive to improve milk fat nutritional properties for humans.

Table 1. Effects of essential oil supplementation on fermentation parameters and blood metabolites in dairy ewes

	Control	ART	ROS	SEM*	*P*-value
pH					
0h	6.7	6.84	6.73	0.05	0.17
3h	6.46	6.33	6.44	0.05	0.14
Protozoa (x10^5/ml)					
0h	1.18	1.11	1.23	0.13	0.83
3h	0.41	0.43	0.42	0.07	0.98
NH_3-N (mg/dl)					
0h	9.17	10.83	9.44	0.99	0.45
3h	14.5	9.92	12.98	1.38	0.07
Total protein (g/l)	63.44^a	83.37^b	80.30^b	2.91	<0.0001
Triglycerides (mmol/l)	0.12^a	0.22^b	0.12^a	0.02	0.01
Milk production (ml)	369.90	350.45	375	20.05	0.66

ART: *Artemisia herba Alba*, ROS: *Rosmarinus officinalis*, *SEM, standard error of the mean.

Table 2. Milk quality and composition in dairy ewes

	Control	ART	ROS	SEM*	*P*-value
Fat (%)	8.91	7.71	9.04	0.42	0.07
Fat-free dry matter content (%)	8.39^a	9.79^b	8.50^{ab}	0.37	0.03
Density (kg/cm3)	1025^a	1030.85^b	1025.28^a	1.37	0.01
Protein (%)	2.62^a	3.20^b	2.65^a	0.13	0.01
Lactose (%)	4.93	5.63	5	0.2	0.05
Fatty acids					
MCFA	53.24^a	59.20^b	55.87^{ab}	1.3	0.01
LCFA	5.03	6.9	7.02	1.58	0.63
MUFA	11.43	10.35	8.42	1.7	0.45
PUFA	2.50^a	2.74^a	2.05^b	0.18	0.03

ART: *Artemisia herba alba*, ROS: *Rosmarinus officinalis*, *SEM, standard error of the mean.

IV – Conclusion

It is concluded that the administration of ART and ROS EOs at 200 mg/kg DM intake to Sicilo-sarde ewes did not affect milk yield. However, drenching ewes with ART essential oils increased milk density, fat-free dry matter content, total protein, and PUFA.

Further studies should be emphasized to identify the mechanism explaining such positive effect.

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Effect of the level of incorporation of olive cake in the diet on lamb fattening performance and carcass characteristics

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Abstract. An experiment was carried out to study the effect of incorporation of dried and partly destoned olive cake (OC) on lamb fattening performance and carcass characteristics. Twenty-four Moroccan synthetic breed lambs were randomly divided into four treatments of six lambs each: Control, OC10%, OC20% and OC30%. Lambs from the last three treatments were fed on a concentrate containing 10%, 20% and 30% of OC (DM basis), respectively. All diets were iso-nitrogenous and iso-energetic. After a 15-day adaptation period to the experimental diets the trial was run for 75 days. Lambs were weighed at the beginning and at the end of the trial, and fortnightly. At the end of the experiment all the lambs were slaughtered, and the carcass dressing percentage, fatness and conformation (SEUROP system) were measured. The incorporation of OC in the diet did not affect either the lamb fattening performance or carcass characteristics (P>0.05). Average daily gain during the whole period was 215, 244, 246 and 226 g/d for Control, OC10%, OC20% and OC30%, respectively, whereas the warm dressing percentage was 46.6%, 48.0%, 48.7% and 48.2%. Average carcass conformation was R, and fatness averaged 2.45 points on a 1-5 scale.

Keywords. Olive cake – Lamb – Fattening – Carcass.

Effet de l'incorporation des grignons d'olive sur les performances d'engraissement et les caractéristiques de la carcasse des agneaux

Résumé. *L'objectif de cet essai était d'étudier l'effet de l'incorporation des grignons d'olive séchés et partiellement dénoyautés (OC) sur les performances d'engraissement et les caractéristiques de la carcasse des agneaux. Vingt-quatre agneaux de race synthétique marocaine ont été répartis aléatoirement selon quatre traitements en quatre groupes de six agneaux chacun, appelés, respectivement "Control" ; "OC10%" ; "OC20%" et "OC30%". Les agneaux des trois derniers traitements recevaient des rations contenant, respectivement, 10%, 20% et 30% de grignons d'olive. Tous les régimes étaient iso-azotés et iso-énergétiques. L'essai a duré 75 jours précédé d'une période d'adaptation aux régimes expérimentaux de 15 jours. Les agneaux ont été pesés au début et à la fin du l'essai et tous les 15 jours. A la fin de l'essai, tous les agneaux ont été abattus et le rendement, l'état d'engraissement et la conformation de la carcasse (système SEUROP) ont été mesurés. L'incorporation de grignons d'olive n'a affecté ni les performances d'engraissement ni les caractéristiques de la carcasse des agneaux (P> 0,05). Le gain moyen quotidien durant toute la période de l'essai a été de 215, 244, 246 et 226 g/j, respectivement, pour les traitements "Control", "OC10%", "OC20%" et "OC30%", tandis que le rendement a été de 46,6% ; 48,0% ; 48,7% et 48,2%. La conformation et l'état d'engraissement des carcasses a été, respectivement, R et 2,45 en moyenne pour tous les traitements.*

Mots-clés. *Grignons d'olive – Agneaux – Engraissement – Carcasse.*

I – Introduction

In Morocco, small ruminant farming plays an important socio-economical role. It is considered as one of the main sources of income to farmers. However, the rainfall irregularity (drought), rangeland degradation and expensiveness of supplements affect negatively the productivity and therefore the farmers' income. The use of alternative feed resources such as local agro-industrial by-products can be considered as a solution to reduce feeding costs. Among these by-products, olive cake may be used and integrated in small ruminant feeding without affecting animal productivity (Ben Salem and Znaidi 2008; Molina-Alcaide and Yañez-Ruiz, 2008; Hadjipanayiotou, 2000; Chiofalo *et al.,* 2004; Keli *et al*., 2009). Despite the large amounts of olive cake produced in Morocco, its use in animal feeding is limited. The objective of the present work was to study the effect of the incorporation of olive cake in the diet of lambs on fattening performance and carcass characteristics in order to optimize its integration in small ruminants feeding.

II – Material and methods

Twenty four Moroccan synthetic breed weaned lambs (entire males), with an average initial live weight of 23.0 ± 0.52 kg and about 90 days of age, were randomly assigned to four treatments (6 animals per treatment) consisting in incorporation of different proportions of dried and destoned olive cake in the diet. Animals consumed a basal diet of alfalfa hay (0.55kg DM/head/day) and a concentrate composed of maize grain, barley grain, sunflower meal and mineral-vitamin premix. Barley grain was partially replaced (DM basis) by 10%, 20% and 30% of olive cake for OC10%, OC20% and OC30% treatments, respectively (Table 1). Diets were formulated to be iso-energetic and iso-nitrogenous and meet nutrient requirements of growing weaned lambs (Bocquier *et al*., 1988). After a 15-day adaptation period to the experimental diets the trial was run for 75 days. Free clean water was available at all times.

Table 1. Composition of concentrates

Ingredient (%, DM weight basis)	Treatment			
	Control	OC10%	OC20%	OC30%
Barley grain	57	50	42	35
Maize grain	16	16	14	13
Sunflower meal	26	24	22	21
Olive cake	0	10	20	30
Vitamin-mineral premix	1	1	1	1

OC10%: Concentrate containing 10% of dried and partly destoned olive cake; OC20%: Concentrate containing 20% of dried and partly destoned olive cake; OC30%: Concentrate containing 30% of dried and partly destoned olive cake.

Lambs were weighed before morning feeding, at the beginning and the end of the trial, and fortnightly.

At the end of the experiment, and after a fasting period of 24 h, all lambs were weighed (slaughter live weight: SLW) and slaughtered, and carcass weight was determined immediately (Hot Carcass Weight: HCW) to determine the dressing percentage (100* HCW/SLW). After an overnight chill (24 h at 4ºC), cold carcass weight (CCW) were recorded in order to determine the cold carcass dressing percentage (100* CCW/SLW), the fatness degree (1 to 5) and carcass conformation according to the SEUROP system (Cañeque and Sañudo, 2005).

The effect of different incorporations of olive cake on fattening performance and carcass characteristics was analyzed by means of a one-way analysis of variance according to the model: $Y_{ij} = \mu + Ti + \varepsilon_{ij}$ where Ti represents the treatment effect and ε_{ij} the experimental error. The PROC GLM procedure of the SAS statistical package (version 8.01) was used for the analysis. Comparisons among mean values were tested using the LSD test.

III – Results and discussion

1. Fattening performance of lambs

Initial and final live weights, as well as average daily gain (ADG), are presented in Table 2. No differences (P>0.1) in live weight were observed among treatments, although ADG during the first 30 days of fattening tended to be greater (P = 0.0517) for the lambs fed treatment OC20%. Lack of differences between levels of olive cake in the diet is in line with the observations of Tufarelli *et al.* (2013) and Sadeghi *et al*. (2009), although other studies have found that olive cake incorporation in lamb diets negatively affected ADG (Molina-Alcaide and Yáñez-Ruiz, 2008). Olive cake has also been incorporated in dairy sheep diets without negative effect on the production performance and milk quality (Chiofalo *et al.,* 2004; Pauselli *et al.,* 2007).

The feed conversion was also not affected by diet (Table 2). The absence of a significant effect may be is associated with a better feed efficiency of concentrates containing dried and partly destoned olive cake for LW gain (Sadeghi *et al.,* 2009). Similar results have been found by Vera *et al.* (2013) and Tufarelli *et al.* (2013) in lambs fed diets containing olive cake.

Table 2. Fattening performance of lambs fed with increasing amounts of dried and partially destoned olive cake

	Treatment					
	Control	OC10%	OC20%	OC30%	SEM	P
Live weight (LW, kg)						
Initial	23.3	22.8	22.8	22.9	1.10	0.9850
30 days	30.3	31.0	31.8	30.9	1.32	0.8695
75 days	39.4	41.0	41.3	39.9	1.62	0.8233
ADG (g/d)						
0-30 days	233	274	300	264	15.9	0.0517
30-75 days	203	224	209	200	13.8	0.6245
0-75 days	215	244	246	226	12.6	0.2765
Feed conversion ratio						
0-75 days	6.2	6.0	6.0	6.6	0.34	0.5420

OC10%: Concentrate containing 10% of dried and partly destoned olive cake; OC20%: Concentrate containing 20% of dried and partly destoned olive cake; OC30%: Concentrate containing 30% of dried and partly destoned olive cake; SEM: standard error of the mean; P: probability of the differences; ADG: Average daily gain.

2. Carcass characteristics

Carcass characteristics are given in Table 3. The analysis of variance revealed no significant effect of the level of olive cake in the diet. Similar results were obtained in other studies with fattening lambs fed a diet containing 20% (Tufarelli *et al.*, 2013) or 33% (Vera *et al.*, 2013) olive cake.

IV – Conclusions

The results of this experiment showed that lambs may be fed dried and partly destoned olive cake at up to 30% of the concentrate during the fattening period without negative effects on fattening performance and carcass characteristics. However, further trials should be carried out involving aspects related to meat quality (chemical, physical and sensory parameters) in order to complete the results obtained in this study.

Table 3. Carcass characteristics of lambs fed with increasing amounts of dried and partially destoned olive cake

	Treatment					
	Control	OC10%	OC20%	OC30%	SEM	P
WCDP (%)	46.6	48.0	48.8	48.3	0.58	0.0902
CCDP (%)	45.4	46.8	47.2	46.8	0.61	0.1957
Fatness	2.4	2.5	2.4	2.5	0.11	0.8114
Conformation	R	R	R	R	–	–

OC10%: Concentrate containing 10% of dried and partly destoned olive cake; OC20%: Concentrate containing 20% of dried and partly destoned olive cake; OC30%: Concentrate containing 30% of dried and partly destoned olive cake; SEM: standard error of the mean; P: probability of the differences; WCDP: Warm Carcass Dressing Percentage; CCDP: Cold Carcass Dressing Percentage.

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Influence of different alpine farming systems on animal activities, heart rate, and milk yield of primiparous cows

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Abstract. Over the past decades, different alpine farming systems have been adopted in order to use and valorise the available alpine pastures: in traditional systems cows were typically sheltered and milked in the barn (TP), but to reduce cost, on many alpine farms dairy cattle remain outdoors during the entire summer period and are milked on pasture in a mobile milking parlour (EP). The findings reported here are based on a study which aimed at comparing cows kept under these two conditions. Heart rate, milking characteristics and daily activities were recorded from five Aosta Red Pied primiparous cows under TP-management and eight under EP-management. Data were collected also before the alpine transhumance in order to assess the ability of the animals to adapt. As soon as the EP-cows had free access to the pasture, they had a longer eating time compared with TP-cows (treatment × time; $P<0.01$). Average heart rate was higher in EP-cows compared with TP-cows especially in the idling phase (72.3 *vs* 67.0 beats/min; $P<0.05$). In conclusion, these results suggest that, although average milk yield remained unaffected, EP-cows spent more time for feed intake, but probably also consumed more energy, as is indicated by the higher heart rate.

Keywords. Dairy cattle – Animal activity – Heart rate – Milking yield – Alpine pasture system.

Influence de différents systèmes de gestion des alpages sur l'activité des animaux, le rythme cardiaque et la production de lait des vaches primipares

Résumé. *Au cours des dernières décennies, différents systèmes de gestion des alpages ont été adoptés afin d'utiliser et de valoriser les ressources fourragères de haute montagne : dans les conditions traditionnelles, les vaches sont abritées et traites à l'étable (TP), mais pour réduire les coûts, dans de nombreux alpages, les vaches laitières restent à l'extérieur durant la période estivale et elles sont traites à l'aide d'un chariot de traite mobile (EP). Les résultats présentés ici sont basés sur une étude qui visait à comparer les vaches gardées dans ces deux conditions. La fréquence cardiaque, les caractéristiques de traite et l'activité journalière ont été enregistrées sur cinq primipares de race Pie Rouge Valdôtaine (gestion TP) et sur huit primipares en gestion EP. Les données ont été recueillies aussi avant la montée en alpage afin d'estimer la capacité d'adaptation des animaux. Dès que les vaches EP avaient libre accès à la pâture, elles ont eu un temps d'ingestion supérieur par rapport aux vaches TP (traitement×temps; $p<0,01$). La fréquence cardiaque moyenne était plus élevée chez les vaches EP par rapport aux vaches TP en particulier dans la phase de repos (72,3* vs *67,0 battements/min; $p<0,05$). Ces résultats suggèrent que, bien que la production de lait moyenne soit demeurée inchangée, les vaches EP pâturait plus longtemps, mais consommaient aussi probablement plus d'énergie, comme l'indique la fréquence cardiaque plus élevée.*

Mots-clés. *Vaches laitières – Activités journalières – Fréquence cardiaque – Production laitière – Gestion d'alpage.*

I – Introduction

The Aosta Valley comprises an alpine region in the very North-West part of Italy, situated at the borders with Switzerland and France. Surrounded by the highest Alpine peaks, it is characterized by an average altitude of 2100 meters (Cerutti, 2006). Although the economy of the region is based on tourism, agriculture contributes and supports it directly through very high quality food products and indirectly by playing a crucial role on the landscape maintenance. Nevertheless, agro-pastoralism is a real challenge for the valley. The livestock systems are characterised by dairy farms: the animals spend the winter in lowland farms fed with hay until the summer transhumance, called *inalpe*, starts. On the alpine pastures, traditionally cows are sheltered and milked in the barn twice a day (TP). However, to reduce costs, on some alpine farms dairy cattle now remain outdoors during the entire summer period and are milked on pasture in a mobile milking parlour (EP), a practice also applied in Switzerland and France (Berard *et al.*, 2013). In the Aosta Valley, because of the very strong link with traditions and cultural heritages, this fully outdoor system was not accepted by the livestock keepers. Because the restoration of the alpine barn is often too expensive, agro-pastoralism is progressively abandoned and the number of cattle farms is decreasing. The Institut Agricole Régional (IAR) set itself the goal to rehabilitate an abandoned mountain pasture using a fully outdoor management system as a demonstration project. A second aim was to investigate productive and physiological parameters of indigenous cows kept under traditional and experimental conditions.

II – Materials and methods

From two herds comprising more than 60 Aosta Red Pied cows, 13 primiparous cows, five under TP-management and eight under EP-management, were selected and equipped with Polar Equine Science® (Polar Electro, Italy) cardio belts for recording heart rate and a MSR Electronics (Henggart, Switzerland) chewing sensor. The latter device records and discriminates between rumination, eating and idling activities during 24 hours (Nydegger *et al.*, 2011). The number of animals used in the TP condition was smaller compared with the EP condition because a previous experiment conducted in the same management systems has revealed a larger variance of the data of EP compared with the TP cows (Berard *et al.,* 2013). On the experimental animals, also a Lactocorder® (WMB AG, Balgach, Switzerland) was applied during milking to record milking characteristics. Data were collected, on a representative day every 3 weeks from April to August 2013, a period which included the time before the alpine transhumance in order to determine the ability of the animals to adapt (cf. Fig. 1).

After the transition period where the animals still were in the lowland barns, cows kept under TP were sheltered and milked in the barn twice a day and had free access to fresh highland alpine grass, approximately 4 h in the morning and 2 h in the evening. Conversely, in EP cows remained outdoors during the entire day and night and were milked on pasture in a mobile milking parlour. Hay, fresh grass and pastures were chosen to offer similar forage quality to the two groups. Representative forage samples were taken every 3 weeks at the general sampling days and were analysed by near-infrared spectroscopy for contents of dry matter, crude protein, ether extract, neutral detergent fibre, acid detergent fibre and acid detergent lignin. Data were subjected to analysis of variance using the MIXED procedure of SAS (version 9.1 Inst. Inc., Cary, NC) by including treatment (EP and TP), time (A to G) and their interaction as fixed effects. Time was considered as repeated factor, with animals nested within treatment as subject.

		Sampling time						
		Barn		Transition		Alp		
EXP		A	B	C	D	E	F	G
TP	feeding	Barn (hay)		Barn (fresh grass)		Pasture		
	milking					Barn		
EP	feeding	Barn (hay)		Pasture		Pasture		
	milking			Barn	Mobile milking parloir			

Fig. 1. Sampling schedule applied for the primiparous cows in the two experimental treatments (EXP), the traditional management system (TP) and the experimental management system (EP). Samplings A and B correspond to the lowland farm when animals were fed with hay; samplings C and D correspond to the lowland farm when animals were in a transition period and fed with hay and fresh grass/pasture; samplings E, F and G correspond to alpine pasture systems.

III – Results and discussion

The quality of the forage offered (in the barn or on the pasture) to both groups did not differ (P>0.2) in any of the parameters analysed. This aspect allowed a direct comparison of the two management systems, albeit they were located in two different places. No differences in eating time were observed when both groups were feed in the barn with hay (average data at time points A and B: EP-cows 253 *vs* TP-cows 294 min/day; P> 0.10). As soon as the EP-cows had free access to the pasture, from the morning until the evening milking time, during times C and D and day and night during times E, F and G, they ate for a longer time compared with the TP-cows (time C: 358 *vs* 268 min/day; time D: 373 *vs* 303 min/day; treatment × time; P<0.01). This was also true in the alpine management system (time E: 304 vs 229 min/day; time F: 370 *vs* 294 min/day; treatment × time; P<0.01). Troxler and Jans (1992) reported that cattle in a full outdoor management system are able to optimise their intake by alternating periods of grazing and rest depending on pasture forage supply and weather conditions; this much better than cows with restricted access to pasture. However, this difference in ingestion did not find a correspondence in the daily rumination time or the rumination time per bolus (respectively P>0.52 and P>0.35) in the present experiment.

Milk yield did not significantly differ between the two management systems (effect of treatment; P>0.10), maybe because of the small number of animals observed. Yield progressively decreased as cows were approaching the end of lactation (effect of time; P<0.01). Nevertheless, the average milk yield fluctuation over time was larger in EP-cows compared with TP-cows (Fig. 2).

The differences in the ingestion time and the lack of difference in milk yield suggest that the energy expenditure of EP-cows, caused by the efforts of thermoregulation, but also by external factors (insects, noise and environmental stress) was higher compared with that of the TP-cows. Costa *et al.* (1990) reported that milk production remains unchanged when dairy cattle are driven in a permanent pasture, despite a longer duration of ingestion and restricted transfer. This hypothesis was confirmed for the present study by the average heart rate that did not differ when both groups were sheltered and milked in the barn (average data on the times A and B: EP-cows 65.6 *vs* TP-cows 65.3 beats/min; P>0.36), but was later significantly higher in EP-cows compared with TP-cows, especially in the idling phase (74.5 *vs* 67.8 beats/min; P<0.05).

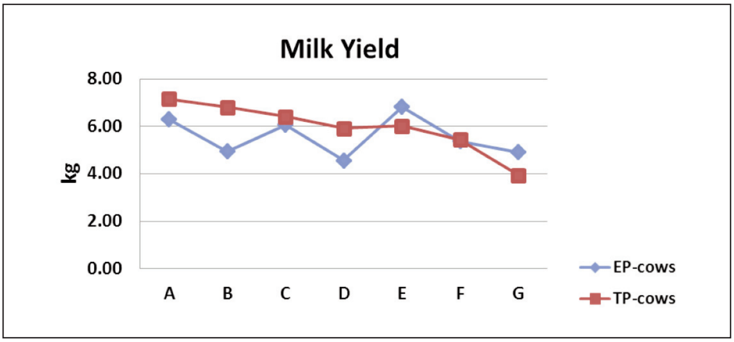

Fig. 2. Effect of management system (EP-cows: blue; TP-cows: red) and time (A, B: lowland farm, fed with hay; C, D: transition period in lowland farm, fed with hay and fresh grass/pasture; E, F, G: alpine pasture systems) on milk yield per milking time.

IV – Conclusions

In conclusion, these results suggest that, despite the small number of animals used in this study, the full outdoor system significantly influenced the cows. They ate more, and probably also consumed more energy, as is indicated by the higher heart rate, than cows in the traditional management system. Nevertheless, average milk yield was only marginally affected, showing a higher fluctuation in the full outdoor system compared to the traditional one. Further investigation on the heart rate variability will be carried out to better understand the adaptive capacity and the potentially higher stress of the animals in this production system.

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Carcass and lamb quality from agro-pastoral system in the Middle Atlas (Morocco)

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Abstract. In Moroccan Middle Atlas and its foothills sheep farming based on Timahdite breed and on the deliberate combination of the various components of the agro-pastoral system. From spring to early fall, feeding of weaned animals and early pregnant females is based exclusively on pasture. It yields carcasses and meat increasingly appreciated by consumers. In order to study the quality of these products, 3 groups of lambs received 3 different rations, were monitored for 3 months. Five animals from each group were slaughtered to study carcass and meat quality. The study of carcass concerned conformation and fatness, using measurements and European grids. Meat quality evaluation concerned the instrumental study of color, according to CIE L*a*b*model, ultimate pH, and sensory parameters with a taste panel. Preliminary results show that animals fed mainly on concentrate feed had better carcass yield, conformation and fatness than those raised on pastoral resources. Lightness of the meat and yellowness of the subcutaneous fat were higher for lambs raised in the extensive system than animals from intensive farming system. They have lower pH and more preferred by the consumer than that from concentrate and hay based-diet animals.

Keywords. Timahdite – Quality – Lamb meat – Carcass – Agro-pastoral system – Middle-Atlas.

Qualité des carcasses et de la viande des agneaux issus du système agro-pastoral dans la région du Moyen Atlas au Maroc

Résumé. *Au Moyen Atlas marocain et ses piémonts, l'élevage de la race ovine Timahdite se base sur des combinaisons de différentes ressources alimentaires du système agro-pastoral. Du printemps jusqu'au début de l'automne, l'alimentation des jeunes sevrés et des brebis en début de gestation se base exclusivement sur la pâture. Les animaux issus de ces élevages donnent des carcasses et des viandes de plus en plus appréciées par le consommateur. Dans le but d'étudier la qualité de ces produits, trois lots d'agneaux, qui différaient par la conduite alimentaire, ont été suivis pendant 3 mois. Cinq animaux de chaque lot ont été abattus. La conformation et l'état d'engraissement ont été étudiés en utilisant des mensurations et les grilles de classification européennes. L'évaluation de la qualité de la viande a concerné l'étude instrumentale de la couleur, selon le modèle CIE L*a*b*, le pH ultime et la qualité sensorielle évaluée par un jury de dégustation. Le rendement et l'état d'engraissement des carcasses du lot élevé sur les aliments concentrés ont été plus importants que ceux des animaux élevés sur la pâture et leur viande était plus foncée alors que leur gras était plus clair. La viande issue du système extensif a présenté un pH plus bas et a été préférée par le consommateur par rapport à celle issue du système intensif.*

Mots-clés. *Timahdite – Qualité – Viande – Carcasse – Agneau – Système agro-pastoral – Moyen Atlas.*

I – Introduction

The national demand for red meat is increasing because of the increase in population consumption. During these last years, an intensification of management on rangelands and a gradual growth in Timahdite-breed-lamb-feedlot had been observed in the Middle Atlas area to cover this demand. However, recently it was remarked that consumers are interested more to meat originating from extensive system than that from intensive system. As lamb's quality depends on a various intrinsic and extrinsic factors, of which the diet constitutes one of the bases of the connection of the meat to its origin, it was important to undertake a study to evaluate carcass characteristics and meat quality of lambs raised on grass compared to those fed partially or completely on concentrate and hay.

II – Materials and methods

1. Animals and feeding system

The experiment was conducted in the Middle Atlas during 3 months (Mai to June), on 15 male lambs' entire of Moroccan Timahdite breed, about 6 months of age, originating from the same farm, weaned at 3 months of age and divided into three equal groups according to live weight (average initial weight of 23 kg). The first group was allowed to graze natural pasture (PP) during the whole experiment period, the second was fed a diet containing about 50% commercial concentrate feed and 50% oat hay (CC) and the last one was allowed to graze pasture and received hay and concentrate as supplements (PC). The commercial concentrate feed provides 18% of crude protein, 10% of minerals, 0.3% of phosphorus and 0.6% of calcium. PP and PC animals grazed the whole day while CC animals received an average of 620 and 800 g/head/day of concentrate and oat hay respectively. Before going to the pasture, PC animals had half of hay and concentrate-quantity given to CC group. Water was available for PP and PC animals when returning from pasture and at all time for CC group.

2. Slaughtering and carcass measurements

The five lambs used in each group, about 9 months age, were slaughtered as the Muslim slaughtering way at the end of the trial at average live weight of 41 kg. Animals were slaughtered on different days each time they reached approximately a 41 kg live weight. Thus the slaughtering process lasted 20 days.

Animals had access to water until approximately 12 hours before slaughtering and then were transported by truck for about 80 km to the slaughter house. Immediately after slaughter, carcasses were weighed and graded for fatness using the European grids. Measurements on carcasses were carried out using compasses, ribbon for tailors and calipers to determine the main indicators of carcass conformation. The index of carcass compacted was calculated through formulas (Ilişiu *et al*., 2010).

Subcutaneous fat color was measured by a Minolta CR410 spectro-colorimeter (CIEL $L^*a^*b^*$) at 12h post mortem. The carcasses were then let for 6 h at ambient temperature and then transported to a cold room set to 4°C.

3. Meat quality assessment

At 24 h post mortem the ultimate-pH was determined. Color measurements were taken by a Minolta CR410 after 12h post mortem on the *semimembranous* muscle.

Taste scoring test concerned meat from PC and CC groups. The day after of slaughtering, two legs from each group were used to carry out the test. Thick pieces were cooked under steam during 1.15 hour and two-cm thick pieces were served warm to 20 inexperienced panelists. During two sessions, panelists evaluated two samples presented in randomized order. Panelists were asked to evaluate the intensity of tenderness, juiciness and meat flavor using a scoring grid for each parameter.

4. Statistical analysis

Analysis of variance was performed by GLM procedure (SAS, 1991). The effect of the diet as a fixed effect on all variables was analyzed according to the following model: Yij = a + Di + Eij, where "Yij" is the variable analyzed; "a" is the overall mean, "Di" is the effect of diet (i = PP, CC and PC). The error term was "Eij". The Student-Newman Keul's procedure was used to separate least squares means when significant main effects were detected.

Taste test data were evaluated using the X^2 test.

III – Results and discussion

1. Carcass characteristics

Effects of diet on carcass characteristics are presented in Table 1. Diet had a significant effect on dressing percent (P = 0.05). Carcasses did not differ for carcass compactness index (P = 0.5). Carcasses from lambs raised on pasture had lower fatness score than those of animals raised with the concentrate based diet. This could be related to the physical activity compared to stall ones.

Subcutaneous fat color from grass lambs was more yellow (b^* higher) than that from stall lambs (P <0.001). The yellowness of fat is related to the presence of carotenoids in grass lambs (Prache and Theriez, 1999; Priolo *et al*., 2002). Carotenoids are pigments found in a higher concentration in fresh grass and give a yellow color to the subcutaneous fat (Jacques and Baba-Khelil, 2010).

Table 1. Carcass characteristics of lambs as affected by diet

	Feeding system			*SEM*	*P-value =*
	PP	CC	PC		
Number of lambs	5	5	5	–	–
Live weight at slaughter (kg)	40.9	40.7	41.4	1.48	0.5
Carcass weight (kg)	19.4	19.5	19.7	0.33	0.6
Dressing percent (%)	47.4^b	48.0^a	47.5^b	0.08	0.05
Fatness (1 to 5 scale)	2	3	2		–
Carcass compactness index (kg/cm)	0.35	0.36	0.35	0.00008	0.5
L^*	76.50^b	84.50^a	76.90^b	0.49	0.0001
a^*	3.68^b	5.23^a	3.37^b	0.09	0.0001
b^*	7.9^b	6.63^a	7.93^b	0.17	0.001

^{ab}: values having the same letter not significant.

2. Meat instrumental and sensorial quality

Impacts of diet on muscle instrumental quality are presented in table 2. Diet affected significantly the ultimate pH (P = 0.0001). However, values were higher than those reported by Muller (2011) for a good quality meat. It ranged between 5.67 and 5.98 *vs* 5.5 and 5.7 for a normal ultimate pH (Muller, 2011). As opposed to the results found by Priolo *et al.* (2002), ultimate pH muscle tended to be higher for the stall lambs compared to the grass lambs (P = 0.0001). Such differences may be attributed partially to the pre-slaughter factors.

According to Institut de l'Elevage (2006), pre-slaughter factors i.e. transport and slaughter process can stress animals, cause the decrease of glycogen reserve in the muscle and therefore increase ultimate pH. In fact, during the slaughter period the transport of stall lambs were done during the hotter days of June (T > 35°C) for a large distance (81 km) separating the farm and slaughter house.

At 12 h post mortem, meat lightness was higher for PP and PC groups than for CC group meat (P = 0.0001). This difference in meat lightness could be linked to the difference in the ultimate pH since high pH meats tend to have a darker colour (Ledward *et al.*, 1986). The index of redness (a^*) is higher in meat from pasture systems (PP and PC) than that from intensive system (CC) which means that grass lamb meat is redder than stall lamb meat.

The results of sensory evaluation are shown in table 3 and. Meats from PC lambs were more tender, juicy and tasty than that from CC lambs. However, the chi-square test results (table 3) show that diet impacted significantly the tenderness and the juiciness of meat (P < 0.05) but not the flavor (P = 0.1).

Table 2. Effect of diet on *semimembranous* muscle characteristics

	Feeding system			*SEM*	*P-value =*
	PP	CC	PC		
Number of lambs	5	5	5		
Ultimate pH	5.67^{b}	5.98^{a}	5.67^{b}	0.004	0.0001
L^*	46.7^{b}	42.2^{a}	46.4^{b}	0.47	0.0001
a^*	21.9^{a}	21.4^{a}	21.8^{a}	0.28	0.5
b^*	6.8^{ab}	5.3^{a}	6.8^{b}	0.57	0.05

^{ab}: values having the same letter not significant.

Table 3. Effects of feeding systems *semimembranous* muscle sensory evaluation

	X^2 Pearson value	Minimum Theoretical effective	P-value =
Tenderness	8.9	1.48	0.011
Juiciness	12.3	2.96	0.006
Flavor	4.4	5.92	0.11

IV – Conclusions

This experiment was designed to compare grass-fed and concentrate-fed lambs, when animals were slaughtered at the same body weight.

Lambs raised on pasture had lower dressing percent, lower and more yellow subcutaneous fat. They have lower pH and more preferred by the consumer than that from concentrate and hay based-diet animals.

Acknowledgments

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Applicability of the genuineness official parameters to the milk fat from cows consuming mountain pasture: the case of triglyceride composition

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Abstract. It is well known that mountain pasture affects the fatty acid (FA) composition of milk fat. The Official EU method for the evaluation of cow milk fat purity is based on the triglyceride (TAG) analysis. The percentage of each TAG is inserted into five specific formulae (S). The resulting five S parameters, for a genuine milk fat, have to fall inside the corresponding limits; if only one of them is outside the limits, the milk fat is judged as adulterated. In this research, milk samples deriving from cows feeding mountain pasture, in absence or with low amounts of concentrates, were analyzed for their FA and TAG composition and the purity was calculated by using the S parameters. All the samples showed the characteristic FA composition of milk fat from mountain pasture-fed cows: high concentration of linolenic acid (1.1 ± 0.32), vaccenic acid (3.8 ± 0.57), *cis*-9,*trans*-11 CLA (1.7 ± 0.25), as well as low concentration of saturated fatty acids (62.9 ± 1.50). However, all the samples provided false positive results for at least one of the five S parameters. In order to avoid improper charges of adulteration, this behaviour should be taken into account by the competent authorities.

Keywords. Mountain pasture – Milk fat – Genuineness – Triglycerides – Fatty acids.

Applicabilité des paramètres officiels d'authenticité à la matière grasse du lait de vache à l'alpage : le cas de la composition en triglycérides

Résumé. *Il est bien connu que les pâturages de montagne modifient la composition en acides gras (AG) de la matière grasse du lait. La méthode officielle de l'UE pour l'évaluation de la pureté de la matière grasse du lait de vache est basée sur l'analyse des triglycérides (TG). Le pourcentage de chaque TG est introduit dans cinq formules spécifiques. Les cinq paramètres S résultants, doivent être compris dans des limites correspondant à une matière grasse du lait pure; même si un seul des paramètres est en dehors des limites, la matière grasse du lait est jugée non conforme. Dans cette étude, des échantillons de lait provenant de vaches pâturant des alpages, en l'absence ou avec de faibles quantités de concentrés, ont été analysés pour leur composition en AG et TG et la pureté a été calculée en utilisant les paramètres S. Tous les échantillons ont montré une composition en AG, caractéristique de la matière grasse du lait de montagne : une concentration élevée en acide linolénique (1,1 ± 0,32), acide vaccénique (3,8 ± 0,57), CLA (1,7 ± 0,25), ainsi qu'une concentration réduite en acides gras saturés (62,9 ± 1,50). Cependant, tous les échantillons ont donné des résultats faux positifs pour au moins l'un des cinq paramètres S. Afin d'éviter des déclarations de falsification incorrectes, ce résultat doit être examiné par les autorités compétentes.*

Mots-clés. *Alpage – Matière Grasse du lait – Authenticité –Triglycérides – Acides gras.*

I – Introduction

The Official EU method for the evaluation of cow milk fat purity is based on the triglyceride (TAG) analysis (Reg. CE 273, 2008) and on the values obtained inserting TAG results into five specific equations. If only one of the results of these five equations falls outside the limits that are characteristic for pure milk fat, the sample is judged as adulterated.

Since TAG are molecules in which three FA are esterified to the glycerol backbone, their composition is strictly dependent on the linked fatty acids and, consequently, they are affected by the same factors of variation, first of all, the feeding system. The high diversity in the botanical composition of grass, the environmental conditions, the low density of net energy of alpine herbage that increases the body fat mobilization, are some of the factors responsible for the particular characteristics of the fatty acid composition of milk fat from cows consuming mountain pasture (Lourenço *et al.*, 2008; Povolo *et al.*, 2013).The saturated FA content, particularly palmitic acid, was lower in mountain milk than that found in milk derived from the intensive breeding systems; at the same time, except for linoleic acid, monounsaturated and polyunsaturated FA, particularly linolenic acid, were higher (Leiber *et al.*, 2005). Finally, the mountain milk fat was characterized by the high content of isomer *cis*-9, *trans*-11 of conjugated linoleic acids and their precursor, vaccenic acid (C18:1 *trans*-11).

In this research, milk samples deriving from cows feeding mountain pasture, in absence or with low amount of concentrates, were analyzed for their FA and TAG composition and the purity was calculated by using the S parameters.

II – Materials and methods

Bulk milk samples were collected in two mountain areas, at altitude varying from 1800 to 2100 m, (East and West Italian Alpine region) during the summer period from cows grazing on pasture in absence (20 samples) or with 1.5 (14 samples) or 3 (13 samples) kg /(cow x day) of concentrate. The pastures of the East and West area were characterized by *Festuca rubra* and *Nardus stricta*, respectively. The concentrate supplemented to the cows grazing in the East zone of the Alpes had a higher protein and a lower fat content than that supplemented to the cows grazing in the West zone.

Milk samples were stored at -20°C until the analyses, which were done in duplicate. The fat fraction was extracted according to ISO 14156 (2001). The FA composition was carried out on methyl esters obtained according to ISO 15884 (2002) and applying the GC conditions described by Povolo *et al.* (2013). The analysis of TAG composition was performed following the Official EU method (Reg. CE 273, 2008).

Data obtained were evaluated by both univariate (ANOVA) and multivariate (PCA) statistical analyses.

III – Results and discussion

The first evaluation of the results was made by applying PCA analysis to the whole data set (47 objects and 43 variables) subdivided into the east (E) and west (W) Alpine area both labelled 0, 1.5, 3, according to the amount of concentrate in the diet (Fig. 1). A well defined separation between the two Alpine zones occurred on the first-component axis. On the contrary, no clear distinction was observed among the different contents of concentrate in the diet, even though a slight tendency to a distribution according to the concentrate content was observed along the second component axis. This result demonstrated that the FA composition of milk was largely influenced by the type of pasture growing in the different Alpine areas and this difference was not affected by the presence of supplementation. This result was confirmed by the ANOVA applied to the FA grouped on the basis of the presence of double bonds (SFA = saturated, MUFA = monounsaturated, PUFA = polyunsaturated), on the position of double bonds (omega-3) and on the geometrical isomerization (Trans). As it is reported in Table 1, all the FA classes showed high significant differences between the types of pastures, independently of the amount of supplementation.

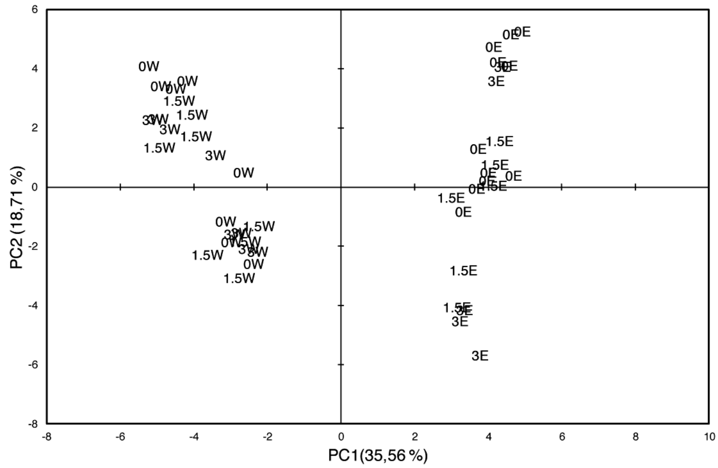

Fig. 1. Plot of the scores of the 47 milk samples on the first and second principal components.

Table 1. Mean and standard deviation of fatty acids, expressed as% on the total fatty acids

	Only pasture			+ 1.5 kg conc.			+ 3 kg conc.		
	East	West		East	West		East	West	
SFA	62.1±1.01	64.2±0.96	**	62.0±1.08	63.9±1.23	*	61.2±1.23	63.3±1.40	*
MUFA	33.1±0.80	29.2±0.74	**	33.1±0.88	29.5±1.04	**	33.6±0.80	29.9±1.00	**
PUFA	4.8±0.35	6.6±0.31	**	4.9±0.43	6.7±0.35	**	5.1±0.57	6.8±0.49	**
Omega-3	0.9±0.11	1.5±0.18	**	0.9±0.08	1.5±0.09	**	0.9±0.13	1.6±0.25	**
Trans	5.5±0.28	7.5±0.40	**	5.2±0.20	7.5±0.43	**	5.4±0.14	7.4±0.29	**
C18:1 *t11*	3.4±0.13	4.3±0.39	**	3.1±0.12	4.3±0.38	**	3.3±0.15	4.2±0.18	**
CLA	1.5±0.12	1.9±0.11	**	1.4±0.09	1.9±0.16	**	1.4±0.13	1.9±0.10	**
C18:2 *t*11,*c*15	0.3±0.08	0.7±0.04	**	0.3±0.03	0.7±0.05		0.3±0.03	0.7±0.08	**

** $P<0.01$; * $P<0.05$.

Moreover all the samples showed a FA composition typical of mountain milk fat: low SFA content, high PUFA, CLA and *trans* fatty acids (Collomb *et al.*, 2002). Among the latter category, it is worth noting the high values of both vaccenic acid (C18:1 *t*11) and C18:2 *t*11,*c*15, the highest non-conjugated linoleic acid isomer found in mountain milk samples, accordingly to Collomb *et al.* (2008).

Figure 2A shows an example of the TAG profile obtained applying the EU official method. Sixteen peaks identified on the basis of the sum of the number of carbon atoms of FA esterified into the TAG, and quantified as percentage on the total TAG content, were obtained.

The values of the five S parameters (S1 to S5) calculated to evaluate the genuineness of milk fat provided the following results: all the samples fell out the limits for S1, 20% of samples for S2, 67% of samples for S3, and 52% of samples for S4 and S5. An example is given in Fig. 2B, where the results of S1 formula are reported, together with the range that is characteristic of the pure milk fat. All the mountain milk fat samples, independently of the possible presence of concentrate in the diet, did not meet the law requirements to be considered as genuine milk fat.

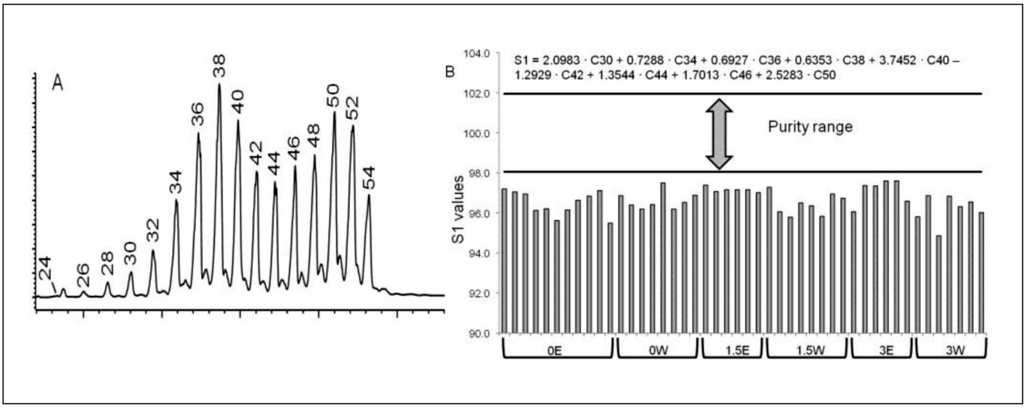

Fig. 2. GC profile of TAG of a mountain milk fat sample (A) and values obtained by the application of S1 purity parameter to all the mountain milk fat samples (B).

IV – Conclusions

Independently of the factors responsible for the particular characteristics of the fatty acid composition of milk fat deriving from cows consuming mountain pasture, this feeding system also affects the TAG composition on which the EU Regulation defines the parameters of the milk fat genuineness. It seems very important to avoid improper charges of adulteration related to milk and dairy products that very often are characterized by high quality composition and unique value. Thus, this evidence has to be pointed out to the competent authorities in order to guarantee the protection of these productions. A first action on this direction has been already undertaken by the Italian delegation of the ISO Committee, to mention this problem within the scope of the ISO 17678 (2010) standard that reports the reference method for milk fat TAG determination.

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Dairy cow grazing selection on upland pasture affects milk fatty acid concentrations

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Abstract. This work aimed to explore variations in milk FA concentrations according to the rate of pasture utilisation and cows grazing selection. Two groups of nine dairy cows were assigned to a long duration (LD) of paddock utilisation (17 days) on heterogeneous pasture, or to a medium duration (MD) of paddock utilisation (7-10 days) on a more intensively managed pasture. Grazing selection was characterized at the beginning and at the end of each MD paddock utilisation and at the same dates for LD. Individual milk samples were collected the first three days and the last two days of grazing on each MD paddock for both systems. A principal component analysis (PCA) was performed on milk fatty acid (FA) concentrations and grazing selection data, aiming to highlight their relationships. The LD samples were poorly separated by the PCA according to the day of paddock utilisation, because of small variations in LD milk FA composition. The free-grazing selection allowed LD cows to ingest herbage with a quite constant nutritional value throughout the experiment. In contrast, the PCA showed a marked separation between samples from the beginning and from the end of each MD paddock utilisation. The MD cows grazed "by layers" inducing a rapid decrease in the nutritive quality of ingested patches during paddock utilisation, with consequently important variations in milk FA composition.

Keywords. Grazing selection – Grazing system – Milk fatty acids – Upland pasture.

La sélection alimentaire des vaches laitières au pâturage sur des prairies de montagne influence les concentrations des acides gras du lait

Résumé. *Deux groupes équivalents de 9 vaches laitières ont été soumis : soit à un pâturage de longue durée (LD) sur une parcelle de prairie hétérogène (17 jours); soit à un pâturage de durée moyenne (MD) sur des parcelles de prairie gérée de façon plus intensive (7-10 jours). La sélection alimentaire au pâturage a été caractérisée au début et à la fin d'utilisation de chaque parcelle de MD, sur les deux systèmes. Des échantillons individuels de lait ont été collectés les 3 premiers et les 2 derniers jours d'utilisation de chaque parcelle de MD, sur les deux systèmes. Une analyse en composante principale (PCA) a été faite sur les données de concentrations en acides gras (FA) du lait et de sélection alimentaire au pâturage, pour mettre en évidence leurs relations. Les échantillons de LD ont été mal discriminés par la PCA selon les jours d'utilisation de la parcelle. Par contre, pour MD, la PCA a montré une nette séparation des échantillons de début et de fin d'utilisation de chaque parcelle. Les vaches sur MD ont pâturé par horizons, avec pour conséquence une diminution rapide de la qualité nutritive de l'herbe ingérée au cours de l'utilisation de la parcelle et des variations importantes de la composition en FA du lait.*

Mots-clés. *Sélection alimentaire au pâturage – Systèmes de pâturage – Acides gras du lait – Prairies de montagne.*

I – Introduction

In the upland farming systems, considerable day-by-day variations in milk yield and composition are frequently reported by farmers and cheese makers with rotational grazing systems, according to the rate of utilisation of each paddock. Among milk components, FA concentrations concur to determine nutritional value and sensory properties of dairy products (Martin *et al.*, 2005). The FA composition of pasture-derived milk is affected by several factors, such as herbage proportion in cow diet, herbage botanical composition, phenological stage and nutritive value, all interacting with cow grazing selection and grazing system (Chilliard *et al.*, 2007; Coppa *et al.*, 2011b; Farruggia *et al.*, 2014). In this experiment, two rotational grazing systems on upland pasture were studied: a long duration of paddock utilisation (LD) on highly biodiversified pasture, which is typical of extensive rotational grazing systems; and a medium duration of paddock utilisation (MD) on a more intensively managed pasture, which is typical of intensive rotational grazing systems. This work aimed to highlight the links between the variations in milk FA composition and changes in grazing selection according to the duration of paddock utilisation on MD and LD systems.

II – Materials and methods

The FA concentrations have been monitored in milk of two equivalent groups of 9 cows in June, during a period of 17 days, corresponding to the duration of the grazing rotation of LD group. At the same time, the MD group cows grazed successively 2 paddocks for 7 and 10 days. The LD paddock (9.7 ha) a highly diversified pasture (139 botanical species) managed under a low stocking rate, while MD paddocks (6.4 ha) were moderately diversified (62 species) and more intensively managed pasture. As usual in the intensive rotational grazing systems, the MD cows were supplemented dairy with 4 kg of concentrate/cow. Grazing selection was characterized through direct observations and simulated bites (Farruggia *et al.*, 2008) collected at the beginning and at the end of the utilisation of two subsequent MD paddocks, and at the same days for LD. Simulated bites were analysed for botanical composition and nutritive value. Individual milk was sampled the first three days and last two days of grazing on each MD paddock, and simultaneously also on LD system. Milk samples were analysed for FA analysis by gas-chromatography. A Principal Component Analysis (PCA) was performed (SPSS software 17.0; SPSS Inc., Chicago, IL) on the main milk FA, parameters of grazing selection and composition of simulated bites, aiming to show the relationships between the milk FA concentrations and grazing selection of cows in the two grazing systems.

III – Results and discussion

On the plot of PCA individual distribution, samples were separated according to the day of paddock utilisation for principal component (PC) 1 and according to the grazing system for both PC1 and PC2 (Fig. 1). On plot of PCA variable distribution, PC1 was positively highly correlated to the neutral detergent fiber (NDF) content of the simulated bites, short vegetative (SV) patches, milk branched chain FA (BCFA) and monounsaturated FA (MUFA) concentrations, and C18:1c9 to C16:0 ratio. The PC1 was also negatively and closely correlated to the organic matter digestibility (OMD) value of simulated bites, total high vegetative (HV) patches, milk saturated FA (SFA) concentration, and C18:1t10 to C18.1t11 ratio. The PC2 was correlated to the crude protein (CP) content, the OMD values, the Legumes proportion and the leaf to stem ratio (L/S) of simulated bites, the HV patches and milk CLAc9t11, sum C18:1t isomers and polyunsaturated FA (PUFA) concentrations and negatively correlated to the NDF content and Grasses proportion of simulated bites, high mature (HM) patches, and milk C18:2n-6/C18:3n-3 and C18:1t10/C18:1t11 ratios.

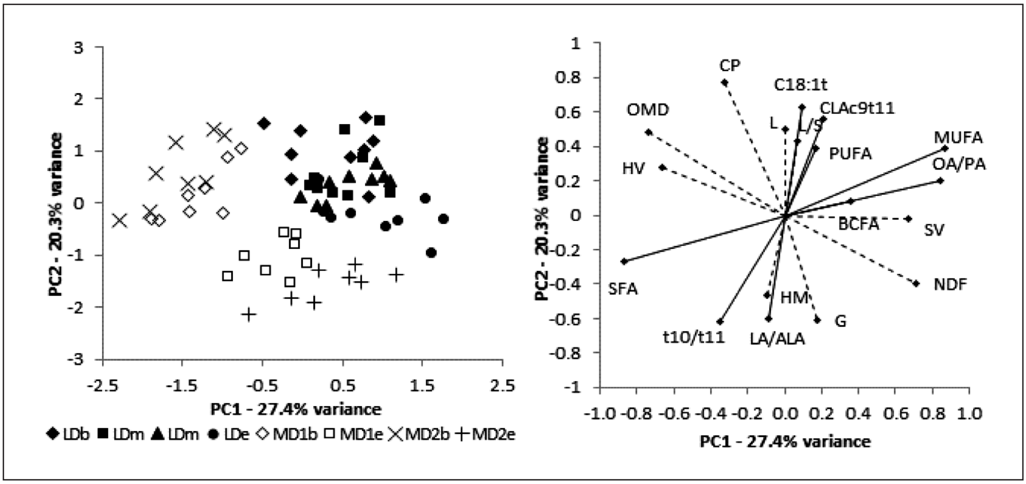

Fig. 1. Principal component analysis (PCA) performed on the main milk fatty acid concentrations, the grazing selection and composition of simulated bites. Plot of sample and variable distribution according to grazing system and day of paddock utilisation, projected on the two principal components (PC1 and PC2).

The variations in LD milk FA composition were small from the beginning to the end of LD paddock utilisation. The free-grazing selection allowed the LD cows to ingest herbage with a nutritional value that was quite constant throughout the experiment (Dumont *et al.*, 2007; Coppa *et al.*, 2011a). Indeed, the CP content and OMD value of the LD simulated bites slightly decreased (-2.8% DM, and -7.2%), and the NDF content only slightly increased (+4.2% DM) from the beginning to the end of paddock utilization. In contrast, important changes in the MD milk FA composition were observed during MD paddocks utilisation. The PCA results showed a clear separation between the samples derived from the beginning and from end of each MD paddock utilisation. The grazing "by layers" of the MD cows could cause a rapid decrease in the nutritional quality of ingested patches (i.e., decreasing the L/S (-0.5) and CP content (-6.4% DM) and increasing the NDF (7.0% DM) and ADF (+5.2% DM) contents of the simulated bites) from the beginning to the end of paddock utilisation (Abrahamse *et al.*, 2008). As herbage C18:3n-3 concentration decreased linearly with the herbage total nitrogen content (Revello Chion *et al.*, 2011), this suggests that the C18:3n-3 concentration of simulated bites decreased during MD paddock utilisation, in parallel to protein content. As a consequence, a decrease in the amount of ingested herbage C81:3n-3 (being) could have reduced the ruminal production of C18:3n-3 biohydrogenation intermediate products (including C18:1t11; -1.71g/100 g FA) and, thus, their milk concentrations, (Chilliard *et al.*, 2007). Moreover, due to a higher proportion of stems, the increased herbage fiber content at the end of MD paddock utilisation could favour the development of cellulolytic bacteria in the rumen. As these bacteria are involved in the production of BCFA (Vlaemink *et al.*, 2006), this could explain the higher milk concentration of BCFA at the end of each MD paddock utilization (on average +0.32 g/100 g FA). A higher C18:1c9 content in stems (Elgesma *et al.*, 2006) compared to leaves could be partly at the origin of the higher milk concentration of this FA at the end of each MD paddock utilization (on average +4.8 g/100 g FA).

IV – Conclusions

The long duration of paddock utilisation on heterogeneous pastures, which is typical of a extensive rotational grazing system, allowed the cows to maintain a rather stable nutritive quality of the selected patches, resulting in only slight day-by-day variations in milk FA concentrations. In contrast, the nutritive quality of the selected patches with a medium duration of paddock utilisation on intensively managed pastures, which is typical of a rotational grazing system, varied strongly during each paddock utilisation, resulting in abrupt changes in milk FA concentrations. Our results confirm the observations reported by farmers and cheese makers on the day-by-day variations in milk characteristics and explain why a longer duration of paddock utilisation could be more favourable for farmhouse cheese making management.

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The main fatty acids of bulk milks can be predicted with rapid farm surveys

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Abstract. This study aimed to predict the cow milk fatty acid (FA) composition using farming practices described through on-farm surveys. The FA composition of 1248 bulk milk samples and the related farming practices came from 20 experiments conducted in 10 different European countries. Samples derived from farms located between 44°N to 60°N altitude, and from sea level to 2000 m altitude. The prediction equations of milk FA composition were considered good (R^2 > 0.50) for C16:0, saturated FA (SFA), poly-unsaturated FA (PUFA), and odd-chain FA (OCFA), and very good (R^2 ≥ 0.60) for C18:1t11, CLAc9t11, total trans-FA, C18:3n-3, n-6/n-3 ratio, and branched-chain FA (BCFA). The main predictors were variables describing diet composition and altitude, whereas animal-related factors (i.e. lactation stage, breed, milk yield, proportion of primiparous cows in the herd) were not significant in any of the models. The predictor having the highest effect in almost all FA models was the proportion of fresh herbage in cow diet. However, when models were calculated using only samples derived from conserved forage-based diets, good predictions were also obtained for OCFA, BCFA, C18:1t10 and C18:3n-3 (R^2 ≥ 0.46, 0.54, 0.52, and 0.70, respectively). These prediction models could be a valuable tool to help farmers to improve the nutritional quality of the milk they produce.

Keywords. Bulk milk – Fatty acid – Farming practices – Prediction models.

Les acides gras du lait de tank peuvent être prédits par des enquêtes rapides en ferme

Résumé. *L'objectif de ce travail était de prédire la composition en acides gras (AG) du lait en utilisant des données de condition de production collectées par des enquêtes rapides en ferme. La composition en AG de 1248 laits de tank et leurs conditions de production associées provenaient de 20 expérimentations réalisées dans 10 pays européens. Les échantillons ont été collectés dans des fermes localisées entre 44°N et 60°N de latitude et entre zéro et 2000 m d'altitude. Les équations de prédiction des AG du lait ont été considérées comme bonnes (R^2 > 0,50) pour le C16:0, les AG saturés (AGS), les AG polyinsaturés (AGPI), et les AG à chaine impaire (OCFA), et comme très bonnes (R^2 ≥ 0,60) pour le C18:1t11, CLAc9t11, les AGtrans totaux, le C18:3n-3, le ratio n-6/n-3, et les AG à chaine ramifiée (BCFA). Les principaux prédicteurs étaient des variables décrivant l'alimentation des troupeaux et l'altitude. En revanche, les facteurs liés à l'animal (tels que stade de lactation, race, production de lait, proportion de primipares dans le troupeau) n'étaient pas significatifs dans les modèles. Dans presque tous les modèles, c'est la proportion d'herbe fraîche dans la ration qui était le meilleur prédicteur des AG du lait. Dans une sous-population d'échantillons de lait issus de troupeaux alimentés seulement avec des fourrages conservés, de bonnes prédictions ont également été obtenues pour les OCFA, BCFA, C18:1t10 et pour le C18:3n-3 (R^2 ≥ 0,46, 0,54, 0,52, et 0,70, respectivement). Ces modèles de prédiction obtenus à l'échelle de l'exploitation pourront être utilisés par les éleveurs pour améliorer la qualité nutritionnelle de leur lait.*

Mots-clés. *Lait de mélange – Acides gras – Conditions de production – Modèles de prédiction.*

I – Introduction

In agreement with the World Health Organisation recommendations on fatty acid (FA) consumption for human nutrition, several dairy companies in various EU countries (including France, Belgium, The Netherlands, etc.) apply a price premium for cow's milk rich in health-promoting FA (i.e. n-3 and PUFA; Borreani *et al.*, 2013). Thus, farmers need to obtain information on the expected FA profile of their milk. However, the majority of studies investigating the effect of diet and animal-related factors on milk FA profile were controlled trials (i.e. Couvreur *et al.*, 2006; Ferlay *et al.*, 2006), usually applying measurements of farming practices not suitable on farm. This is also the case for milk FA prediction models that are reported in literature (Glasser *et al.*, 2008; Moate *et al.*, 2008). To our knowledge, no model has yet attempted to predict FA composition of bulk milk from commercial farms, based on simple farm surveys. Farming practices vary widely according to country and agronomical context, but most of the literature tends to operate at tight territorial scale. Collecting data from a wide territory makes it possible to explore a broad range of farming practices and thus of FA profiles of commercial milk. This study aimed to predict the cow milk FA composition using farming practices collected via on-farm surveys in different European countries.

II – Materials and methods

The FA profiles of 1248 bulk milk or cheese samples and their related farming practices were compiled from a selection of 20 published or unpublished studies carried out from 2000 to 2010 in 10 different European countries: France, Germany, Italy, Norway, Slovakia, Slovenia, Czech Republic, Denmark, Sweden, and The Netherlands. The details of the experiments used are given by Coppa *et al.* (2013). The experiments were conducted on-farm and included bulk milk collected on commercial farms at between 44°N to 60°N latitude, from sea level up to 2000 m altitude, from 13 different cow breeds during different seasons. Data on farming practices were collected on-farm at each milk sampling by surveys (Coppa *et al.*, 2013), that included herd characteristics, diet composition of lactating cows, and altitude. The milk FA analyses were performed by 5 different laboratories using gas-chromatographic methods. To develop a prediction of FA composition based on farming practices data, a general linear model (GLM) was applied using experiment as fixed factor and farming practices as covariates. Root mean square error (RMSE) and R^2 were used to describe model fitting. The Fisher's F-distribution of each variable included in a model was used as an indicator of the relative weight of the variable in determining the model itself. As the proportion of fresh herbage in cow diet was expected to be the main covariate of most models, new models were developed on a subset of data where milk samples derived from cow fed diets based on conserved forages. Statistics were performed with Minitab 14.1 software (Minitab Inc., State College, PA).

III – Results and discussion

The predictive equations of milk FA composition are given in Table 1 and were considered as good ($R^2 > 0.50$) for C16:0, saturated FA (SFA), polyunsaturated FA (PUFA), and odd-chain FA (OCFA), and very good ($R^2 \geq 0.60$) for C18:1t11, CLAc9t11, total trans-FA, C18:3n-3, n-6/n-3 ratio, and branched-chain FA (BCFA). The C16:0 increased with concentrates and decreased with fresh herbage and grass silage proportions in herd diet. The increase in milk SFA was well predicted by increases in all the conserved forages and concentrates in herd diet, confirming the high proportion of SFA found in milk from conserved forages and concentrate-rich diets (Dewhurst *et al.*, 2006; Ferlay *et al.*, 2008). The OCFA increased with the increasing proportions of hay and grass silage in the diet and decreased with increasing proportions of maize silage and concentrates. The BCFA were well predicted by an increase in fresh herbage and hay and a decrease in maize silage and concentrates in diet. This is consistent with the hypothesis that high-NDF feeds (i.e. fresh herbage and hay) favour ruminal populations of cellulolytic bacteria (Vlaemink *et al.*, 2006).

Table 1. Prediction models of FA proportions (g/100g FA) in bulk milk based on farming practices†

Fatty acids	Global equations	n	RMSE	R^2
All milk samples				
C16:0	32.83(±0.28)-7.51(±0.28)×FH-2.42(±0.47)×GS+4.33(±0.71)×C	987	2.12	0.57
C18:1t11	1.39(±0.18)+1.9(±0.1)×FH+0.43(±0.13)×GS-0.61(±0.15)×MS-9.31(±2.16)×C	592	0.50	0.72
C18:1c9+t13	19.11(±0.34)+2.2(±0.29)×FH-1.95(±0.35)×H+2.76(±0.69)×C	993	1.90	0.41
C18:2n-6	0.97(±0.04)-0.14(±0.05)×GS-0.11(±0.04)×H+0.50(±0.06)×MS+0.66(±0.08)×C +0.217(±0.030)×A	902	0.25	0.36
C18:3n-3	0.65(±0.04)+0.26(±0.03)×FH+0.28(±0.03)×H-0.39(±0.05)×MS-0.37(±0.06)×C	990	0.15	0.66
CLAc9t11	0.9(±0.04)+0.77(±0.03)×FH-0.31(±0.06)×MS-0.61(±0.09)×C	996	0.27	0.70
SFA	58.69(±0.29)+6.31(±0.54)×GS+7.68(±0.40)×H+7.87(±0.58)×MS+6.21(±0.8)×C	930	2.58	0.55
MUFA	25.4(±0.39)+4.22(±0.31)×FH-1.58(±0.48)×H-0.050(±0.030)×A	666	2.09	0.41
PUFA	2.8(±0.08)+1.58(±0.09)×FH+0.28(±0.14)×H+0.547(±0.080)×A	684	0.62	0.54
OCFA	2.36(±0.03)+0.40(±0.03)×H-0.17(±0.05)×MS-0.97(±0.06)×C	739	0.20	0.50
BCFA	2.45(±0.06)+0.33(±0.05)×FH+0.43(±0.06)×H-0.41(±0.08)×MS-0.93(±0.11)×C 737 0.24 0.61			
Σ trans-FA	2.56(±0.11)+3.21(±0.14)×FH	540	0.96	0.66
Σ n-6/Σ n-3	4.49(±0.15)-3.56(±0.16)×FH-3.24(±0.24)×H-3.77(±0.21)×GS	435	0.59	0.67
Only conserved forages-derived milk samples				
C18:1t10	0.06(±0.19)+0.23(±0.02)×MS+0.42(±0.04)×C	226	0.06	0.56
C18:3n-3	0.45(±0.02)+0.43(±0.03)×H-0.33(±0.04)×MS	442	0.12	0.75
OCFA	2.24(±0.06)+0.51(±0.06)×H-0.78(±0.13)×C	298	0.19	0.61
BCFA	1.45(±0.09)+0.83(±0.13)×GS+1.19(±0.11)×H+0.52(±0.13)×C +0.213(±0.046)×A	330	0.19	0.65

† FH, GS, H, MS, and C indicate fresh herbage, grass silage, hay, maize silage and concentrate in the cow diet, respectively, expressed as percentage divided by 100; A: altitude, expressed as km a.s.l.; Coefficients are reported as means (± SE); RMSE: root mean square error.

Increasing fresh herbage and hay and decreasing maize silage and concentrates in the diet increased milk C18:3n-3 proportion, in agreement with literature data (Chilliard *et al.*, 2007). Milk C18:2n-6 proportion increased with increasing maize silage and concentrate proportions in the diet. The C18:2n-6 is already an indicator of maize silage-based diets as maize is rich in this FA (Dewhurst *et al.*, 2006). Even so, the prediction was relatively poor ($R^2 = 0.36$), possibly due to the multiple dietary sources of C18:2n-6 in cow diet (Chilliard *et al.*, 2007). The decrease in milk PUFA and n-6/n-3 with decreasing fresh herbage or hay proportions in the diet is in agreement with the higher n-3 PUFA and relatively lower n-6 intake with these diets (Chilliard *et al.*, 2007). The increases in CLAc9t11, C18:1t11 and total trans FA proportion with increasing proportion of fresh herbage and grass silage and decreasing proportion of maize silage and concentrates are in agreement with literature (Dewhurst *et al.*, 2006). The low fits of C18:1c9+t13 can be related to the multiple sources of this FA in milk, being mainly derived from mammary Δ9-desaturation of C18:0, from diet and from mobilization of body fat reserves, (Chilliard *et al.*, 2007), but also depending on pasture type and phenology (Coppa *et al.*, 2011).

The quality of the models was maintained for BCFA and n-6/n-3 ratio and improved for OCFA, C18:1t10, C18:2n-6 and C18:3n-3 when calibration was made only on milk samples derived from conserved forages diets. The C18:1t10 increased with increasing starch and C18:2n-6 sources in the diet, in agreement with Griinari *et al.* (1998). Milk C18:3n-3 proportion increased with increasing proportion of hay in the diet but decreased with increasing proportion of maize silage, confirming that hay-derived milk fat is rich in C18:3n-3 (Chilliard *et al.*, 2007).

IV – Conclusions

This work provided original models to predict the FA profile of bulk milk based on farming practices collected via rapid on-farm surveys. An European scale dataset was used. Good prediction models were found for several FA. The large range of our dataset and the quality of the predictions highlighted the robustness of the cow feed effect on milk FA profile found in controlled conditions compared to animal-related factors, that seem to be negligible at farm scale. These prediction models could offer a valuable tool to help farmers to increase the proportions of health-promoting FA in milk fat.

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The effect on milk production and composition of incorporating lupin and triticale into dairy goat diets

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Abstract. In northern Morocco, goat feeding is based on rangelands that would not satisfy nutritional needs. Feed improvement is necessary. Lupin and triticale are both available resources in the region. The objective of this work is to study the effect on milk production and composition of utilizing lupin and triticale in dairy goat diets. During 115 days, 21 goats were divided into three lots of 7 each (Control, R2 and R3). The basic food ration was based on rangeland and *ad libitum* oat hay and supplemented with 3 concentrate diets with 0, 25, 50% of lupin and 0, 50, 25% of triticale, respectively. Milk production was quantified every two weeks and milk samples were collected monthly to determine chemical composition (fat, protein, lactose and defatted dry extract) using an infrared method. Milk production was not affected significantly by concentrate ration (P>0.05). Milk production was estimated at 446.5 g/d, 416.8 g/d and 495.0 g/d for the control, R2 and R3, respectively. Protein content, lactose, and defatted dry extract were not affected by lupin and triticale introduction. But fat was significantly higher with 50% DM of lupin (P < 0.05). Recorded fat was 3.44%, 3.00% and 4.33% for the control, R2 and R3, respectively. Lupin and triticale can be introduced into dairy goat diets without negative effects on milk production and composition.

Keywords. Lupin – Triticale – Dairy goat – Milk production – Milk composition.

Effet de l'incorporation du lupin et du triticale dans la ration sur la production et la composition du lait des chèvres laitières

Résumé. *Au Nord du Maroc, l'alimentation des caprins est basée presque exclusivement sur l'exploitation des ressources sylvo-pastorales. L'amélioration du calendrier alimentaire s'avère nécessaire, pour répondre aux besoins des animaux. Ce travail a étudié l'effet de l'incorporation dans la ration du lupin et du triticale, deux ressources alimentaires disponibles dans la région, sur les performances de production et la composition du lait des chèvres laitières. Durant 115 jours, 21 chèvres ont été réparties en 3 lots (Témoin, R2, R3) de 7 chèvres chacun. Leur alimentation est basée sur le parcours et le foin d'avoine à volonté, supplémentés par 3 rations de concentré contenant 0, 25, 50% du lupin et 0, 50, 25% du triticale, respectivement pour les lots Témoin, R2 et R3. La production laitière a été mesurée tous les 15 jours et des échantillons du lait ont été prélevés mensuellement pour déterminer la composition chimique du lait par la spectrométrie dans le proche infrarouge. La production laitière journalière et les teneurs du lait en protéines, lactose, et extrait sec dégraissé n'ont pas été affectées par l'introduction du lupin et du triticale. Par contre la teneur en matière grasse du lait du lot R3 a été significativement supérieure à celle des lots témoin et R2 (4,33%, 3,44% et 3,00%*; P<0,05). *Le lupin et le triticale peuvent être introduits dans la ration de la chèvre laitière sans affecter négativement la production et la composition du lait.*

Mots-clés. *Lupin – Triticale – Chèvre laitière – Production laitière – Composition du lait.*

I – Introduction

In the mountainous region of the North of Morocco (Tangier-Tetouan), goat population represents 37% of ruminant livestock and contributes to more than 70% in household income (Chentouf *et al.*, 2011). However, feeding is mainly based on forest rangelands and characterized by strong seasonal variability (Chentouf *et al.* 2004) responsible of the low productivity of herds (Chentouf *et al.,* 2006). Lupin and triticale are two potential feed resources in the region that can improve feed calendar of goat livestock in the region. In this context, the objective of this study was to analyze the effect of incorporation of lupin and triticale in dairy goat diet on milk production and composition.

II – Material and methods

The study was conducted in INRA experimental station of Tangier located at latitude 35°66' N and longitude 5°85' W. During 115 days, 21 goats were divided into 3 groups (control, R2 and R3 lots) of 7 goats each. The basic food ration of these lots was based on rangeland and ad-libitum oat hay and was supplemented by three types of iso-energetic and iso-nitrogenous concentrate composed by barley grain, triticale, lupin, faba beans and a mineral-vitamin supplement.The rates of lupin - triticale incorporation were 0% -0%, 25% -50% and 50% -25% dry matter of concentrate respectively for control, R2 and R3 lots. During lactation period, milk production was recorded every two weeks by quantifying milk production of 24 hours to determine milk yield. Milk samples were collected every month to determine the chemical composition of milk (fat content, protein content, lactose and defatted dry extract) using infrared method by MilkoScan ™ Minor ®. Statistical analysis of data to determine means and variance analysis of one factor (ANOVA 1) was performed using Excel 2007 and SAS (2001) programs.

III – Results and discussion

1. Milk production

The average daily milk production was estimated to 446.5 g/d, 416.8 g/d and 495.0 g/d respectively for control, R2 and R3 lots (Table 1). This production was not significantly affected by ration of concentrate (P> 0.05). The registered milk production was less than cited by El Otmani *et al.* (2013) (597.9 g/d) with Beni Arousse North Moroccan local breed.

During lactation period, estimated at 120 days, milk production average was around 58.6 kg, 54.8 kg and 65.8 kg / lactation respectively for control, R2 and R3 lots (Table 1). As daily milk production, this production per lactation was not significantly affected by introduction of lupin and triticale (P>0.05) (Table 1). The registered milk yield was similar that cited by El Otmani *et al.* (2013) with the local breed of northern Morocco Beni Arousse in the extensive system with 60.5 kg/lactation and by Hassani (1997) with 59 kg/lactation in Western rif population.

Table 1. Average milk yield per day and per lactation of tests lots (R2 and R3) and control lot (n = 7)

Lot	Lupin-Triticale in concentrate	Daily milk production (g / d)	Milk production per lactation (kg/120d)
Control	0%-0%	446.47	58.60
R2	25%-50%	416.83	54.80
R3	50%-25%	494.97	65.77
Probability	0.52	0.44	
Signification	NS	NS	

NS: not significant (P>0.05).

2. Milk composition

Protein content, lactose, and defatted dry extract in goat milk of each lot were not affected by the introduction of lupin and triticale in dairy goat diet (Table 2). However fat content in milk in lot R3 (50% lupin and 25% of triticale) were higher than Control and R2 lots and respectively 4.33%, 3.44% and 3.00% (P<0.05).

This superiority can be explained by the estimated fat content in lupin grain that is 93 g / kg of crude lupin (Moss *et al.,* 2001). Fat induces a more important liberation of acetate in rumen, known as a precursor of milk fat. Similar results were reported by by Masson (1981) in goats and Brunschwig and Lamy (2001) and Froidmont and Bartiaux-Thill (2003) in cows.

Table 2. Milk chemical composition of control, R2 and R3 lots (n = 7)

%	Lupin-Triticale in concentrate	Fat (%)	Protein (%)	Lactose (%)	Defatted dry extract (%)
Control	0%-0%	3.44[b]	3.87	4.62	9.36
R2	25%-50%	3.00[b]	4.08	4.62	9.59
R3	50%-25%	4.33[a]	4.24	4.64	9.69
Probability		0.02	0.52	0.99	0.44
Signification		S	NS	NS	NS

[a,b]: values followed by different letters are statistically different at 5%.

S: significant (P<0.05); NS: not significant (P>0.05).

No differences were observed in lactose and defatted dry extract contents produced during lactation between control, R2 and R3 lots (Table 3). However, fat and protein production per lactation were significantly higher, with a rate R3 lot compared to those observed in control and R2 groups (P < 0.05; Table 3). Produced fat was estimated to 1.91, 1.65 and 3.08 kg/lactation respectively for control, R2 and R3 lots. This superiority is mainly due to the high content of lupin in fat.

No differences were observed between the three lots regarding protein milk content, however protein production during lactation was higher in R3 lots than Control and R2 lots and respectively 2.23, 2.19 and 2.97 kg/lactation.

This high content of protein per lactation in lot R3 (Table 3) receiving 50 % of lupin and 25 % of triticale is explained by lupin effect on increase of total protein, casein, αS1 - casein and αS2 - casein in milk of dairy goats (Morales *et al.*, 2008).

Table 3. Chemical composition of milk produced during lactation of control, R2 and R3 lots (n = 7)

	Lupin-Triticale in concentrate	Fat/Lactation (kg/lactation)	Protein/ Lactation (kg/lactation)	Lactose/ Lactation (kg/lactation)	Defatted dry extract / Lactation (kg/lactation)
Control	0%-0%	1.91[b]	2.23[b]	2.75	5.48
R2	25%-50%	1.65[b]	2.19[b]	2.53	5.20
R3	50%-25%	3.08[a]	2.97[a]	3.26	6.79
Probability		0.02	0.04	0.21	0.09
Signification		S	S	NS	NS

[a,b]: values followed by different letters are statistically different at 5%.

S: significant (P<0.05); NS: not significant (P>0.05).

IV – Conclusion

The incorporation of lupin and triticale in dairy goats' diet with respective proportions of 50% - 25% DM of ration concentrate improves milk fat content about 26% and protein produced per lactation. Their incorporation in goats' dairy diet is recommended to improve the animals' food calendar and their productivity.

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Influence of Alpine highland pasture on the fatty acid and terpene composition of milk and Plaisentif cheese from various Piedmont farms

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Abstract. The aim was to characterize, monitor and certify Plaisentif, known as the "cheese of the violets", produced with raw milk from cows fed on pastures in the Chisone and Susa valleys (NW Italy) when violets are in bloom. A preliminary study was conducted over the summer of 2013 on five Alpine dairy farms to determine the fatty acid (FA) composition and terpenoid profile for the first growth cycle in permanent meadows, and for milk and ripened cheese. The pastures showed a wide diversity both in FA and terpenoid profiles. Among FAs, the most abundant were α-linolenic acid (from 40 to 61% of total FA) and linoleic acid (from 13 to 31% of total FA), while p-Cymene and α-Pinene were the most important terpenoids. As far as milk and cheese FA content are concerned, palmitic and oleic acid accounted on average for 47.2 and 47.7% of total FA, respectively. Healthy FAs, such as α-linolenic acid and conjugated linoleic acid, showed mean values of 1.4-2.1% of total FA, respectively. Terpenoid profiles of milk and cheese were very similar, even though a slight concentration of some terpenes in cheese was observed compared to the corresponding milk. Moreover, Alpine highland pasture modified the FA and terpenoid profile of Plaisentif cheese, while processing milk into ripened cheese did not affect its FA composition and terpene profile with the exception of eicosapentaenoic, butyric and caproic acids among FA, and limonene, p-Cymene and allo-Ocimene among terpenes.

Keywords. Fatty acid – Terpene – Mountain – Milk.

Influence du pâturage alpin sur la composition du lait et du fromage « Plaisentif » dans différentes fermes du Piémont

Résumé. *Le but était de caractériser le Plaisentif, le « fromage des violettes », produit avec du lait cru de vaches nourries sur les pâturages des vallées de Chisone et Suse (NO, Italie) pendant la période de floraison des violettes. Une étude a été réalisée pendant l'été 2013 dans cinq fermes laitières alpines pour déterminer les profils des acides gras (AG) et des terpènes de prairies lors du premier cycle de pâturage, du lait et du fromage affiné. Les pâtures ont montré une grande diversité dans la composition en AG et en terpènes. Les AG les plus abondants étaient l'acide α-linolénique (de 40 à 61% du total AG) et l'acide linoléique (de 13 à 31% du total AG), tandis que les terpénoides les plus importants étaient le p-Cymène et α-Pinène. En ce qui concerne le profil des AG des laits et des fromages, les acides palmitique et oléique représentaient respectivement de 47,2 à 47,7% du total des AG. L'acide α-linolénique et l'acide linoléique conjugué, ont montré des valeurs moyennes respectivement de 1,4 à 2,1% du total des AG. Les profils terpénoides des laits et des fromages sont très semblables, même si une légère concentration de les terpènes dans le fromage a été observé par rapport au lait correspondant. En outre, le pâturage des prairies alpines a affecté le profil en AG et en terpènes du fromage Plaisentif, alors que la transformation du lait en fromage affiné n'a pas modifié la composition et le profil en AG et en terpènes à l'exception de l'acide eicopentaénoïque, acide butyrique et acide caproïque parmi AG, et le limonène, le p-Cymène et l'allo-Ocimène parmi les terpènes.*

Mots-clés. *Acides gras – Terpènes – Montagne – Lait.*

I – Introduction

In Italian mountain regions, most of the milk produced is transformed into traditional cheeses. One of them, Plaisentif, also known as the ancient "cheese of the violets", is produced in the Piedmont Region during the flowering period of violets (June-July) using raw cow's milk. It has been shown how grazing quality can greatly affect the organoleptic characteristics of raw milk, with particular reference to fatty acid (FA) composition and volatile aromatic compounds such as terpenes, alcohols and ketones (Revello Chion *et al*., 2010). Several aspects of terpenes have been studied, in particular as potential biomarkers of diet, used to trace milk and mountain cheeses (Martin *et al*., 2005; Tornambé *et al*., 2006). In dairy products, particular attention concerns the content of n-3 polyunsaturated FAs and conjugated linoleic acid (CLA). Many studies have shown that these FA have beneficial effects on human health (Parodi, 2003). The presence of these compounds in milk is due to the rumen biohydrogenation of polyunsaturated FAs in animals fed with fresh forage. For this reason, their content tends to increase in milk produced from cows reared in the wild or fed with fresh grasses (Leiber *et al*., 2005; De Noni and Battelli, 2008; Revello Chion *et al*., 2011). The aim of the present study was to characterize the FA and terpenoid profile in pasture, milk, and Plaisentif cheese produced on different Piedmont mountain farms.

II – Materials and methods

A preliminary study was conducted over the summer of 2013 in five Alpine dairy farms located at 1400-1800 m a.s.l. in the Chisone and Susa valleys (NW Italy). Samples of pasture, pooled milk and 60-day ripened cheese were analysed to determine the FA and terpenoid profiles. Samples of pasture and milk were immediately frozen, freeze-dried and then stored at -20°C until the FA extraction phase. After ripening, the cheeses were cut into wedges and then frozen at -20°C. FA analyses were performed according to the method described by Revello Chion *et al*. (2010). The FA methyl esters in hexane were then injected into a gas chromatograph (Dani Instruments S.P.A. GC 1000 DPC; Cologno Monzese, Italy) equipped with a flame ionisation detector, a PTV injection port and a Supelcowax-10 fused silica column (60 m × 0.32 mm, 0.25 μm). The peak area was measured using a Dani DDS 1000 Data Station. Each peak was identified according to pure methyl ester standards (Supelco and Restek Corporation, Bellefonte, PA) and the data were expressed as relative values. The FA composition was expressed as g/100 g of FA. Terpene analysis was carried out on freeze-dried pasture and on the milk and ripened cheese fat (200 mg) extracted without the use of solvents. Terpene analysis was performed according to the method described by De Noni and Battelli (2008) by means of dynamic headspace extraction (Dani Instruments S.p.A.), gas chromatography-mass spectrometry (Agilent Technology; 500 ml He_2 for 18 min at 65°C). Data were expressed as arbitrary units, as $\log_{10}$ of the peak area of the corresponding selected ion. Data were analysed according to ANOVA in order to evaluate the effect of transformation of milk into cheese.

III – Results and discussion

The three dominant FAs detected in the pasture were α-linolenic acid (ALA, C18:3n-3), linoleic acid (LA, C18:2n-6) and palmitic acid (PA, C16:0) that accounted on average for more than 81% of total FA. Concerning milk and cheese FA composition, five FAs were the most abundant: PA, oleic acid (C18:1n-9), stearic acid (C18:0), myristic acid (C14:0) and vaccenic acid (C18:1n-7), that accounted for an average of more than 74% of total FA, while the sum of ALA and LA contents resulted lower than 4% of total FA both in milk and cheese. Conjugated linoleic acid (CLA, C18:2 cis-9,trans-11) content ranged from 1.6 to 2.4% of total FA in milk and from 1.7 to 2.5% of total FA in cheese, respectively (Table 1). The FA content of Plaisentif cheese was similar to that reported for the Toma Piemontese and Bitto cheeses produced in the Italian alpine area (Revello Chion *et al*., 2010; De Noni and Battelli, 2008). The terpenes found in all samples of pasture, milk and cheese were as follows: α-Pinene, Camphene, β-Pinene, δ-3-Carene, Limonene, p-Cymene and allo-Ocimene. The most important terpenoids in the pasture were p-Cymene and α-Pinene, while α- and β-Pinene were the most abundant in milk and cheese. The latter two were also the main terpenes found in other cheeses produced in Italian alpine regions (De Noni and Battelli, 2008; Berard *et al*., 2007). The terpene profile of pasture differed strongly from that of milk and cheese, due to the comparatively high amount of allo-Ocimene, and low amount of δ-3-carene (Table 2). The terpenoid profiles of milk and cheese were very similar, even though a slight concentration of limonene, p-Cymene and allo-Ocimene in cheese was observed compared to the corresponding milk.

Table 1. Fatty acid (FA) content (g/100 g of total FA) of pasture (n = 9), milk (n = 10), and Plaisentif cheese (n = 10) from five Piedmont farms

	Pasture				Milk				Cheese				
	Min	Max	Mean	SD†	Min	Max	Mean	SD†	Min	Max	Mean	SD†	Prob.
C4:0					2.8	3.6	3.1	0.25	2.6	2.9	2.7	0.11	0.001
C6:0					1.4	1.7	1.5	0.10	1.2	1.6	1.3	0.11	0.001
C8:0					0.58	0.87	0.76	0.10	0.52	0.77	0.67	0.09	0.061
C10:0					1.3	2.2	2.0	0.30	1.3	2.0	1.7	0.24	0.083
C12:0					1.8	2.7	2.4	0.33	1.8	2.7	2.3	0.27	0.486
C14:0					8.8	11.6	10.2	0.96	8.6	11.0	9.6	0.90	0.190
C14:1					0.49	0.90	0.63	0.15	0.48	0.82	0.64	0.12	0.808
C15:0					1.1	1.4	1.3	0.07	1.1	1.4	1.3	0.09	0.480
C16:0	8.2	10.9	9.5	0.79	23.6	27.9	26.4	1.49	23.4	26.9	25.5	1.25	0.150
C16:1n-7					1.3	1.5	1.4	0.08	1.3	1.6	1.5	0.09	0.089
C17:0					0.80	1.1	0.96	0.08	0.72	1.2	0.90	0.16	0.328
C17:1					0.17	0.34	0.22	0.05	0.21	0.47	0.28	0.09	0.105
C18:0	1.3	2.5	1.8	0.42	9.5	12.4	11.0	1.09	10.2	12.6	11.3	1.01	0.552
C18:1n-9	2.6	8.5	4.5	1.88	19.0	23.9	20.8	1.59	20.0	24.4	22.2	1.59	0.070
C18:1n-7					4.4	7.0	5.8	1.00	4.8	7.0	6.0	0.85	0.602
C18:2n-6	13.0	30.8	17.2	5.07	1.9	2.4	2.2	0.16	2.1	2.5	2.3	0.15	0.171
C18:3n-6	0.73	4.3	2.5	1.09	0.05	0.07	0.06	0.01	0.05	0.07	0.06	0.01	1.000
C18:3n-4					0.12	0.19	0.14	0.02	0.12	0.16	0.14	0.01	0.892
C18.3n-3	39.7	60.6	54.7	5.72	1.2	1.5	1.4	0.12	1.3	1.5	1.4	0.11	0.635
CLA1‡					1.6	2.4	2.0	0.30	1.7	2.5	2.2	0.34	0.262
CLA2§					0.09	0.17	0.13	0.03	0.09	0.15	0.13	0.03	0.684
C20:0					0.22	0.36	0.27	0.04	0.24	0.28	0.26	0.01	0.457
C20:1n-9					0.07	0.26	0.14	0.08	0.10	0.27	0.18	0.06	0.234
C20:3n-6					0.00	0.06	0.04	0.02	0.04	0.05	0.04	0.00	0.362
C20:4n-6					0.08	0.15	0.10	0.02	0.08	0.11	0.10	0.01	1.000
C20:4n-3					0.05	0.09	0.07	0.01	0.06	0.08	0.07	0.01	1.000
C20:5n-3					0.07	0.08	0.08	0.00	0.08	0.10	0.09	0.01	0.015
C22:0					0.09	0.11	0.10	0.01	0.08	0.15	0.11	0.02	0.291
C22:5n-3					0.12	0.40	0.17	0.08	0.11	0.19	0.14	0.03	0.327
Unknown	6.6	13.7	9.8	1.72	4.2	5.2	4.6	0.32	4.4	5.3	4.8	0.31	0.255

† SD: standard deviation. ‡ cis-9,trans-11 conjugated linoleic acid. § trans-10,cis-12 conjugated linoleic acid.

Table 2. Terpene composition of pasture (n = 9), milk (n = 10), and Plaisentif cheese (n = 10) from five Piedmont farms

	Pasture				Milk				Cheese				Prob.
	Min	Max	Mean	SD†	Min	Max	Mean	SD†	Min	Max	Mean	SD†	
α-Pinene§	6.48	7.60	7.07	0.42	5.88	6.44	6.15	0.18	5.91	6.52	6.24	0.24	0.376
Camphene	5.49	6.78	6.02	0.40	4.85	5.49	5.18	0.22	4.95	5.92	5.32	0.29	0.237
β-Pinene	6.05	7.61	6.86	0.53	5.48	5.89	5.64	0.14	5.46	6.00	5.73	0.20	0.240
δ 3-Carene	4.85	5.64	5.26	0.26	4.71	5.88	5.21	0.38	4.91	5.91	5.41	0.37	0.250
Limonene	4.79	6.93	5.88	0.72	5.08	5.61	5.43	0.15	5.45	6.41	5.65	0.28	0.046
p-Cymene	6.36	7.76	7.17	0.55	5.05	5.57	5.27	0.15	5.25	5.89	5.51	0.20	0.009
allo-Ocimene	5.26	6.81	6.10	0.59	4.01	4.51	4.23	0.20	4.10	4.70	4.43	0.24	0.050

† SD: standard deviation. § Data expressed as arbitrary units of log10 of the peak area of the corresponding selected ion.

IV – Conclusions

Grazing Alpine highland pasture affected the FA and terpenoid profiles of dairy products, while processing milk into ripened cheese did not substantially modify the FA composition and terpene profile of Plaisentif cheese with the exception of eicosapentaenoic, butyric and caproic acids among FA, and limonene, p-Cymene and allo-Ocimene among terpenes. These results confirm the importance of Alpine highland pasture in obtaining milk and cheese that have a favourable FA profile, potential health benefits and an aromatic profile with molecules that confer specific organoleptic and nutritional properties to the Plaisentif cheese.

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Sensory characteristics and fatty acid composition of Raschera PDO cheese according to the production system

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Abstract. The Raschera is a PDO semi-cooked and pressed cheese made from partially skimmed milk, which is produced within the Cuneo Province, in North-West Italy. Aiming to explore the widest variation in production conditions and cheesemaking technology, twenty Raschera cheeses were sampled (ten in winter, W; and ten in summer, S) from ten dairy plant producing almost all of the total PDO Raschera cheese production. The cheeses were divided in three production systems: (i) raw milk (IR) or (ii) pasteurized milk (IP) cheeses from intensive farming system, feeding cows mainly on maize silage and concentrates, and (iii) raw milk cheese from extensive farming system (ER), feeding cows mainly with hay in winter or fresh herbage in summer. The principal component analysis (PCA) performed on sensory attributes clearly separate summer from winter cheeses, the first being characterized by stronger notes. Within summer cheeses, ER were clearly separated from IP and IR cheeses, being the ER cheeses characterized by stronger, herbaceous and vegetables notes, and the IP and IR by more cream and butter notes. The FA composition of the cheeses also allowed to a similar differentiation, but the separation between the season was evident only for ER system. The research highlighted that the sensory properties and FA composition of Raschera PDO cheese depend on the production system and on its seasonal variations.

Keywords. Farming system – Cheesemaking technology – Milk fatty acids – Sensory properties – Raschera PDO cheese.

Caractéristiques sensorielles du fromage Raschera AOP selon les systèmes de production

Résumé. *Le Raschera est un fromage AOP à pâte pressée et demi-cuite, fabriqué à partir du lait partiellement écrémé et produit dans le département de Cuneo, dans le nord-ouest de l'Italie. Pour explorer la plus large variation des conditions de production et de technologie fromagère, vingt formes de Raschera ont était échantillonnée (dix en hiver, W ; dix en été, S) dans les 10 fromageries qui produisent presque la totalité de Raschera AOP. Les systèmes de production et de fabrications des fromages ont été classés dans trois groupes : (i) fromage au lait cru (IR) et (ii) au lait pasteurisé (IP) issus de systèmes d'élevage intensives, dans lesquels les vaches laitières sont nourries principalement avec de l'ensilage du maïs et des concentrées, et (iii) fromages au lait cru issu de systèmes d'élevage extensives (ER) dans lesquels les vaches laitières sont nourries principalement avec du foin en hiver et au pâturage en été. L'analyse des composants principaux (PCA) faite sur les descripteurs sensoriels séparait clairement les formages d'hiver et d'été, ces derniers caractérisés de notes plus fortes. Parmi les fromages d'été, les fromages ER ont était nettement séparée des fromages IR et IP, en montrant les ER des notes plus fortes, des notes d'herbe et des végétaux, et les IR et IP avaient des note de crème et de beurre plus marquées. Comme pour les caractéristiques sensorielles, la composition en acides gras différenciait aussi ces fromages, mais la séparation entre saisons était évidente seulement pour les fromages ER. Ce travail montre que les caractéristiques sensorielles et la composition en acides gras du fromage Raschera AOP dépend du système de production en lien avec ses variations saisonnières.*

Mots-clés. *Système de production – Technologie fromagère – Acides gras du lait – Caractéristiques sensorielles – Fromage Raschera AOP.*

I – Introduction

Most of the milk produced in Northern Italy is transformed into traditional and typical cheeses, which are often granted with PDO label. Among them, the Raschera is a PDO semi-cooked and pressed cheese made from partially skimmed milk (raw or pasturized), which is produced within the Cuneo Province, in North-West Italy, and which is ripened for a minimum period of 60 days. However, the Raschera PDO cheese specifications do not include restrictions on composition of animal diets, which can vary from extensive to intensive dairy systems. Consequently, the sensory properties of the resulting cheese can be expected to vary widely because of the broad range of milk production conditions and cheese-making practices (Martin *et al.*, 2005). Similarly, a large variation can also be expected for cheese fatty acid (FA) composition, which has important implication for human health and cheese sensory properties (Givens, 2010; Coppa *et al.*, 2011b). Among several factors, the major impacts on cheese FA composition are related to the farming system and to its seasonal variation in cow feeding (Chilliard *et al.*, 2007). The aim of this research was to highlight the relationships between the production conditions and their seasonal variations according to the farming system applied and the sensory and FA profiles of Raschera PDO cheese.

II – Materials and methods

Aiming to explore the widest variation in production conditions and cheesemaking technology, twenty samples of 60-day ripened Raschera were collected from ten dairy plant producing more than 80% of total Raschera PDO cheese production. One cheese was sampled in winter (W) and one in summer (S), per each dairy plant. The production condition applied in the dairy farms from which derived the milk used for each cheesemaking were recorded through on-farm surveys, according to Borreani *et al.* (2013). Cheesemaking technology was also characterized. To describe the sensory properties of cheese, a Quantitative Descriptive Analysis (QDA) was performed on cheeses of each factory for both winter and summer seasons. Ten expert panellists were selected to form the panel, subjected to a training period for QDA and involved in the definition of a list of attributes for texture, odour, taste and aroma of cheese. Attributes generated from each assessor were characterised and agreed on a round table-meeting involving sampling taste and collective discussion to create the final list of attributes which described the cheese sensory profile. Subsequently, in the test, attributes were evaluated on an intensity scale from 1, when the attribute was defined as not perceptible, to 9, when the attribute had the maximal expression. Each cheese was sub-sampled and analysed for the FA methyl esters by gas chromatography, as reported by Revello Chion *et al.* (2010). Aiming to explore the relationship between production conditions and sensory or FA profiles, two principal component analyses (PCA) were performed, one on data of cheese sensory descriptors, the other on cheese FA concentrations, using the SPSS for Windows software package (version 17.0; SPSS Inc., Chicago, IL).

III – Result and discussion

The farms from which dairy plants collected the milk used to produce the Raschera PDO cheese covered overall a wide variation in production conditions (i.e. cow diet composition and milk production level). However, within each dairy plant, the characteristics of the farms that supplied milk were quite homogeneous. Some plants collected milk almost from intensive farms, feeding cows mainly on maize silage and concentrates, whereas, other plants mainly from extensive dairy farms, feeding cows mainly with hay in winter or fresh herbage in summer. Within the dairy plants collecting milk from intensive farms, some produced Raschera PDO from raw milk (IR), others from pasteurized milk (IP), whereas the dairy plants collecting milk from extensive farms only produced Raschera PDO from raw milk (ER).

On the plot of PCA performed on data of sensory descriptors, the Raschera PDO cheeses were separated according to the season of production by both principal components (PC) 1 and 2 (Fig. 1). The summer cheeses (S) were characterized by higher notes for odour and aroma of rennet, strong toasted, barn, garlic, bread a, boiled vegetable, smoked, hazelnut, grass, and for silage odour and soft toasted aroma. Summer cheeses had a less melting texture. Systems were in average scarcely differentiated: except for ER cheeses produced in summer, which were clearly separated from all the other samples. These cheeses were characterised by lower cream and butter odours. The ER summer cheeses also have higher strong toasted odour and aroma, silage odour, barn odour and aroma, smoked odour and aroma, hazelnut odour and bitter taste. These results are in agreement those presented by Coppa *et al.* (2011b) and by Martin *et al.* (2005) when comparing conserved forages derived cheese to pasture derived cheeses. The stronger notes found for pasture-derived cheeses were explained by the effect of fresh herbage in cow diet on milk fat and FA composition (Martin *et al.*, 2005). In particular the stronger notes were related to the odour active compounds generated by the oxidation of polyunsaturated FA (PUFA), more abundant in pasture derived cheeses, during ripening, and to their interaction with the microbial flora (Coppa *et al.*, 2011a,b).

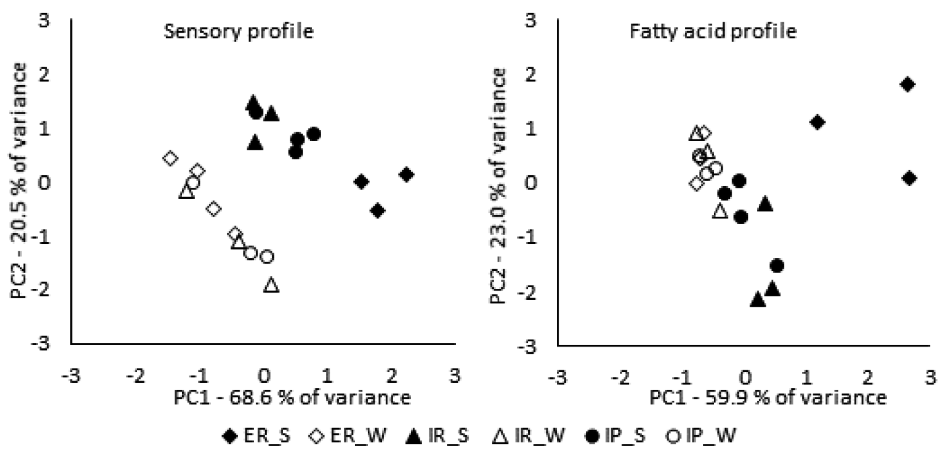

Fig. 1. Principal component analysis (PCA) performed on sensory descriptors (on the left) and on milk fatty acid concentrations (on the right). Plot of sample distribution according to production system and season[1] projected on the two principal components (PC1 and PC2). ER = Extensive faming system, raw milk; IR = Intensive farming system, raw milk; IP = Intensive farming system, pasteurised milk; S = summer; W = winter.

[1] LD = long duration of paddock utilisation on heterogeneous pasture; MD = medium duration of paddock utilisation on intensively managed pastures; b = beginning; m = middle; e = end; 1 and 2 in MD indicated the paddocks; BCFA = branched-chain FA; C18:1t = Σ of trans C18:1isomers; LA/ALA = C18:2n-6/C18:3n-3; MUFA = monounsaturated FA; OA/PA = C18:1c9/C16:0; PUFA = polyunsaturated FA; SFA = saturated FA; t10/t11 = C18:1t10/C18:1t11 ratio; HM = high mature patches; HV = high vegetative patches; SV = short vegetative patches; CP = simulated bites crude protein; G = simulated bites grasses proportion; L = simulated bites legumes proportion; L/S = simulated bites grasses leaf to stem ratio; NDF = simulated bites neutral detergent fibre; OMD = simulated bites organic matter digestibility.

The PCA performed on cheese FA composition showed a sample distribution similar to those of cheese sensory profile, however summer and winter cheeses were weakly separated, especially for IP W and S cheeses, which were confounded (Fig. 1). On the contrary, the PCA on milk FA profile showed a clear separation of ER Raschera PDO cheeses produced in summer, as for the PCA based on cheese sensory profile. The ER summer cheese were characterized by higher concentration of C18:1t11, CLAc9t11, C18:3n-3, odd and branched chain FA (OBCFA), and by lower concentrations of C14:0, C16:0, and C18:2n-6. A similar FA profile is in agreement with FA composition of milk derived for pasture fed cows (Coppa *et al.*, 2013). Fresh herbage being richer in C18:3n-3 resulted in milk richer in this FA and in all intermediate products of its ruminal biohydrogenation, such as CLAc9t11,and C18:1t11 (Chilliard *et al.*, 2007). Similarly, feeding cows with fresh herbage increase the proportion in milk of OBCFA, deriving from ruminal bacteria responsible for fiber digestion (Vlaemink *et al.*, 2006). Lower C18:2n-6 and saturated FA (SFA) concentrations in milk when cows were fed pasture instead of maize silage and concentrate based diets has also been observed (Coppa *et al.*, 2013; Chilliard *et al.*, 2007).

IV – Conclusions

In conclusion, this research highlighted that the sensory properties and FA composition of Raschera PDO cheese depend on the production system applied in the farms that supply the milk. Seasonal variations in production conditions have an important effect on cheese sensory properties and FA composition, especially in extensive farming systems.

Acknowledgments

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Influence of grazing on meat oxidation in light lamb

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Abstract. Oxidation is one of the primary reasons for meat deterioration, decreasing freshness and consumer acceptance. Vitamin E in the diet reduces these oxidative processes. The objective was to asses the effect of grazing alfalfa on plasmatic α-tocopherol concentration and meat oxidation. Twenty single reared male lambs of Rasa Aragonesa breed were used. Twelve weaned lambs (49 days old) were fed a commercial concentrate indoors, and eight unweaned lambs of 29.5 ± 0.95 days old grazed continuously with their dams. Lambs were slaughtered when they reached 22 to 24 kg live weight. *Longissimus thoracis* muscle was extracted to determine α-tocopherol concentration and lipid oxidation after 0, 2, 5 and 7 days of display. Plasmatic α-tocopherol concentration in concentrate-fed lambs remained steady throughout the experimental period (P>0.05; 0.24 to 0.47 µg α-tocopherol/ml). Plasmatic α-tocopherol concentration of grazing lambs (0.78 to 1.53 µg α-tocopherol/ml) was approximately 3-fold higher than that of concentrate-fed lambs. Lipid oxidation on day 0 and 2 of display did not differ between grazing and concentrate-fed lambs. In longer display periods, lipid oxidation increased significantly in both treatments (P < 0.05). In grazing lambs, lipid oxidation decreased as the grazing period was extended, showing that a grazing period longer than 58 days was enough to reduce the lipid oxidation below 0.6 mg MDA/kg muscle. Grazing resulted in an improvement of meat oxidative stability compared to feeding a concentrate-based diet without α-tocopherol supplementation.

Keywords. Alfa-tocopherol – Alfalfa – Plasma.

Influence du pâturage sur l'oxydation de la viande des agneaux légers

Résumé. *L'oxydation détériore la qualité de la viande, diminuant la fraîcheur et l'acceptation par les consommateurs. Le teneur en vitamine E dans le régime alimentaire diminue les processus oxydatifs. L'objectif de cette étude était d'évaluer l'effet du pâturage de la luzerne sur la concentration plasmatique en α-tocopherol et l'oxydation de la viande. Vingt agneaux mâles provenant d'une naissance simple de race Rasa Aragonesa ont été utilisés. Douze agneaux sevrés (49 ± 0,2 jours vieux) ont été alimentés avec un concentré commercial (concentré) et 8 agneaux non sevrés (29,5 ± 0,95 jours) ont pâturé continuellement avec leurs mères (pâturage) jusqu'à l'abattage à 22-24 kg. La concentration plasmatique en α-tocopherol des agneaux «concentré» est resté stable pendant la période expérimentale (P>0,05; 0,24-0,47 µg α-tocopherol/ml). Les agneaux «pâturage», ont eu une concentration du α-tocopherol (0,78-1,53 µg α-tocopherol/ml) trois fois plus élevée que les agneaux «concentré». L'oxydation lipidique à 0 et 2 jours de présentation a été similaire pour les deux traitements. Dans des périodes de présentation plus longues, l'oxydation lipidique a augmenté dans les deux traitements (P < 0,05). Chez les agneaux «pâturage», l'oxydation lipidique a diminué avec l'allongement de la période de pâturage, montrant que le pâturage pendant 58 jours a réduit l'oxydation lipidique au-dessous de 0,6 mg MDA/kg muscle. Le pâturage a amélioré la stabilité oxydative de la viande comparée à l'alimentation à base de concentré sans supplément de α-tocopherol.*

Mots-clés. *Oxydation de la viande – α-tocopherol – Luzerne – Plasma.*

I – Introduction

Oxidation is one of the primary reasons for quality deterioration in meat products. In Mediterranean countries, light lamb meat is commonly consumed and the appearance of freshness is the most important intrinsic quality attribute for the consumers (Bernués *et al.*, 2012). The addition of vitamin E in the animal diet reduces the oxidative processes in meat products (Jensen *et al.*, 1998). However the high cost of α-tocopherol requires accurate feeding and quantity of α-tocopherol must be adjusted to reduce the cost of the diet. Grazing can increase the intake of α-tocopherol cheaply. Numerous studies have shown that lambs finished on pasture had higher α-tocopherol content in meat than those fed high concentrate diets (Turner *et al.*, 2002). The objective of the present study was to asses the effect of alfalfa grazing on plasmatic α-tocopherol concentration and meat oxidation in light lambs.

II – Materials and methods

Twenty single reared male lambs of Rasa Aragonesa breed were used. Twelve weaned lambs (49±0.2 days old), were indoors fed a commercial concentrate (185 g crude protein/kg dry matter, DM; 190 Neutral detergent fiber/kg DM; and 13.22 MJ/kg DM, 30 mg α-tocopheryl acetate/kg of concentrate) (C). Eight unweaned lambs (29.9 ± 0.95 days old) grazed continuously on alfalfa pasture with their dams (Gr), and had free access to the same commercial concentrate. In C treatment dams and lambs during lactation were indoors concentrated-fed, while in Gr treatment, ewes and lambs grazed alfalfa since one week after lambing. When the lambs reached 22 to 24 kg of live weight, they were slaughtered, at weekly intervals. The experimental period lasted 33.7 ± 2.90 d in C and 36.0 ± 1.87 in Gr treatments. The age of lambs at slaughtering was 74.9 ± 3.17d and 65.9 ± 2.47d in C and Gr treatments, respectively.

Lambs were bled weekly throughout the experimental period to determine α-tocopherol concentrations, which were analyzed following Lyan *et al.* (2001) method by HPLC. After slaughter (24 h at 4ºC), the *Longissimus thoracis* (LT) muscle was extracted from the left half of the carcass and sliced to determine oxidation and α-tocopherol content. Samples were displayed for 0, 2, 5 and 7 days in darkness at 4ºC. Muscle lipid oxidation (TBARS) was analyzed according to Pfalzgraf *et al.* (1995). Muscle α-tocopherol content was determined using the methods described in Prates *et al.* (2006).

III – Results and discussion

1. α-tocopherol content in plasma and muscle

The average concentrate fed during the experimental period was 24.3 and 7.4 kg per lamb, in C and Gr treatments, respectively. Lambs grazing alfalfa had levels of α-tocopherol in the plasma higher than those of C treatment at the beginning of the study (0 days) as a result of grazing and then, to milk suckled ($P<0.001$; Fig. 1). Calderón *et al.* (2007) observed a rapid increase of α-tocopherol during the first week of eating fresh forage. Plasmatic α-tocopherol concentration in concentrate-fed lambs remained steady throughout the experimental period ($P>0.05$; 0.24 to 0.47 μg α-tocopherol/ml), whereas in Gr lambs (0.78 to 1.53 μg α-tocopherol/ml) concentration was approximately 3-fold higher than that of concentrate-fed lambs ($P<0.001$). Guidera *et al.* (1997) found that α-tocopherol supplemented ewes had greater concentration α-tocopherol in serum and milk than control ewes just after a week on the experimental diets. In Gr lambs, the plasmatic α-tocopherol changed during the grazing period ($P<0.001$), although, there was not a clear effect of the length of the grazing period. In agreement to that, α-tocopherol concentration in LT muscle was greater in Gr ($P<0.001$). D'Alessandro *et al.* (2012) found suckling lambs whose dams grazed had greater α-tocopherol content in muscle than suckling lambs whose dams were fed hay and concentrates.

2. Lipid oxidation of *Longissimus thoracis* muscle

Lipid oxidation was affected by the interaction between treatment and days of display (P<0.05; Figure 2). Grazing and concentrate-fed lambs had similar lipid oxidation at 0, 2 and 5 days of display (P>0.05) but Gr lambs had lower lipid oxidation at 7 days of display (P<0.05). Similar results were reported by Luciano *et al.* (2009) in lambs fed fresh forage or concentrates. Lipid oxidation at 7 days of display was correlated with α-tocopherol content in meat (r = 0.67, P<0.001).

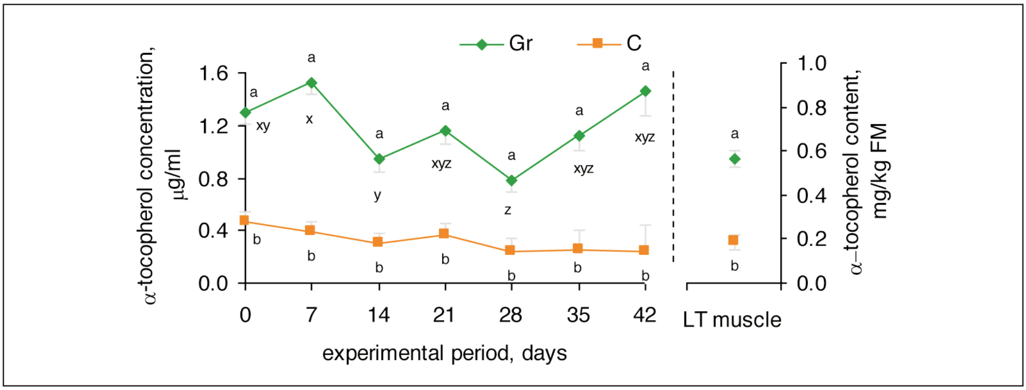

Fig. 1. Evolution of α-tocopherol in plasma throughout the experimental period and α-tocopherol content in LT muscle of unweaned lambs grazing in alfalfa (Gr) or weaned concentrate-fed lambs (C). Differences within a treatment between days are shown as x, y, z (P<0.05). Differences within a day between treatments are shown as a, b (P<0.05).

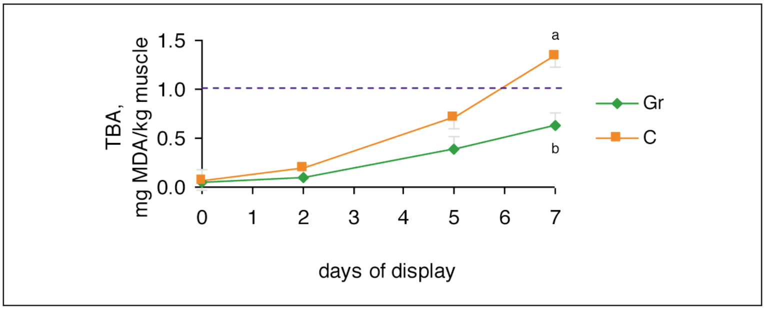

Fig. 2. Evolution of lipid oxidation of *Longissimus* muscle of grazing (Gr) and concentrate (C) fed lambs with days of display. Differences between treatments are shown as a, b (P<0.05).

In Gr lambs, lipid oxidation decreased as the grazing period was extended (Fig. 3), being highest at 28 days of the experimental period and at 7 days of display. At this moment, lipid oxidation achieved values of 1.1 mg MDA/kg muscle. The limiting threshold for oxidized meat acceptability, according to Ripoll *et al.* (2011), is 1.0 mg MDA/kg muscle in light lamb meat. To ensure levels below 1.0 mg MDA/kg of meat at 7 days of display in Gr treatment, unweaned lambs must be older than 58 days (29.9 d old at starting experimental trial plus 28 d of experimental trial) and grazing since one week age. Sixty-five days grazing time reduced the lipid oxidation below 0.6 mg MDA/kg muscle, regardless of the time of display.

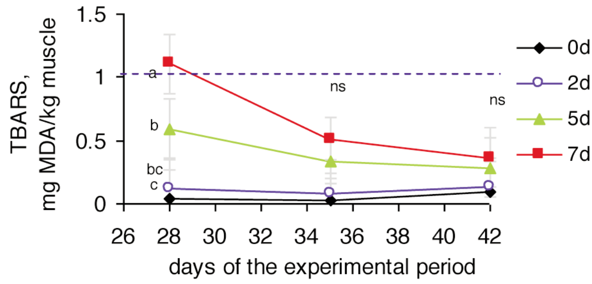

Fig. 3. Lipid oxidation (TBARS) of *Longissimus thoracis* from alfalfa grazing lambs according to the length of the experimental period and the days of meat display (0, 2, 5 and 7 days). Different letters within a day mean significant differences among days of display (P<0.05).

IV – Conclusions

The results of the present study showed that alfalfa grazing increased α-tocopherol concentrations in serum and in LT muscle compared to concentrate feeding in light lambs. Grazing resulted in a general improvement of meat oxidative stability compared to feeding a concentrate-based diet without α-tocopherol supplementation. Alfalfa grazing in light lambs is also a feasible alternative for increasing the shelf-life of meat. To reduce the lipid oxidation below 0.6 mg MDA/kg muscle, it was necessary a grazing period longer than 58 d.

Acknowledgments

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Rumen fermentation pattern and blood metabolites of lambs from three breeds reared on pasture or feedlot

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Abstract. This study compares the rumen facies and blood metabolites of sheep reared on natural grassland in north-west of Tunisia or on feedlot. For this, 36 lambs (26 kg live weight, in average) from Barbarine (BB), Queue Fine de l'Ouest (QFO) and Noire de Thibar (NT), were equally divided in stall-fed (S) and pasture (P) group. In each feeding system, there were 6 lambs from each breed. After 60 days, fasting plasma was collected as well as the rumen liquid at 0, 2, 5 and 8 hours after feeding. The glucose, magnesium and iron contents in blood were higher for the S system (P = 0.001); while cholesterol and urea contents were more elevated for the P system. The protozoa population in rumen fluid was globally similar for P and S systems. The N ammonia was not affected by the feeding system. Before feeding the acetic acid was higher for P group (43.44 vs. 40.37%; P = 0.03). The propionic acid had the highest percentage 8 hours after feeding (28.98%). The butyric acid was not affected by both factors. The BB lambs present the highest glycaemia and rumen N ammonia contents, while those from NT breed present the highest creatinine concentration. The effects of both breed and feeding system were more spectacular in blood metabolites than in rumen fermentation pattern, this is in relation with the stability of the in the microenvironment.

Keywords. Blood metabolite – Pasture – Stall-fed – Rumen facies.

Profils fermentaires dans le rumen et paramètres sanguins chez des agneaux de trois races élevés au pâturage ou en « feedlot »

***Résumé**. Cette étude compare le faciès fermentaire et les métabolites sanguins de moutons élevés sur les prairies naturelles du nord-ouest de la Tunisie ou en bergerie. Pour cela, 36 agneaux (26 kg de poids vif, en moyenne) de races Barbarine (BB), Queue fine de l'Ouest (QFO) et Noire de Thibar (NT), ont été répartis dans le groupe de bergerie (S) et le groupe de pâturage (P). Chaque groupe contenait six agneaux de chaque race. Après 60 jours, des échantillons de sang ont été collectés à jeun, ainsi que le jus de rumen à 0, 2, 5 et 8 heures après le repas. Les concentrations de glucose, de magnésium et de fer dans le sang étaient plus élevés pour le groupe S (P = 0,001), tandis que le cholestérol et l'urée étaient plus élevés pour le groupe P. La population de protozoaires dans le fluide du rumen était globalement similaire pour les deux groupes. La teneur en ammoniac n'a pas été affectée par le système d'alimentation. A jeun la teneur en acide acétique été plus élevée chez le groupe P (43.44 vs. 40.37%; P = 0.03). La teneur en acide propionique avait le pourcentage le plus élevé 8 heures après le repas (28.98%). La teneur en acide butyrique n'a pas été affectée par les deux facteurs. Les agneaux BB avaient les concentrations de glucose et d'ammoniac les plus élevées. Les agneaux NT avaient le taux de créatinine la plus élevé. Les effets de la race et du régime étaient plus spectaculaire en métabolites sanguins que dans les paramètres de fermentation dans le rumen, ce n'est en relation avec la stabilité de la dans le microenvironnement.*

***Mots-clés.** Métabolites sanguins – Pâturage – Stabulation – Faciès fermentaire.*

I – Introduction

Rustic sheep breeds are better able to conserve fat during feed restriction than less adapted breeds, possibly because of differing responses to homeostatic signals (Chilliard *et al*., 2000). However, domestication and breeding for better productivity, such as muscle, wool, or milk, may impact some of the adaptive mechanisms regulating energy metabolism in relation with rumen facies and blood metabolites. The aim of the present study was to examine the influence of breed and diet quality and the interaction between both factors on some blood metabolites and rumen fermentation pattern.

II – Material and methods

Thirty-six lambs (26 kg live weight) from tow rustic breeds; Barbarine (BB), Queue Fine de l'Ouest (QFO) and one meat breed, Noire de Thibar (NT), were equally divided into two groups, stall-fed (S) (500 g of concentrate and 500 g of oat hay; 11% of crude protein) and pasture fed (P). In each feeding system, there were 6 lambs from each breed. The grazed land covered 1600 m² and the land pasture was composed by 45% grass, 14% legumes and 41% other species (10% of crude protein). The trial lasted 60 days. At the end of the trial, fasting blood samples were taken in heparinized tubes of 10 ml and immediately centrifuged at 3000 rpm for 15 mn and the plasma was kept in plastic tubes of 2.5 ml at -20ºC. A 400 µl aliquot of plasma was taken for assaying some plasma metabolites (glucose, cholesterol, triglyceride, urea, creatinine, calcium, phosphore, magnisium and iron). The rumen liquid was collected at 0, 2, 5 and 8 hours after feeding. Samples of rumen liquid used for NH3, AGV analyses were filtered for all times. The rumen liquid samples used to count protozoa were collected only at 2, 5 and 8 hours. Statistical analysis of blood metabolites were performed by analysis of variance using the GLM procedure of SAS (1999). A 2x2 factorial design was adopted to test the diet and breed effects. Rumen fermentation pattern variables were analyzed using the MIXED procedure for repeated measures. The factors included were diet or breed as between-subject fixed effects, time as within-subject effect and animal as subject (experimental unit).

III – Results and discussion

1. Blood metabolites

The QFO breed had the highest glucose concentration. The stall fed diet based on concentrate leads to highest glucose concentration in blood (Table 1). In fact stall-fed diet is essentially composed by concentrate rich in starch which is a polymer of glucose. The interaction between both factors was significant for this parameter (P = 0.03). In fact this parameter measure the energetic valorization of the diet by different breeds; in pasture the NT breeds had the same concentration as in stall (3.11 mmol/l) however the QFO breed had the highest concentration (3.38 mmol/l) and the BB breed had the lowest concentration (2.92 mmol/l). In Stall QFO and BB breeds had higher concentration of glucose (3.75 and 3.65 mmol/l respectively) and remain more adapted then NT breed to this type of diet. The breed had no effect on the cholesterol level, however the diet had a significant effect on the cholesterol concentration wish was more important for animals conducted in pasture (Table 1). Studies with calves, humans, monkeys, chicks, and pigs have also found elevated cholesterol levels resulting from low protein diets (Mann, 1960; Beveridge *et al.,* 1963). Triglyceride concentration was not affected by both factors. This result shows that both diets and all breeds lead to the same amount of lipids (Table 1).

The urea concentration was higher in pasture-fed group. In fact, high concentrations of plant N (> 30 g of N/kg of DM) result in production of excess ruminal ammonia N, which is absorbed into the bloodstream and excreted as urinary urea N (Dellow *et al.,* 1988). Thomas *et al.* (1988) reported that serum albumin and blood urea nitrogen reflected the dietary protein intake which explains the lower concentration of urea N in stall-fed group (Table 1).The creatinine is influenced by the breed and the NT breed had the most elevated level of creatinine. The rate of blood creatinine may be considered as an index of endogenous protein catabolism (Patrick *et al*., 1998). This can be justified by the fact that the NT breed produced more muscle (Hajji *et al*., 2013), thus this breed had higher protein degradation. The diet had no effect on the creatinine concentration this is in relation to the ingested protein level which is similar in both diets. In comparison to the present, Patrick *et al*. (1998) found that Lambs fed low CP diet tended to have greater levels of serum protein and had greater creatinine levels than lambs fed the high CP diet.

Calcium and phosphore were not affected by both breed and diet. However magnesium and iron were significantly higher in stall fed group then in pasture group (Table 1).

Table 1. Effects of breed and diet on some blood metabolites

	Breed			Diet		Statistic			
	BB	QFO	NT	S	P	SME	Breed	Diet	Breed* Diet
Glucose†	3.33	3.60	3.11	3.53	3.12	0.05	**	**	**
Cholesterol†	1.39	1.30	1.50	1.28	1.54	0.03	NS	**	NS
Triglyceride†	0.24	0.23	0.19	0.222	0.22	0.01	NS	NS	NS
Urea†	5.47	5.02	4.91	4.70	5.63	0.17	NS	**	NS
Creatinine$^{\mu}$	61.36	60.20	66.63	62.00	63.73	0.84	**	NS	NS
Calcium†	2.23	2.34	2.27	2.37	2.16	0.08	NS	NS	NS
Phosphore†	2.10	2.29	2.18	2.29	2.07	0.06	NS	NS	NS
Magnisium†	0.78	0.84	0.69	0.82	0.70	0.02	NS	*	NS
Iron$^{\mu}$	23.17	21.98	18.27	24.61	17.12	1.40	NS	*	NS

† mmol/l; µ: µmol/l; NS: insignificant; **: P < 0.01; *: P < 0.05.

2. Rumen fermentation pattern

The time of sampling had a significant effect on the ammonia production (P = 0.0001). Before feeding and 5 hours after the ammonia production was not affected by both diet and breed and the interaction between the factors was not significant. Two hours after feeding only the diet had an effect on the ammonia production and the stall-fed animals had the highest concentration and the interaction between diet and breed was significant (P = 0.05). Knowing that the urea concentration was higher in pasture-fed group, we can conclude that the ammonia transformation to urea in kidney is more efficient in pasture-fed group. Eight hours after feeding the interaction between both factors was significant (P = 0.0001), this may correspond with the time of rumination, which may be of different speed between breeds. The breed had a significant effect on the ammonia production (P = 0.0001) and the NT breed had the lowest value. The NT lambs had the highest level of creatinine so the highest protein catabolism which explains the lowest ammonia amount.

The most important protozoa population was counted at the fifth hour (P = 0.01). Two hours after feeding, the protozoa population was not affected by both factors. At the fifth hour the protozoa was affected by both diet and breed and the interaction was significant between the factors. Generally, the size of the microbial population increases with the pasture and decreases with the diet rich in starch. The present results can not clearly express the effect of the diet or the breed.

The acetic acid production was globally affected by both diet and breed (P = 0.001 and P = 0.001 respectively). The time of sampling had no effect on the acetic acid production. The interaction between factors was significant at 2, 5 and 8 hours post feeding. Before feeding the percentage of acetic acid was affected only by diet and the highest percentage was recorded in P group (43.44 vs. 42.80% respectively) this is in accordance with the finding of Cuvelier *et al*. (2005) who announced that acetic acid production is promoted by diets rich in fibers. The propionic acid percentage was influenced only by the time of sampling and the highest percentage was 8 hours after feeding (28.98%). The butyric acid percentage was not affected by any factor and it averaged 22.89%.

IV – Conclusion

The effects of both breed and feeding system were more spectacular in blood metabolites than in rumen fermentation pattern. The NT breed has the same energetic valorization of both diets. The QFO breed was the best adapted in both production systems. In stall, the BB lambs were better adapted then the NT ones and this result was inversed in pasture system. Also the interaction between both factors was more widespread in rumen fermentation pattern than in the blood metabolites, this is in relation with the stability of the in the microenvironment.

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Protein and fat content in colostrum and milk of Barbarine ewes treated by water deprivation during late gestation-early lactation

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Abstract. The effect of water deprivation was investigated in Barbarine ewes raised under dry conditions. In experiment 1, 24 adult ewes were divided into two groups balanced for age and weight. Control ewes (C1) had free access to water while deprived ewes (D2) had free access to water only every 3 days during the last 15 days of pregnancy and the first 60 days of suckling. C1-ewes tended (P>0.05) to accumulate more colostrum at birth and within the first 24 h than ewes subjected to water deprivation. C1 and D1-ewes exhibited the same contents of protein and fat in colostrum. C1-ewes yielded more milk (P<0.01) than D1-ewes on days 30 and 60 post-partum. However, fat and protein contents of milk were similar in the two groups. In experiment 2, 24 adult ewes were allotted to treatments C2 and D2 as above except that for D2-ewes, water deprivation started 50 days before lambing up to 60 days postpartum. Colostrum yield and protein level were not affected (P>0.05) by water deprivation. However, colostrum fat increased (P<0.01) only at 2 hours post-partum. Milk production recorded in days 10 and 45 post-partum was higher (P<0.01) in C2-ewes. Milk fat was not affected (P>0.05) by water deprivation. However, protein concentration was higher (p<0.01) in the milk of D2-ewes and in the milk from C2-ewes controlled at 30, 45 and 60 days of lactation.

Keywords. Water deprivation – Barbarine ewes – Colostrum – Milk – Protein – Fat.

Taux protéique et lipidique du colostrum et du lait de brebis Barbarine ayant subi une privation d'eau durant la fin de la gestion et le début de la lactation

Résumé. *L'effet de la privation d'eau a été étudié chez les brebis Barbarine élevées dans des conditions sèches. Dans l'expérience 1, 24 brebis adultes ont été divisées en deux groupes équilibrés selon l'âge et le poids vif. Les brebis du lot témoin (C1) ont eu un accès libre à l'eau, tandis que les brebis du lot privé (D1) ont eu un accès à l'eau seulement un jour sur 3. L'essai s'est déroulé durant les 15 derniers jours de la gestation et les 60 premiers jours d'allaitement. Les brebis témoins ont une tendance, non significative à accumuler plus de colostrum à la naissance et dans les premières 24 heures par rapport aux brebis soumises à la privation d'eau avec des teneurs comparables en protéines et matières grasses. La production de lait aux jours 30 et 60* post partum *est plus élevée chez les témoins (p<0,01), avec une teneur comparable en matière grasse et en protéines. Dans l'expérience 2, 24 brebis adultes ont été soumises à des traitements C2 et D2 comme dans la 1ère expérience, sauf que la privation d'eau a été appliquée 50 jours avant l'agnelage et jusqu'à 60 jours après la mise-bas. La production de* colostrum *et le niveau des protéines n'ont pas été affectés (P>0,05) par la privation d'eau. Cependant, la teneur en matière grasse a augmenté (P<0,01) à deux heures post-partum. La production de lait a été plus élevée chez les témoins à 10 et 45 post-partum (P<0,01). La teneur en matière grasse du lait n'a pas été affectée (P>0,05) par la privation d'eau. Cependant, la concentration des protéines est plus élevée (p<0,01) dans le lait des brebis privées d'eau (D2) par rapport au lait des brebis témoins (C2) à 30, 45 et 60 jours de lactation.*

Mots-clés. *Privation d'eau – Brebis Barbarine – Colostrum – Lait – Protéines – Matière grasse.*

I – Introduction

Barbarine is the most common breed of sheep in Tunisia. The largest population of the Barbarine sheep is raised in the Center and the South of Tunisia where arid conditions and drinking water scarcity are prevailing. Breeds of ruminants native to arid lands exhibit better performances under harsh environmental conditions than their non native counterparts (Ben Salem *et al.,* 2011) and are able to withstand prolonged periods of undernutrition (Atti *et al.,* 2004) and water deprivation (Bayer and Feldmann, 2003). Late pregnancy and early lactation are critical periods for sheep, and any physiological stress during these stages may affect growth rate of the fetus (Dawson *et al.,* 1999), mammary gland development (Neville *et al.,* 2013), milk production (Aganga, 1992), colostrum yield and quality (Ocak *et al.,* 2005). Information about the combined effect of water stress and gestation – lactation stages in Barbarine breeds is scarce. The objective of this study was to determine the effect of water deprivation during late gestation-early suckling on fat and protein contents of *colostrum* and milk in Barbarine ewes raised under dry conditions.

II – Materials and methods

Two experiments were conducted in the experimental station of the National Institute of Agricultural Research of Tunisia (INRAT) at Bourbiaa (Latitude 36°38′N; longitude 10°07′E). The average annual rainfall is 350 mm. In each experiment 24 pregnant Barbarine ewes were provided from a flock of oestrous synchronised ewes. Dates of mating were recorded individually and animals were divided on the basis of gestational age. Ewes were divided into two groups and were subjected to one of two treatments. Ewes in treatment C (control) had a daily access to tap water and treatment D (deprivation) corresponds to water distribution once every three days where animals were subjected to an adaptation period (10 days). The first experiment (C1, D1) lasted 75 days and water regimes were applied from 2 weeks before lambing until 60 days after (December-February). The second experiment (C2, D2) lasted 110 days and water regimes were applied from 7 weeks before lambing until 60 days after (November- February). Ewes were placed in individual boxes, received 1 kg/ewe/day of barley straw and barley grains (0.5 kg) that was formulated to cover 140% of maintenance requirements of metabolisable energy of ewes. At lambing, the amount of colostrum accumulated was measured by hand stripping of one teat after an intramuscular (im) injection of 10 i.u. of oxytocin to ensure complete milk letdown (Doney *et al.,* 1979). The teat was then covered to prevent suckling. Milking was repeated at 0, 2, 15 and 24 h postpartum with the recorded amount multiplied by 2 to calculate total udder production. Each subsequent yield represented quantities secreted since the previous milking (Boland *et al.,* 2005). At each milking, the amount of colostrum was weighed and a 40 ml-sample was conserved and stored at −20°C for analysis of fat and protein. At 10, 30, 45, and 60 days after lambing, milk yield was determined according to Ricordeau *et al.* (1960). On each milk sampling and after lambs' withdrawn, ewes received an im injection of oxytocin and then were hand-milked. The harvested milk was discarded. Two hours later, the ewes received a second im injection of oxytocin and milk collected was weighed. The yielded volume was then multiplied by 12 to calculate daily milk production. Fat and protein contents were determined, after an adequate dilution, using an integrated milk analyser (Combifoss 5300, Foss Electric, Hillerød, Denmark). Data were analysed using the PROCMIXED procedure (SAS Version 9.1, SAS Inst. Inc., Cary, NC, USA).

III – Results and discussion

1. Colostrum yield, fat and protein contents

There was a wide variation in colostrum yield at each milking (Figs. 1 and 2). Hydrated ewes tended (P>0.05) to accumulate more colostrum at birth and within the first 24 h than ewes subjected to water deprivation. The C1 and D1 ewes exhibited the same contents of protein and fat in colostrum. At lambing, the fat content averaged 9.12 and 10.04 g/L (S.E.M = 0.51) and protein content averaged 6.27 and 6.71 g/l (S.E.M. = 0.53) in C1 and D1 ewes respectively. Similarly, at 24 h after birth the values of protein and fat were respectively 4.11 ± 0.36 g/l and 4.74±0.62 g/l in C1 group and 4.06 ± 0.36 g/l and 5.76 ± 0.62 g/L in deprivation-group (P > 0.05). But in experiment 2, colostrums' fat increased (P<0.01) only at 2 hours post-partum (12.7 ± 0.88 g/l *vs* 17.1 ± 0.88 g/l in C2 and D2 ewes respectively). Colostrum production increased between 2 h and 24 h. Rekik *et al.* (2010) reported similar yields in the same sheep breed and season.

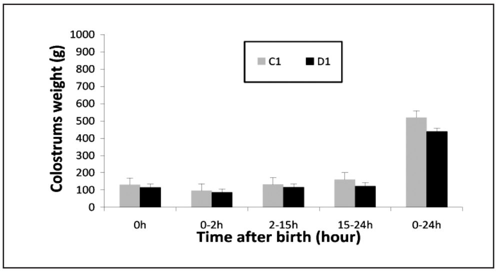

Fig. 1. Average weight (g) of colostrum accumulated at or secreted after parturition. Experiment 1.

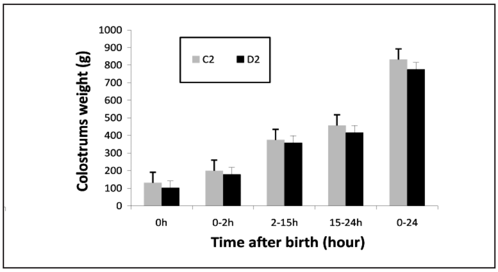

Fig. 2. Average weight (g) of colostrum accumulated at or secreted after parturition. Experiment 2.

2. Milk yield, fat and protein contents

The effect of water deprivation is more pronounced on milk production. In the first experience (Fig. 3) we showed that the C1 ewes yielded more milk (P<0.01) than the D1 ewes on days 30 and 60 post-partum (1487.4 ± 106.2 *vs* 1096.6 ± 106.2 g/24 h and 983.4 ± 70.2 *vs* 639.2 ± 70.2 g/24 h, respectively). However, the fat and protein contents of milk were similar among the two groups (Table 1). But in the second experience (Fig. 2) we showed that milk production recorded in days 10 and 45 post-partum was highest (P<0.01) in C2 ewes (1296 ± 296.4 *vs* 964 ± 216.5 g/24h and 579 ± 193.2 *vs* 370 ± 102.2 g/24 h respectively).

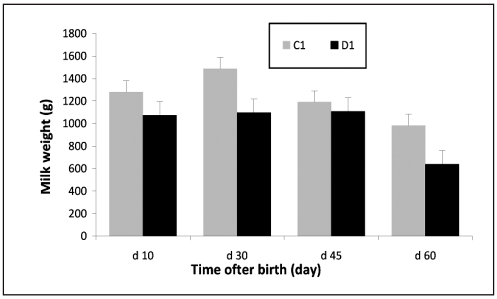

Fig. 3. Average weight (g) of milk secreted at different stage of lactation in experiment 1.

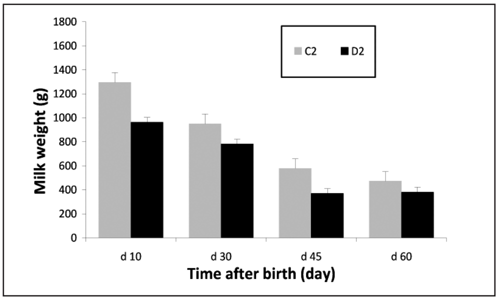

Fig. 4. Average weight (g) of milk secreted at different stage of lactation in experiment 2.

Milk fat was not affected (P>0.05) by water deprivation. However, protein concentration was higher (p<0.01) in the D2 ewes milk than that from C2 ewes controlled at 30, 45 and 60 days of lactation (Table 2). Our results are in line with those obtained by Aganga (1992) on ewes subjected to 3 days of water deprivation. Different results were reported by Casamassima *et al.* (2008) who did not find any change in the quantity and quality of milk in Comisana sheep under water restriction despite of the decrease of ewes' live weight. Theses authors hypothesized that water restriction improved feed digestion through the increase of the retention time of feed particles in the rumen. Aganga (1992) reported that the milk produced by dehydrated ewes was much more viscous than that produced by watered ewes. Therefore, the protein, fat, ash and non-fat solids contents of the ewes' milk increased with more severe water restriction.

Table 1. Milk's fat and protein concentrations in experiment 1

	C1	D1	SEM, Effect
Fat (g/l)			
up to 10 days	8.475	8.430	0.354 ns
up to 10 days	7.056	6.743	0.456 ns
Protein (g/l)			
up to 10 days	3.900	3.871	0.121 ns
up to 10 days	4.198	3.992	0.143 ns

Table 2. Milk's fat and protein concentrations in experiment 2

	C2	D2	SEM, Effect
Fat (g/l)			
up to 10 days	6.331	7.072	0.373 ns
up to 60 days	7.056	6.249	0.771 ns
Protein (g/l)			
up to 10 days	3.830	4.015	0.136 ns
up to 60 days	4.479	5.336	0.171 **

ns: non significant;** significant difference $P < 0.01$).

IV – Conclusion

This study showed that during late autumn – winter season, watering ewes once every three days during late pregnancy and lactation resulted in decrease in milk and colostrum yield at different stages of lactation. However, fat and protein contents were not affected by these conditions, except for the experience 2.

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Range management and cows' consumption of *Trichloris crinita*

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Abstract. Continuous use of the livestock fields in the middle valley of the river Negro, Northern Patagonia, Argentina is causing rangeland degradaion. Cattle breeding using rotation regimes between plots of known vegetation composition in a valley field, with 303 mm historical annual rainfall, was planned to evaluate the population of *Trichloris crinita*, a native to the Americas known by the common name False Rhodes Grass, and to estimate its consumption and preference by cows. To describe the floristic composition, identification of the plant species was undertaken on point intercepting lines. The diet of the grazing animals was determined by microhistological studies using epidermal characteristics to identify the plant components in fecal samples of cows. Plots at the lower edge of the plateau that surrounds the valley, with alluvial soils and little biodiversity, where *T. crinita* grows spontaneously, were left free from animals during the summer and autumn, allowing vegetative and reproductive development of the plant species. The use of this forage in winter as deferred pasture permitted the increase of the *T. crinita* population with higher annual dry matter production per plant, and it resulted in enhanced cow consumption.

Keywords. North Patagonia – Cattle breeding – Semiarid region – Native grasses.

Gestion des pâturages et consommation de* Trichloris crinita *par les vaches

Résumé. *L'utilisation continuelle des prairies d'élevage de la moyenne vallée du Río Negro, dans le nord de la Patagonie en Argentine, cause la dégradation des pâturages. Pour évaluer la population de* Trichloris crinita*, une plante originaire d'Amérique connue comme fausse herbe de Rhodes, et estimer sa consommation et sa préférence par les vaches, on a planifié l'utilisation de ces prairies avec des bovins d'élevage sous un régime de rotation sur des parcelles de composition végétale connue. Pour décrire la flore, on a identifié les espèces sur des droites d'intersection. Le régime alimentaire des animaux au pâturage a été déterminé au moyen d'analyses micro-histologiques utilisant les caractéristiques épidermiques pour identifier les composantes végétales dans des échantillons fécaux des vaches. Les parcelles situées au pied du plateau qui limite la vallée, avec des sols alluviaux et peu de biodiversité, mais sur lesquelles la* T. crinita *pousse spontanément, ont été privées d'animaux pendant les mois d'été et d'automne, pour permettre le développement végétatif et reproductif de l'espèce. Le pâturage en hiver, comme pâture différée, a permis l'augmentation de la population de* T. crinita*, une plus grande production annuelle de matière sèche par plante, et s'est soldé par une augmentation de la consommation des animaux.*

Mots-clés. *Nord de la Patagonie – Élevage – Région semi-aride – Espèces autochtones.*

I – Introduction

Biodiversity on cattle farms in semi-arid regions is greatly dependent on the plant/animal relationship. In the middle valley of the river Negro, Northern Patagonia, Argentina, many fields are still used for extensive cattle raising, using spontaneous pasture. Historically the annual rainfall for the area was 303 mm with notable inter annual variation, but during the last decade the precipitation was 36% below average and the number of animals in the area suffered a decline of 50%. The continuous use of the livestock fields combined with severe drought caused forage degradation.

A long term study was planned to identify and evaluate the different soil/landscape/vegetation units in a cattle field representative of the region. Monitoring of the forage resources and micro-histological cows' diet analysis showed that in the extremely dry year, 2010, few *Trichloris crinita* plants lived in the protected areas and animal consumption of the species was evident.

Trichloris crinita (Lag.) Parodi, commonly known as False Rhodes Grass or *plumerillo,* is an important native perennial grass, widespread in the range areas of the arid and semi-arid phytogeographical region of Monte (scrublands), Argentina. As it is a C4 type of Poaceae, it only grows in summer, using water efficiently. As a native species, *T. crinita* is well adapted to the environmental conditions of this semi-arid region (Greco and Cavagnaro, 2005; Fioretti and Brevedan, 2012).

Assuming that native grasses must be preserved, *T. crinita* became a target species and was monitored during the following years (2011-2013). The aim of the study presented here was to relate the *T. crinita* population with cow consumption on a yearly timed grazing schedule planned to increase the presence of this native species especially in parcels with poor forage.

II – Material and methods

Study place. A 550 ha cattle breeding field (39° 28' S - 65° 32' W) has been used to identify and evaluate the different soil/landscape/vegetation units of the middle valley and the cows´ diet. It has 12 parcels ranging from 7 to 100 ha, divided with traditional or electric fences in order to rotate the grazing of the animals. Land was stratified into landscape units and subdivided into soil/vegetation subunits for monitoring (Herrick *et al*. 2009). Historic climatic data were obtained from INTA (2000) and the precipitation was recorded in the field. Soil texture was described for each subunit and the salinity and fertility were analyzed at the LANAQUI laboratory with an Atomic Emition Spectrometer (ICP-AES), Shimadzu ICPE – 9000 in soil samples obtained from different units and depths.

Landscape and vegetation. As a pilot monitoring program (year 2010) vegetation identification was carried out in quadrats distributed systematically throughout the field, using a grid cell method to define 200 x 200 m macroplots and using a GPS to position the sampling points previously defined on a map (Elzinga, Salzer and Willoughly, 1998). These studies demonstrated the presence of the native *T. crinita* in two different landscapes. Since then (2011 to 2013) the studies on the *T. crinita* populations have been made on two 40 ha parcels, one near the river identified as **RPD** (rich plant diversity) and the other at the lower edge of the plateau that limits the valley named **PPD** (poor plant diversity), at a distance of 1500 m from each other. Vegetation richness was evaluated in both parcels following the grid cell method on 100 x 100 m macro-plots and identifying vegetation in a 1 sq m quadrat for each plot, Soil cover was measured with Line-point intercept and Gap-intercept methods (Herrick *et al*. 2009) on five 10 m transects for each study site in spring (October). These measurements facilitated the identification of the specific areas where the populations of *T. crinita* developed in RPD and PPD, occupying ca. 8 ha in both parcels. In each of these two areas where the presence of the target species was detected, ten randomly placed quadrants (1 sq m) were used to determine the number of *T. crinita* plants per m^2, plant size, number and height of flowering stems in every year in February (summer). Mean dry matter production (g DM/plant year) was estimated each year, in March (autumn), in samples obtained from small areas protected from grazing.

Diet micro-histological studies. Plant epidermal characteristics were used to identify components in fecal samples and to study the diet of the cows. Feces were collected from the cows as they came to the drinking areas. Immediately after they evacuated, 100 cm^3 of fecal material per cow was sampled in a plastic bag. Once at the laboratory the feces were oven dried at 60°C during 48 h, and then ground and conserved for further use. 15 cow feces samples were collected at the beginning of the grazing period, five days after the cows entered the parcel and 15 samples were collected at the end of the grazing period before moving the cows to another plot. For the analysis of cow feces, microscope slides were made for each sample site and date (Lindström *et al*., 1998) and 40 fields per microscope slide were systematically observed with 100X magnification. Reference slides of leaf, stem and fruit of the species present in the area were prepared with diaphanized material (Dizeo de Stritmatter, 1973), an epidermis fragment was removed by scraping (Metcalfe, 1960) according to the method described by Hansen *et al.* (1977) and it was used for the subsequent identification of epidermal fragments in the fecal samples.

Livestock management. For several **y**ears before this study was started, and up to 2011 during the severe drought period, livestock management consisted in moving the animals from one plot to another without a pre-designed timed grazing schedule. In order to avoid grazing in the parcels most affected by drought, rotational grazing was planned during the summer of 2011. Since 2012 the RPD plot has been used in January (summer) and the PPD parcel is grazed in July (winter). During the rest of the year the cattle graze in other field parcels. The stocking rates vary from 110 cows with their 2 to 5 month old calves (80 to 90) in January, to the cows with the remaining, yet unsold, 7 to 9 month old calves (around 40) in July.

III – Results and discussion

The climate is cold temperate semi-arid to arid. The average temperature ranges from 6.83°C in July to 23.02°C in January. The average annual precipitation is 303 mm, falling mostly during the spring and autumn. Annual evapotranspiration is over 800 mm, with a negative water balance throughout the year (INTA, 2000). The annual rain at the study site was only 230 mm in 2010 and 168 mm in 2011, falling mostly in summer. During 2012 it rained 401 mm, distributed throughout the year, but it was down to 287 mm in 2013, with no rain during the spring season.

In RPD the soils are deep, light, sandy loam, slightly alkaline (pH 8 to 8.5) and the electric conductivity is less than 4 Mmhos / cm. The organic matter content is between 3 and 6.5% in the 0-20 cm layer. Soils at PPD are alluvial and hence vary with the topography. The soil where *T. crinita* usually occurs is a sandy loam with deep layers of clay, slightly alkaline (pH 8.3 to 8.8), electric conductivity less than 4 Mmhos / cm and no sodium or excess salt, with 0.5 to 1.2% organic matter.

Although both the RPD and PPD parcels are at different sites in the valley they show relicts of river courses and/or of stream channels over 45% of their surface. Occasional flooding can occur (the last one was in 2007) when the river Negro flows through them. In RPD this area is occupied mainly by *Elaeagnus angustifolia* an invasive tall shrub that has become a food resource for the cows, even though plant development underneath its canopy is diminished. In PPD the ancient river course is a grazing plain that is mostly covered by *Distichlis spicata* during severe drought.

At RPD edible plants are represented mainly by the trees *Elaeagnus angustifolia* and *Salix sp.*, the shrub *Lycium sp*. and 74 herbaceous species, such as *Bromus*, *Nassella*, *Poa* and *Piptochaetium* (Poaceae). At PPD the edible plants are mainly the shrubs *Atriplex lampa*, *Lycium chilense*, *Lycium tenuispinosum* and *Suaeda divaricata* and *22* herbaceous plants, mostly grasses, such as *Poa ligularis*, *Piptochetium napostaense, Nassella sp., Distichlis spicata* and *Trichloris crinita.*

During summer in RPD the forage supply for livestock is generally ensured due to natural soil moisture. Data from January 2013 show that, when considering species with more than 2% contribution, at the beginning of the grazing period nearly 70% of the cows´ diet was provided by only six species: *Elaeagnus angustifolia* 21%, *Lycium chilense* 19%, *Medicago minima* 10%, *Trichoris crinita* 8.5%, *Nassella tenuis* 6.5% and *Poa ligularis* 4.5%. At the end of the grazing period *E. angustifolia* contributed with 66%, *L. chilense* with 10% and *N. tenuis* with 2.5%. The rest of the edible species, including *T.crinita,* completed the diet*,* supplying less than 1% each.

In PPD*, T. crinita* was scarcely found along the fences (less than 0.1%) in 2010 and 2011. When PPD was grazed in winter (July 2012 and 2013), the halophyte shrub *Atriplex lampa* contributed 25 to 40% of the cows´ diet at both the beginning and end of the month, whereas *Distichlis spicata* contributed 8 to 28% and *T. crinita* contributed 3% and 11.4% to the diet at the beginning of the period in 2012 and 2013 respectively. These values may be related to the increase in the number of plants per sq m, in the diameter of each plant and in the annual dry matter production per plant found within the *T. crinita* population site. No differences of the number and height of flowering stems were detected between years. (Table 1).

Table 1. Variation of plant cover in PPD (poor plant biodiversity) plot in 2010-2011 (in italics, pilot monitoring) and from 2012 to 2013; the incidence of *T.crinita* in the diet of breeding cows at the beginning and end of the grazing period and *T. crinita* plant population characteristics

		PPD (40 ha)		***T. crinita* population (8 ha)**				
Year	**Plant cover (%)**	**Cows' consumption (% *T.crinita*)** ***Initial***	***End***	***T.crinita* (plants/ m^2)**	**Plant diameter (cm)**	**Flowering stems (number/ plant)**	**Height of flowering stems (cm)**	**Annual dry matter (g/plant)**
2010	12			0.1	3 - 10	5	50	–
2011	9			0.1 a	3 - 10	6 a	45 a	19 a
2012	55	3.0	<0.1	3.0 b	5 - 20	7 a	40 a	74 b
2013	80	11.4	<0.1	7.0 c	10 - 40	6 a	55 a	97 c

Data were analyzed with ANOVA, means separated using Duncan test. Within a column, means with the same letter are not significantly different (p>0.05).

IV – Conclusion

Native forage grasses, such as *T. crinita*, have become adapted over time to poor soils and extreme climatic conditions in this semiarid region. The population of *T. crinita* may be influenced by the time of foraging. By leaving the populations of this species free from grazing during the growing period it permitted a greater vegetative growth and a higher productivity per plant, while germination of seeds increased the number of plants. Animals consume this grass as deferred pasture in the dormant season. Appropriate management promotes conservation of the species and may increase, in the future, the sustainability of cattle fields of poor biodiversity.

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Riboflavin secretion in cow's milk varies according to diet composition and season

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Abstract. In ruminants, B-vitamin supply from the diet and synthesis by the rumen microflora is considered sufficient to avoid deficiency. Nevertheless, factors affecting their concentrations in milk have never been studied in-depth, even if dairy products are among the best contributors of several vitamins (especially riboflavin) in human nutrition. We compared, during a year, riboflavin concentrations in bulk tank milks from 20 groups of 5 commercial farms divided among production systems mainly characterized by the forage nature (grass or maize silage). Riboflavin concentrations were greater in milks from grass-based than maize silage systems (1.91 *vs* 1.70 mg.L^{-1}, P<0.001). Moreover, they increased during summer (from 1.71 to 1.99 mg.L^{-1},P<0.001) whatever the feeding system. These differences were largely explained by a dilution effect due to the level of the milk yield but the mean amount of riboflavin secreted in milk per cow per day was higher when cows were fed a diet rich in maize silage by comparison to a herb-based diet (42.5 *vs* 33.4 µg.d^{-1}, respectively, P< 0.001). Conversely to what should be thought, riboflavin concentrations in milk are submitted to variations, and more interestingly regulations, that influence the global nutritional quality of milk.

Keywords. Cow milk – Vitamin – Feeding system – Season.

La sécrétion de riboflavine dans le lait de vache varie selon la composition de la ration et la saison

Résumé. *En raison de leur double origine alimentaire et microbienne ruminale, la disponibilité en vitamines B chez les ruminants est considérée pouvoir couvrir les besoins de ces animaux. C'est la raison pour laquelle, la variabilité de leurs concentrations dans le lait n'a jamais été explorée, même si le lait et les produits laitiers sont parmi les premiers contributeurs de certaines vitamines (dont la riboflavine) en nutrition humaine. Nous avons déterminé les concentrations en riboflavine dans des laits de tournées simulées correspondant à 20 groupes de 5 fermes commerciales caractérisés par leur système fourrager (basé sur l'herbe ou l'ensilage de maïs). Les concentrations de riboflavine étaient supérieures dans les laits issus des systèmes à base d'herbe par rapport à ceux utilisant préférentiellement le maïs (1,91* vs *1,70 mg.L^{-1}, P<0,001). Elles ont augmenté également pendant l'été quel que soit le système considéré (de 1,71 à 1,99 mg.L^{-1}, P<0,001). Ces différences s'expliquent principalement par un effet de dilution lié à la quantité de lait produite ; cependant, la quantité moyenne de riboflavine sécrétée dans le lait par vache et par jour était supérieure lorsque les vaches recevaient une ration à base d'ensilage de maïs que lorsqu'elles recevaient une ration à base d'herbe (respectivement 42,5* vs *33,4 µg.j^{-1}, P<0,001). Contrairement au concept couramment admis, la concentration de riboflavine du lait est variable, et de manière encore plus intéressante, elle semble être régulée, ce qui impacte la qualité nutritionnelle globale du lait et des produits laitiers.*

Mots-clés. *Lait de vache – Vitamine – Système d'alimentation – Saison.*

I – Introduction

For decades, availability of B vitamins has been globally considered as sufficient to cover the estimated requirements of dairy cows (except vitamins B_5 and B_9) thanks to supply from the diet and/or from synthesis by rumen microorganisms (National Research Council, 2001). However, as milk production levels considerably increased through bovine genetic selection and optimised feed efficiency, it is obvious that cow requirements for B vitamins, which are involved in the main metabolic pathways (cell respiration, energy production, nucleic acid synthesis, amino-acid metabolism and protein synthesis, neoglucogenesis...), increased proportionally (Girard *et al.*, 2010). To date, the relationship between performance levels and B vitamins requirements has not been studied. Proofs that B vitamin availability to lactating cows would be lower than needs are insufficient even though some experimental results suggested it. For example, increasing B vitamin supply (especially B_9 and B_{12}) to lactating dairy cows has beneficial effects, including on milk performance (Girard *et al.*, 2010). Moreover, it was also observed that their dietary supplementation raised their concentration in milk (Graulet *et al.*, 2007). This latter observation was interesting from a nutritional point of view, because milk and dairy products are good sources of vitamin A, B_{12} (cobalamins) and B_2 (riboflavin) (Coudray, 2011). However, the factors regulating concentration of B vitamins in milk have not been fully characterized. In a first publication, we reported that the highest levels of milk vitamin B_9 and vitamin B_{12} were generally associated with grass- and maize silage-based diets, respectively (Chassaing *et al.*, 2011). In the present work, we compared riboflavin secretion in milks obtained from different production conditions varying in term of diet composition, season or altitude.

II – Materials and methods

The study was carried out in 20 groups of five farms divided among four production systems mainly characterized by their forage system and altitude: feeding systems based on grass in Mountain (GM) or in Lowland (GL) and maize silage feeding systems located in Mountain (MM) or in Lowland (ML). In GM and GL, forages were mainly hay during the wintering period and fresh grass during the grazing period. The proportion of maize in cow diets was lower in MM than in ML whatever the period of the year. It was particularly marked in summer when the proportion of maize silage was extremely reduced in MM at the benefit of pasture / grass silage or grass silage / hay combination. In each group of farms, bulk tank milk was sampled five times in the course of the year 2008 at key times in animal feeding patterns: twice in the over-wintering period with diets based on preserved forage (January and February), and three times during the grazing period: in May, July and September. During the week of each milk sampling, a survey was carried out to record herd characteristics, performance and feeding. Average diets for each group were described on the basis of proportions of forages and concentrate in the diet calculated from the declared quantities the farmers dispensed. When the amount of one feed ingested was unknown (such as pasture), the estimation of the amount ingested was based on the energy requirements. The energy balance was supposed equal to zero. Milk riboflavin was extracted in duplicate by successive acid hydrolysis and enzymatic treatments using papain and acid phosphatase. Vitamin concentrations were measured in the extracts using a Acquity UPLC equipped with a 150 x 2.1 mm HSS T3, 1.8-µm column (Waters, France) and fluorescence detection (λ_{exc} = 400 nm; λ_{em} = 520 nm). Data were processed by Anova using the MiniTab16 software introducing the production system, period, and the interaction into the model as fixed effects. Because the characteristics of the production systems changed between periods, especially the diet composition, period was not considered a repeated factor.

III – Results and discussion

Riboflavin concentrations in the hundred milks studied varied from 1.51 to 2.15 mg.L^{-1} with a mean value of 1.78 ± 0.02 mg.L^{-1}. As for vitamin B_9 (Chassaing *et al*., 2011), riboflavin concentrations were greater in milks from grass-based than maize silage systems (1.91 *vs* 1.70 mg.L^{-1}, P<0.001, Fig. 1A). However, the interaction between diet composition and altitude was significant (P<0.01) because riboflavin concentrations were the highest in milks produced in lowland grass-based systems whereas the lowest values were observed in maize silage based systems also in lowland. Whatever the production systems, riboflavin concentrations increased during summer (from 1.71 to 1.99 mg.L^{-1}, P<0.001). Values observed in maize silage systems were in agreement with food tables (Graulet *et al*., 2013). However, riboflavin concentrations in milks produced in a grass-based system were higher (+14%), reinforcing the nutritional value of these milks.

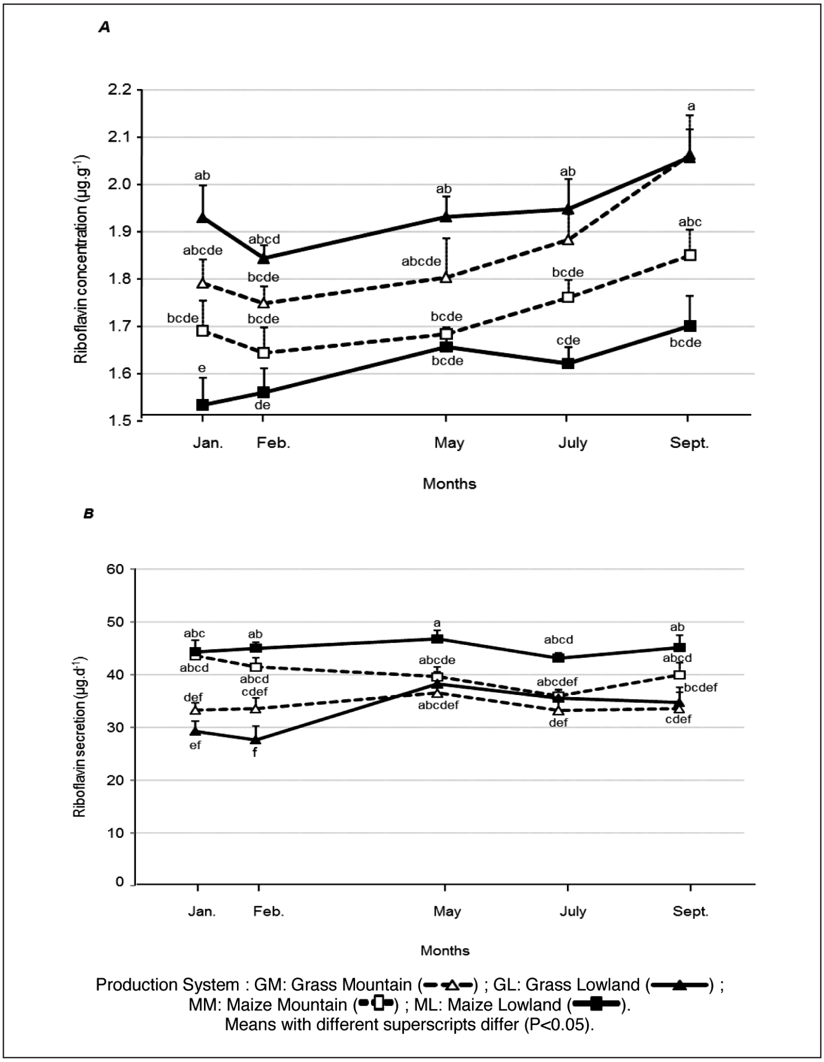

Fig. 1. Variations in milk riboflavin concentration (A) and secretion (B) according to feeding system, altitude and season.

Riboflavin secretion in milk per day and per cow was estimated for each system using the corresponding mean milk yield. Milk production levels were largely higher in maize-silage than in grass-based systems, especially in winter and in lowland. Consequently, the amount of riboflavin secreted in milk per day per cow was higher in maize- than in grass-based systems (42.5 *vs* 33.4 $\mu g.d^{-1}$, respectively, P< 0.001, Fig.1B). However, it was almost stable during the year and equivalent between lowland and mountain systems. Thus, variations in riboflavin concentrations in milk were largely explained by a dilution effect due to the higher milk yield in maize based-systems. The effects of season and altitude on the total amount of riboflavin secreted in milk are negligible. However these data suggest that riboflavin supply is greater for cows fed maize silage than for cows fed grass-rich diets, as illustrated by the amounts of vitamin secreted by the mammary gland. Of course, riboflavin could be provided to cows directly by the diet or indirectly by the influence of the diet on rumen fermentations, that is to be studied through complementary experiments. Finally, this last observation raise a concern about the adequacy of riboflavin supply to cows fed grass-rich diets and its role as a limiting factor for production efficiency.

IV – Conclusions

These results complete those obtained on folates (B_9) and vitamin B_{12} (Chassaing *et al*., 2011) confirming that milk concentrations of B vitamins vary according to diet and seasons even though complementary studies are needed for the other B vitamins and to better understand the underlying mechanisms. More interesting is the fact that riboflavin concentrations in milks produced by cows fed grass-rich diets especially in summer are higher than reference values reported in tables, reinforcing the interest of milk as a riboflavin source in human nutrition in general and giving an added value to milks produced in grass -based systems.

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Climate-impacts on autumn lamb weight

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Abstract. Year to year variation in weather conditions might affect lamb growth in different ways. The climate conditions might affect the animals directly, through increased stress levels and altered grazing behaviour. The main effect however, is expected to be indirect, through climate affecting the quantity and quality of the vegetation. Furthermore, previous studies indicate that the climate effect on lamb growth depend on the area under study. In Norway, lambs are born indoor in the spring (April and early May) and left out on pasture for grazing until slaughter in September when the lambs are five to six month of age. In this paper, we sum up results from three surveys performed on lambs grazing on mountain pastures in southern and northern parts of Norway. Study I and II include 83,331 and 38,587 lambs, respectively, during the years 1992 to 2007. Study III includes 8,696 lambs during the years 1983 to 2002.The results indicate that snow depth during the previous winter, precipitation and temperature in spring and summer affect lamb autumn body weight either positively or negatively. The effects are not consistent between study areas. We found a positive effect of early spring plant growth, an earlier spring resulting in heavier lambs in the autumn. Climate change effect studies are complex; however, by use of long-term databases, it is possible to reveal long-term trends. By use of climate statistics, satellite derived vegetation data and agricultural statistics, we have been able to show how climate changes might influence autumn weight for lambs in Norway. Our results might alter recommendations for sheep management during summer grazing.

Keywords. Climate change – Norway – Sheep management.

Impacts du climat sur le poids des agneaux à l'automne

Résumé. *La variation interannuelle des conditions météorologiques pourrait affecter la croissance des agneaux de plusieurs manières. L'effet des conditions climatiques sur les animaux pourrait être direct, via l'augmentation du niveau de stress et la modification du comportement au pâturage. Toutefois, l'effet principal serait indirect, à travers l'impact des conditions météorologiques sur la quantité et la qualité de la végétation. En outre, des études précédentes indiquent que l'effet du climat sur la croissance des agneaux dépend de la zone considérée, l'impact pouvant être positif ou négatif et d'intensité variable. Dans cet article, nous résumons les résultats d'études effectuées sur les agneaux qui pâturent dans des zones de montagne méridionales et septentrionales de la Norvège. Les résultats indiquent que la hauteur de neige au cours de l'hiver précédent, les précipitations et la température au printemps et en été influencent le poids des agneaux à l'automne. Nous avons également constaté un effet positif d'un développement précoce de la végétation, un printemps précoce donnant lieu à des agneaux plus lourds à l'automne. Les études sur l'effet du changement climatique sont complexes; néanmoins, l'utilisation de séries de données historiques pourrait révéler des tendances à long terme. Par l'utilisation conjointe des statistiques agricoles, des données météorologiques et de données satellitaires relatives à la végétation, nous avons été en mesure d'indiquer la façon dont les changements climatiques pourraient influencer le poids des agneaux à l'automne en Norvège. Nos résultats pourraient modifier les recommandations relatives à la gestion des ovins pendant la saison de pâturage.*

Mots-clés. *Changement climatique – Norvège – Gestion des ovins.*

I – Introduction

Local weather conditions affect ecosystems in general and the performance of out-door grazing livestock in particular. Though climate effects are operating on local scales, global climate indices such as the North Atlantic Oscillation (NAO) have proved to be useful tools for explaining local phenomena. NAO has been shown to represent large-scale weather patterns across Europe ultimately affecting ecosystems at local scales (Stenseth *et al*. 2003). Climate change might affect livestock production due to e.g. increased precipitation or drought. Alpine and arctic ecosystems are regarded in particular sensitive to climate changes as future changes are expected to be most severe at high latitude and elevation (IPCC, 2007). Under these conditions, temperature during early summer as well as snow accumulation the previous winter affect the start of the vegetation season and are regarded as key factors determining plant growth and phenology and in turn quality for alpine grazers (Nielsen *et al*., 2012; Nielsen *et al*., 2013; Nielsen *et al*. *submitted*). Plant growth and phenology can be quantified with the aid of the satellite-derived Normalized Difference Vegetation Index (NDVI) and several measures of NDVI have shown to correlate with the performance of animals (Pettorelli *et al*., 2005; Pettorelli *et al*., 2011).

In Norway, the sheep production industry depends on free-range grazing during summer. The sheep are kept indoors during the winter from mating in November until lambing in April and early May. During winter the ewes are fed mainly silage and some concentrate. Shortly after lambing, the sheep typically graze cultivated pastures and, as soon as the vegetation in the mountains allows for grazing (June), the sheep are released onto the mountain pastures. Each year, approximately two million sheep graze unfenced mountain or forest pastures over summer, until the autumn (September) when most lambs are slaughtered, five to six month of age. The mountain pastures represent a high value food source during summer and, although the quality of the pastures might vary within region and between districts, mountain grazing lambs have been shown to grow faster and bigger than lambs grazing in the lowlands (Nielsen *el al., submitted*; Gudmundsson, 2001).

Year-to-year variation in weather conditions might affect lamb growth on mountain pastures over summer. Climate conditions might affect the animals directly, through increased stress levels and altered grazing behaviour. Despite this, the main effect of year-to-year variation in lamb autumn weight is considered indirect through climate affecting the quantity and quality of the vegetation. Previous studies indicate however, that climate effects operate on different spatial scales and that they are spatially inconsistent. For instance, Nielsen *et al*. (2012) found that lamb autumn weight was positively affected by spring temperature in two areas, negatively affected in one area and not affected in the fourth area.

We have been involved in three studies investigating direct and indirect effects of climate on growth or autumn live weight of lambs grazing Norwegian mountain pastures during summer. The studies were performed along a significant climate gradient from Setesdal in the south (N59°) to Tjøtta in the north (N66°) of Norway using long-term data series for climate and sheep production. This paper sums up the results from the three studies.

II – Materials and methods

In study I (Nielsen *et al*., 2012), the dataset included 83,331 Norwegian white sheep (NWS) lambs from years 1992 to 2007 grazing in four alpine ranges (Setesdal, Hardangervidda west, Hardangervidda east and Forollhogna) in southern Norway. Study II (Nielsen *et al*., 2013) included the NWS lambs from Forollhogna in study I in addition to Norwegian spel lambs from the same area and during the same period, making up a total of 38,587 lambs. The aim of study II was to compare climate effects on different breeds. The third study, study III (Nielsen *et al*., *submitted*) included 8,696 domestic lambs from the years 1983 to 2002 from one single farm in northern Norway

(Tjøtta research farm). In this study several breeds and combinations thereof were included in the dataset. Focus in this paper was not on breed and this variable was therefore not included in our models. All focal areas are located outside the core areas for large carnivores and mortality rates were within the range of 'normal losses' in Norway at 4%.

The datasets from Study I and II were derived from the Norwegian Sheep Recording System. A local sheep recording system for ewes and lambs has been maintained at Tjøtta research Farm since the early 1970'ies and the dataset from Study III was derived from these records. For all datasets in this paper, lamb age at autumn weighing (between 110 and 160 days), litter size (single, twin or triplet), sex and maternal age (1 to 9 years) were included as individual based covariates in the models where the climate variables (Table 1) were main factors.

For all studies, we used the North Atlantic Oscillation Index (NAO) to quantify large scale among years variation in winter conditions, snow depth (Hurrell, 1995). We used winter NAO as this has shown to be a stronger predictor than spring NAO. We used the Principal Component (PC) based index over the months December to March. NAO has been shown to be related to the amount of winter precipitation, with high NAO resulting in more snow, at least in mountain areas.

To measure the year-to-year variations in plant growth and phenology we used the Normalized Difference Vegetation Index (NDVI) (Pettorelli *et al*., 2005). This index is derived from the red – near infrared reflectance ratio (NDVI = (NIR-RED)/(NIR+RED), where RED is red reflectance and NIR is near infrared reflectance from the vegetation). NDVI is presented as a value between -1 and +1, where higher values indicate greener vegetation and negative values indicate lack of vegetation. Despite its coarse spatial scale (8 km x 8 km pixels), the Global Inventory Monitoring and Modelling Study (GIMMS) dataset used has proven to be a very useful measure for inter-annual variation in vegetation growth and phenology. Spring NDVI (here NDVI in the second half of May) has been shown to provide a good representation of annual variation in spring green-up, indicating the arrival of spring.

To model the direct and indirect effects of different climate change scenarios, we built hierarchical path models and fitted them with Bayesian inference. This modeling framework allows us to estimate direct climate effects on the lambs together with indirect effects operating through climate effects on the vegetation. Our results are therefore the expected effect of a certain climate change based on the combination of direct and indirect processes. See Nielsen *et al*. (2012, 2013) for details on the methods.

III – Results and discussion

The results from the three studies reveal some general pattern (Table 1), but our general conclusion is that climate effects are spatially inconsistent. Snow depth the previous winter (high NAO index) had the most consistent effect on lambs' autumn live weight. We expect that snow cover have an indirect effect on lamb growth rate due to the effect of snowmelt on the onset of plant growth in the spring as well as the length of the melting season. Snow rich winters in the mountains extend the period of fresh vegetation emerging in snow beds, increasing the quantity and quality of forage for a prolonged period. The animals follow the snowmelt and are thus allowed fresh forage for a longer period of time.

Spring temperature has a positive effect in the colder areas but a negative effect in the warmer areas. In Northern and alpine regions, low temperatures are the limiting factor for plant growth, and consequently climate warming might increase primary production. The same global warming might, however, limit water availability, cause heat stress to plants in warmer and arid environments, and thus cause the opposite effect. Encroachment of shrubs as well as an elevation of the tree line is however expected with increasing temperatures at these latitudes. Early summer temperature (July) has a negative effect in the warmer areas and a positive effect in the colder areas while late summer temperature (August – with high values most likely indicating prolonged plant growing season) in general has a positive effect. Precipitation has a positive effect in the dryer areas and a negative effect on the wetter, more western areas. This suggests a potential for drought stress in the vegetation in dry and warm summers. We also found a positive effect of early spring plant growth and phenology (NDVI index spring) indicating that an earlier spring resulted in heavier lambs in the autumn. The NDVI is a representation of the greenness of whole plant communities. In study II, it is suggested that plant functional groups respond differently to similar climate conditions. This might have implications for the development of the plant communities under future climate conditions.

Table 1. Factors affecting lambs' autumn live weight. +: positive effect, -: negative effect, 0: no significant effect, na: not included based on initial model selection procedures, or in the case of precipitation in Study III data not available. Note that the results from Forollhogna (study I) are identical to the results from study II

	Study I; Nielsen *et al.*, 2012				**Study III; submitted**
	Setesdal	**Forollhogna (Study II; Nielsen *et al.*, 2013)**	**Hardanger West**	**Hardanger East**	
NAO previous winter	0	+	+	+	+
Spring temperature	0	+	–	+	–
Spring precipitation	Na	–	–	+	na
July temperature	–	na	–	+	+
August temperature	+	+	na	na	+/–
July precipitation	–	na	–	+	na
August precipitation	–	+	na	na	na
NDVI	+	+	0	+	+

NAO: North Atlantic Oscillation, NDVI: Normalized Difference Vegetation Index.

There is little doubt that the global mean temperature is increasing and at the same time the regional climate variations, particularly of precipitation, are expected to be more unpredictable. The ability of plant functional traits to adapt to disturbances from herbivores is well documented. It is on the other hand not clear how plant communities along the browse – grass continuum adapt to annual climate variations. The changes in both temperature and precipitation may affect the communities in contrasting ways depending on the main limiting factor.

IV – Conclusions

By use of climate statistics, satellite derived vegetation indices and agricultural statistics we have been able to show how climate changes might influence autumn weight for lambs in Norway. Our main conclusions are that the severity of the previous winter is important and that climate change effects in general are site specific suggesting that local conditions play a significant role. We therefore recommend the farmers not to take into account the potential effects of future climate change when deciding on their use of different pastures, but rather focus on adapting the length of the grazing season to optimize meat production.

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Effect of whole or extruded linseed and of *Acacia cyanophylla* foliage intake in grazing dairy ewes

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Abstract. This experiment was conducted to investigate the effects of two different forms of linseeds (whole or extruded) and *Acacia Cyanophylla* tannins on milk yield and fatty acid (FA) profile and nitrogen balance in dairy ewes. Four groups of ten ewes, grazing triticale pasture, were supplemented with 250 g of soybean meal and 70 g of whole linseed (SW) or with 70 g of extruded linseed (SE), or with whole linseed and 100 g of acacia foliage (SWA) or with extruded linseed and 100g acacia foliage (SEA). Extruded linseed induced a significant decrease (P<0.05) of NDF digestibility of 2.2% over whole linseed. Intake of acacia foliage decreased (P<0.05) urinary nitrogen by 1.4 g/d and increased (P<0.0005) the nitrogen retention by 4.1 g/d. Milk production and composition were not affected by the diets except milk urea which decreased significantly (P<0.05) with extruded linseed and with the intake of acacia foliage. Stearic acid (C18:0) in ewe's milk was significantly decreased (P<0.006) with extruded linseed and with acacia and extruded linseed (P<0.03). Extruded linseed and acacia induced a decrease (P<0.0001) of oleic acid (C18:1 cis-9) by -1.82% and -1.23%. Acacia had no effects on omega-3 fatty acids and on the CLA, but fatty acid of the omega-6 group like $ -linolenic acid (C18:3 cis-6, cis-9, cis-12 (n-6)) were increased.

Key words. Linseed – Tannins – Nitrogen balance – Milk yield – Fatty acid – Ewe.

Effet de la graine de lin entière ou extrudée et de l'ingestion de feuilles d'**Acacia cyanophylla** ***chez la brebis laitière au pâturage***

Résumé. *Cette expérience a été réalisée pour étudier les effets de deux formes différentes de graines de lin (entier ou extrudé) et les tanins d'*Acacia cyanophylla *sur la production laitière, le profil des acides gras du lait et le bilan azoté chez les brebis laitières. Quatre groupes de dix brebis sur pâturage de triticale ont été complétés avec 250 g de tourteau de soja plus 70 g de lin entier pour le lot (SW) et 70 g de lin extrudé pour le lot (SE). Les brebis des lots (SWA) et (SEA) reçoivent en plus par rapport aux lots (SW et SE) 100 g de feuillage d'acacia. Le lin extrudé a induit une diminution significative (P<0,05) de la digestibilité du NDF de 2,2% par rapport au lin entier. L'ingestion d'acacia a diminué (P<0,05) l'azote urinaire de 1,4 g/j et a augmenté (P<0,0005) la rétention d'azote de 4,1 g/j. La production et la composition du lait n'ont pas été affectées par les régimes à l'exception de l'urée du lait qui a diminué de façon significative (P<0,05) avec l'ingestion de graines de lin extrudées et d'acacia. L'acide stéarique (C18:0) dans le lait des brebis a diminué de manière significative (P<0,006) avec l'ingestion du lin extrudé seul et avec l'ingestion d'acacia et de lin extrudé (P<0,03). Les graines de lin extrudées et l'acacia ont induit une baisse (P<0, 0001) de l'acide oléique (C18:1 cis-9) de -1,82% et -1,23%. L'acacia n'a eu aucun effet sur les acides gras du groupe oméga-3 et sur le CLA, mais les acides gras du groupe oméga-6 comme l'acide * -linolénique (C18:3 cis-6, cis-9, cis-12 (n-6)) a augmenté.*

Mots-clés. *Lin – Tanins – Bilan azoté – Production laitière – Acide gras – Brebis.*

I – Introduction

Oilseeds could be incorporated in ruminant diets in order to increase polyunsaturated fatty acids (PUFA), content in dairy products, and thus to improve their nutritional quality (Shingfield *et al*., 2013). The changes in PUFA content of dairy products depend on the basal diets and oilseeds. In manufacturing feed, the extrusion technique is used to destroy the enzymes which are responsible for rancidity and anti-factors' nutrient, present in the seeds. This reduces hydrogenation of unsaturated FA in the rumen. *Acacia Cyanophylla* contains tannins, which could partially protect dietary proteins and lipids from rumen metabolism by modifying environment in rumen and microorganisms' activity. The objective of this experiment was to study the impact of the form of linseed (whole or extruded) and of a supplementation with acacia foliage on sheep milk production fatty acid profile and nitrogen balance.

II – Materiel and methods

The experiment was carried out in the dairy experimental farm of the National Institute of Agricultural Research of Tunisia (INRAT), on 40 Sicilo-Sarde breed ewes divided into four homogeneous groups: 10 ewes each, according to their age, parity and milk production (567 ml/day). Ewes were conducted together during the day (from 1000 h to 1500 h) on triticale pasture with rotational grazing system with a stocking rate of 26 ewes/ha. Indoors, ewes were separated and lodged per groups, receiving 250 g of soya bean meal. Such diet was complemented by 70 g of whole linseed for the first group (SW), 70 g of extruded linseed for the second group (SE), 70 g of whole linseed together with 100 g *Acacia Cyanophylla* foliage for the third group (SWA) and 70 g of extruded linseed with 100 g acacia foliage for the fourth group (SEA). The experiment lasted 70 days. Five animals from each group were placed in individual metabolic cages during 2 weeks for a digestion trial (10-day adaptation period, 5-day period of total faecal and urine collection). Concentrate, linseed and acacia were offered once daily at 09:00. Fresh cut triticale and oat silage were distributed in two equal meals at 09:00 and 16:00 in separate troughs. Milk fat, protein, and urea N were analyzed by a MilkoScan 4000 (Foss Electric, integrated Milk Testing). Methyl esters of FA were analyzed by gas chromatography (GC) (Shimadzu, GC-14 A). Data of milk yield, composition, fatty acid profile, diet digestibility and nitrogen balance (twice a month for two months and a half), were analyzed as repeated measures using the mixed procedure of SAS (2000). The statistical model included: experimental diet, time of sampling and their interactions as fixed effects. The data recorded during pre-experimental period (milk yield and composition) were used as covariates and included in the model. The following contrasts were used to compare the effects of different diets: Contrast 1: linseed form effect {SW, SWA vs. SE, SEA}; Contrast 2: acacia effect {SW, SE vs. SWA, SEA}; Contrast 3: acacia effect according to linseed form {SWA vs. SEA}.

III – Results and discussion

The chemical composition of experimental feeds was presented in Table 1. The protein content of triticale was around 9.7%. This content is considered low as a consequence of the absence of nitrogen fertilization during growing period.

The feed intake was average of 1.84 kg/ewe/d and the total intake of 2.17 kg/ewe/d. The digestibility of organic matter did not varied with diets and reached 83.8% (Table 2). The digestibility of CP tended to differ ($P < 0.10$) between groups. According to contrasts studied, extruded linseed tended ($P = 0.08$) to increase the CP digestibility by 1.9% over the whole linseed (contrast C1). *Acacia cyanophylla* (contrast C2) tended ($P = 0.09$) to increase the CP digestibility by 1.9%. The same for the contrast C3, the contribution of acacia with extruded linseed tended ($P = 0.08$) to increase the CP digestibility by 2.6%. These results could be explained partly by the fact that the extrusion reduces ruminal degradability of protein in rumen. The digestibility of the NDF fraction was significantly decreased by 2.2% with extruded linseed compared to whole linseed.

Table 1. Chemical composition of triticale, Soya bean meal, linseeds (whole and extruded) and *Acacia Cyanophylla* (in% of DM)

Chemical composition	Triticale	Soya bean meal	Whole linseed	Extruded linseed	*Acacia cyanophylla*
Dry matter (DM) (%)	23.7	85.4	92.2	92.5	97.7
Organic matter	93.5	93.2	96.3	95.5	90.8
Crude protein	9.7	42.9	19.6	19.2	14.3
Neutral-detergent fibre	53.9	34.4	56.2	48.6	44.5
Acid-detergent fibre	29.9	6.6	33.7	27	38.2
Fat matter	–	–	29	30.8	–
Ash	6.5	6.8	3.7	4.5	9.2
Total phenols†	–	–	–	–	27.5
Condensed tannins††	–	–	–	–	32.7
Palmitic acid	–	–	6.6	–	–
Stearic acid	–	–	4.13	4.2	–
Oleic acid	–	–	18.4	18.6	–
Linoleic acid	–	–	14.1	14.3	–
Linolenic acid	–	–	53.8	53.1	–

† Expressed as g tannic acid equivalent per kg DM. †† Expressed as g leucocyanidin equivalent per kg DM.

Table 2. Effect of experimental diets on forage and dry matter intake and diet digestibility in dairy ewes

	SW	SE	SWA	SEA	m.s.e	Pr.>F	Contrasts Pr.> F		
							C1	C2	C3
DM forage intake (g/d)	1742	1866	1892	1892	156.7	0.5	0.4	0.3	0.9
Total DM intake (g/d)	2020	2144	2267	2267	156.7	0.1	0.4	0.04	0.9
OM digestibility (%)	83.6	83.2	83.5	85	1.86	0.4	0.4	0.3	0.2
CP digestibility (%)	79.5	80.6	80.6	83.2	2.02	0.1	0.08	0.09	0.08
NDF digestibility (%)	81.8	78.4	82.5	81.5	2	0.06	0.03	0.1	0.3

m.s.e: mean standard error.

Acacia supply increased ($P < 0.0001$) the nitrogen intake (Table 3). Diets did not significantly affect faecal nitrogen (g/day), but C1 and C3 contrasts showed significant differences. In fact, extruded linseed intake and with *Acacia cyanophylla* induced a decrease of faecal nitrogen (0.5 g/day and 0.8 g/day respectively) compared with whole linseed intake.

Table 3. Effect of experimental diets on nitrogen balance in dairy ewes

	SW	SE	SWA	SEA	m.s.e	Pr.>F	Contrasts Pr.> F		
							C1	C2	C3
N intake (g/day)	27.4	27.9	30.4	30.3	0.8	0.0002	0.5	0.0001	0.9
Fecal N (g/day)	5.6	5.4	5.9	5.1	0.5	0.1	0.05	0.9	0.03
Urinary N (g/day)	9.5	9.8	8.4	8.1	1.2	0.2	0.9	0.04	0.7
N retention (g/day)	12.2	12.8	16.1	17.1	1.6	0.002	0.3	0.0002	0.3
N Absorbed (g/day)	21.7	22.5	24.5	25.2	1.2	0.002	0.2	0.0004	0.3

m.s.e: mean standard error.

Urinary nitrogen (g/day) ranged from 8.1 g/day and 9.8 g/day, without significant effects of diets. Acacia (contrast C2) induced a significant decrease ($P< 0.05$) in urinary nitrogen by 1.4 g/day and a significant increase in nitrogen retention (g/day) of 4.1 g/day. For the absorbed nitrogen (Nab/g/day), the respective values ranged from 21.7 g/day to 25.2 g/day, with significant differences ($P<0.003$) between diets. This parameter increased significantly with acacia supply (C2, $P<0.0005$) by 2.8 g/day.

Milk production as well as fat and protein contents were not significantly affected by the diets (Table 4). Fat and protein content were on average 7.3 and 4.8%, respectively. Milk urea, significantly ($P<0.05$) varied according to experimental diets. Indeed, extrusion of linseeds notably ($P=0.05$, contrast C1) decreased milk urea by about 3 mg/dl. Similarly, *Acacia Cyanophylla* supply (contrast C2) induced a significant ($P<0.05$) decrease of milk urea by 3.8 mg/dl, which could be a result of a better use of food proteins, following their protection by tannins in the rumen. Milk urea for ewes fed with extruded linseeds and tannins of acacia has the lowest value. This result agrees with that of Maamouri *et al.* (2011), who suggested that *Acacia Cyanophylla* supply much decreased ewe's milk urea. The application of heat (extrusion) may reduce the bacterial protein de-amination in the rumen. Stearic acid (18:0) varied significantly ($P <0.04$) between groups. Indeed, this fatty acid considerably decreased (contrast C1, $P <0.006$) with extruded linseed intake (-2.5%). The decrease was also about -2.2% with *Acacia Cyanophylla* (C3 contrast, $P <0.03$). Oleic acid (c9-18:1), the second most important fatty acid in milk' ewes, with an average percentage of 18.8%, was significantly decreased by extruded linseed and Acacia Cyanophylla ($P<0.0001$). The percentage (% of total FA) of rumenic acid (c9, t11-18:2, CLA isomer) ($P<0.05$) increased by 0.5% in the sheep milk with extruded linseed (C1, $P<0.05$). *Acacia Cyanophylla* also increased by 0.7% the content of this particular fatty acid in milk with extruded linseed (C3, $P<0.05$). Finally *Acacia Cyanophylla* intake induced an important increase (C2, $P<0.05$) for "n-6" FA such as $ -linolenic acid (c6, c9, c12-18:3 (n-6)).

Table 4. Effect of experimental diets on milk yield and fatty acid composition (g/100g of Tot FA) in dairy ewes

	SW	SE	SWA	SEA	m.s.e	Pr.>F	Contrasts Pr.> F		
							C1	C2	C3
Milk yield (ml/day)	630	641	628	692	5.6	0.6	0.3	0.5	0.3
Fat content (%)	7.4	7.4	7.4	7.2	0.05	0.8	0.7	0.6	0.5
Protein content (%)	4.9	4.9	4.8	4.8	0.03	0.7	0.7	0.3	0.9
Milk urea N (mg/dl)	27.8	24.1	23.7	20.6	0.8	0.05	0.05	0.03	0.2
C18:0	13.5	10.7	12.7	10.5	0.3	0.04	0.006	0.4	0.03
c9-18:1	20.9	17.8	18.4	17.9	0.2	0.0001	0.0001	0.0001	0.0002
c9, t11-18:2	1.03	1.3	0.88	1.6	0.06	0.05	0.01	0.7	0.01
c9, c12, c15-18:3 (n-3)	1.06	1.3	0.99	1.27	0.03	0.14	0.03	0.7	0.08
c6, c9, c12-18:3 (n-6)	0.09	0.11	0.12	0.13	0.004	0.13	0.19	0.04	0.4

m.s.e: mean standard error.

IV – Conclusion

Extruded linseed decreased NDF digestibility. Acacia intake seems to play a role in the decrease of urinary nitrogen and an increase of the nitrogen retention while did not affect milk production and composition except milk urea which also decreased with extruded linseed intake in comparison with whole linseed. On the fatty acid profile of milk, extruded linseed and acacia induced a decrease of oleic acid (C18:1 cis-9). The extrusion of linseed leads to an increase in fatty acids omega-3 group and the CLA.

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Seasonal preferences of grazing goats in a Mediterranean oak-juniper rangeland

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Abstract. The purpose of this study was to investigate the seasonal grazing behavior of goats in an oak - juniper rangeland ecosystem in the Mediterranean region. The research was conducted in Megalo Dereio, which is located in Evros region, northeastern Greece and is grazed by a flock of 750 local goats. Grazing behavior data were recorded in late spring (May), middle of summer (July) and late autumn (November) of 2010 and 2011. Behavioral data from five adult goats, randomly selected every time, were recorded for four consecutive days during each trial period. These animals were monitored sequentially for five minutes, in the morning and in the afternoon (total observation period of 50 min per day). Measurements included: number of bites per plant species and bite size as the average of hand-plugged samples similar to those consumed by the animals. Statistical analysis was conducted to test the seasonal preferences on the base of plant group species. According to the results significant differences on preferences were observed among the tested periods. Herbaceous vegetation was preferred during spring, while during summer and late autumn goats grazed mainly the woody species of the region (*Juniperus oxycedrus, Quercus frainetto, Cistus creticus*). The most preferred woody species was *Quercus frainetto* indicating that oak is the most essential browse species of the region for goat nutrition.

Keywords. Browse – Grazing behavior – Oak – Direct observation.

Préférences saisonnières des chèvres pâturant un parcours de chêne-genévrier méditerranéen

Résumé. *Le but de cette étude était d'étudier le comportement saisonnier des chèvres en période de pâturage dans un écosystème de chêne-genévrier dans la région méditerranéenne. L'étude a été menée dans Megalo Dereio, qui est situé dans la région d'Evros, au nord-est de la Grèce, dans une prairie qui est pâturée par un troupeau de 750 chèvres locales. Les données sur le comportement de pâturage ont été enregistrées à la fin du printemps (mai), au milieu de l'été (juillet) et à la fin d'automne (novembre) de 2010 et 2011. Les données comportementales de cinq chèvres adultes, sélectionnées chaque fois au hasard, ont été enregistrées pendant quatre jours consécutifs au cours de chaque période d'essai. Chaque animal a été surveillé pendant cinq minutes, le matin et l'après-midi (période d'observation totale de 50 min par jour). Les mesures comprenaient : le nombre de bouchées de chaque espèce végétale et la taille de la bouchée, qui a été calculée par la moyenne des prélèvements simulés (cueillis à la main) correspondant à chaque type de bouchée. L'analyse statistique a été réalisée pour tester les préférences saisonnières sur la base du groupe d'espèces végétales. Selon les résultats des différences de préférences considérables ont été observées parmi les périodes examinées. La végétation herbacée a été préférée au printemps, tandis que durant l'été et à la fin de l'automne les chèvres pâturent principalement les espèces ligneuses (*Juniperus oxycedrus, Quercus frainetto, Cistus creticus*). L'espèce ligneuse la plus préférée était* Quercus frainetto *indiquant que le chêne est l'espèce essentielle de la région pour la nutrition des chèvres.*

Mots-clés. *Parcours – Comportement de pâturage – Chêne – Observation directe.*

I – Introduction

Oak woodlands and shrub-lands are important forage source for grazing animals and mainly for goats in the Mediterranean basin (Perevolotsky *et al.*, 1998). It is well documented that goats prefer woody species more than the herbaceous ones and their diet mainly consists of lignified species (Dumont *et al.*, 1995). Due to their metabolic efficiency and their ability to convert the low-quality vegetation into high-quality products, they are able to utilize hilly and shrubby rangelands that cannot be used by other domestic animals. On the other hand, it has been reported that herbaceous species are preferred by goats during spring (Kababya *et al.*, 1998).

As goats are classified as selective feeders because of their special feeding behavior (Ngwa *et al.*, 2000), the further study of their seasonal preferences and the exploration of the botanical composition of their selected diet are of great interest. The purpose of this study was to investigate the seasonal grazing behavior of goats on a mixed oak-juniper rangeland ecosystem in the Mediterranean region.

II – Materials and methods

The research was conducted in an open oak forest in Megalo Dereio, Evros region, Northeastern Greece, at 380 m a.s.l. The climate of the area is characterized as Sub-Mediterranean. The mean annual precipitation is 560 mm and the mean temperature is 13.7 ^{o}C. The vegetation of the area on average consists of: *Quercus frainetto (8.93*%), *Juniperus oxycedrus* (8.46%), *Cistus creticus* (15.85%), other woody (0.72%), grasses *(35.76%),* legumes *(14.24%)* and forbs (16.04%). The dominant herbaceous species were the grasses *Dactylis glomerata, Poa pulbosa, Aegilops lorentii,* the legumes *Trifolium arvensis, Trifolium campestre, Lotus corniculatus* and the forbs *Sanquisorba minor, Matricaria chamomilla, Anthemis parnassica*. The area is grazed mainly by goats and less by sheep and cattle.

A representative flock of 750 local breed goats which are fed exclusively in the rangeland without any additional feeds was studied. Grazing behavior data were recorded in spring (May), summer (July) and late autumn (November) of two consecutive years 2010 and 2011. Behavioral data from five adult goats, randomly selected every time, were recorded for four consecutive days during each test period according to Altman (1974) sampling method and its modification described by Mancilla-Leytón *et al.* (2012). Each animal was monitored for 5 minutes in the morning and 5 minutes in the afternoon (total observation period of 50 min per day). The observations were performed sequentially with an interval of 10 to 20 minutes to collect forage samples for identification, covering a large part of the grazing time for each day.

Measurements included: Number of bites per plant species and bite size as the average of hand plucked samples to those consumed by the animals (Cook, 1964). Plant samples were collected in paper bags, oven-dried at 65°C for 48 hours and weighed. Thus, the average weight of dry matter of bites per plant species was calculated. Herbaceous species were grouped into grasses, legumes and forbs.

The percentage of bites per plant group species was calculated using the following formula:

$$\frac{\text{Number of bites per plant group species}}{\text{Total bites}} \times 100$$

In order to calculate diet composition data were further grouped into four major categories: Oak, other woody species, acorns and herbaceous species. Diet composition was calculated for each observation day and period using the following formula:

$$\frac{\text{Number of bites per plant group species x Weight of its bite}}{\text{Total bites all plant groups species x Weight of its bites}} \times 100$$

All measurements were subjected to an analysis of variance using version 8.0 of the JMP software (SAS Institute Inc, Cary, North Carolina). A multiple comparisons for all pairs of means were performed using Tukey-Kramer HSD. The significance level was set to P<0.05.

III – Results and discussion

The percentage of bites of woody species (93.03%) was significantly higher in summer than the other two studied seasons (Table 1), while the higher percentage of herbaceous species was in spring and autumn. These results were expected as the available herbaceous vegetation is limited during summer due to the dry and warm weather conditions (Papachristou *et al*., 2005). The most selected woody species was *Quercus frainetto* which was preferred mostly in summer with a significantly higher percentage (56.41%) than in spring and in autumn (Table 1). *Juniperus oxycedrus* was consumed by goats mainly in spring when its leaves were more gently. The deciduous species *Carpinus orientalis* was preferred mainly in summer. Similar findings have been reported by Papachristou (1996) in Northern Greece. On the contrary, *Cistus creticus* was selected mainly in autumn, when the more palatable deciduous woody species had started to drop their leaves. There were no significant differences among the seasons for *Rubus* sp. and *Paliurus spina-christi.* Regarding the herbaceous species, grasses were the most preferred by 15.09% and 20.55% respectively, especially in spring and autumn. Their relatively high percentage of preference in autumn could be related to their high regrowth rate, especially in 2010. Legumes were selected mainly in spring at a rate significantly higher than the other two seasons. Acorns were selected only in the autumn of 2010 due to the oak's masting that year.

Table 1. Total bites/ species/ season (%) produced by the direct observation of goats

	Spring	Summer	Autumn	p-value
Woody	**50.91**	**93.03**	**60.32**	***
Quercus frainetto	19.94 ^{B}	56.41 ^{A}	24.58 ^{B}	***
Juniperus oxycedrus	20.61 ^{A}	7.89 ^{AB}	6.28 ^{B}	*
Cistus creticus	4.52 ^{B}	1.50 ^{B}	29.02 ^{A}	***
Rubus sp.	1.03	2.37	0.44	NS
Carpinus orientalis	4.51 ^{B}	22.47 ^{A}	0.00 ^{B}	***
Paliurus spina-christi	0.29	2.39	0.00	NS
Herbaceous	**49.09** ^{A}	**6.97** ^{B}	**34.45** ^{A}	***
Grasses	15.09 ^{A}	3.44 ^{B}	20.55 ^{A}	**
Legumes	21.78 ^{A}	1.27 ^{B}	4.29 ^{B}	***
Forbs	12.23 ^{A}	2.26 ^{B}	9.61 ^{AB}	*
Acorns	**0.00**	**0.00**	**5.23**	***

*P<0.05, **P<0.01, ***P<0.001, NS: non significant. Means in the same row followed by the same letter are not significantly different (P ≥ 0.05).

The largest proportion of the total goats' diet consisted of woody species, particularly *Quercus frainetto* (Fig. 1). The high contribution rate of *Quercus frainetto* is due to its high preference and the large amount of weight of each bite. The participation rates of the other woody species were not significantly different among the seasons. The proportion of herbaceous species in goats' diet was significantly higher (42.09%) in spring compared to autumn although there were no differences in the corresponding percentages of bites. This result is probably explained by the larger size of bites in the spring compared to the autumn. Acorns participated only in autumn in goats' diet at a rate of 25% approximately, which was significantly higher than the corresponding level number of bites in the same period (Table 1) due to the very large weight of each bite which consisted of a whole acorn.

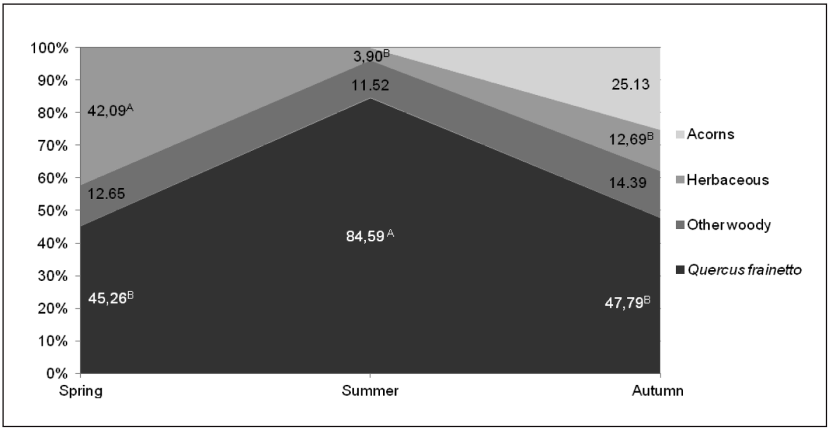

Fig. 1. Percentage (%) of goats' diet composition in major plant categories.
Means followed by the same letter are not significantly different (P ≥ 0.05).

IV – Conclusions

Although preliminary, the results indicate that the herbaceous vegetation was equally preferred to woody species only during spring, while during summer and autumn goats grazed mainly the woody species. Acorns are also an important part of goats' diet during mast years. The most preferred species was *Quercus frainetto* indicating that it is an essential browse species for goat nutrition in the dry periods of the year in the Mediterranean basin. Thus, this fact should be taken into consideration for the sustainable management of oak woodlands.

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This paper is dedicated to the loving memory of associate professor Zafeiris Abas, Democritus University of Thrace, Greece. He was not only a superior scientist, but also a warm-hearted human being.

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Effect of growth hormone polymorphisms and of diet on the productive performance and technological quality of Serra da Estrela sheep milk

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Abstract. Sheep milk composition influences, not only cheese yield, but also cheese quality by providing different milk clotting behaviour. This work addresses the effect of the growth hormone (GH) polymorphisms and diet on milk production, composition and technological properties of 83 Serra da Estrela sheep. The daily production and milk properties were analysed at 42, 60 and 90 days of their first lactation. Samples were analysed for pH, and fat, protein and total solids contents. The potential cheese making yield was evaluated and the milk technological properties were assessed by Optigraph, measuring the time to onset of flocculation, casein micelle aggregation rate and gel firmness. There were no differences between the GH genotypes for any of the milk parameters evaluated, which might be due to the low adaptability of primiparous sheep to machine milking. The lighter sheep fed only pasture, hay and silage (group R) showed significantly higher protein, non-fat milk, and solids contents, and also higher values of AR, A40 and lower OK20, especially evident in the genotypes AA and AE.

Keywords. Growth hormone – Sheep milk – Milk technological aptitude.

Effet des polymorphismes de l'hormone de croissance et du régime alimentaire sur la performance productive et la qualité technologique du lait de brebis Serra da Estrela

Résumé. *La composition du lait de brebis influence, non seulement le rendement fromager, mais aussi la qualité du fromage en provoquant un comportement du lait différent à la coagulation. Cette étude porte sur l'effet des polymorphismes de l'hormone de croissance (GH) et du régime alimentaire sur la production, la composition ainsi que sur les propriétés technologiques du lait de 83 brebis de la race Serra da Estrela. La production journalière ainsi que les propriétés du lait ont été analysées à 42, 60 et 90 jours pendant la première lactation. Le pH et la teneur en matière grasse, en protéine brute et en solides totaux ont été analysés. Le rendement potentiel de la fabrication de fromage a été analysé et les propriétés technologiques du lait ont été évaluées par Optigraph, en mesurant le temps pour le démarrage de la floculation, le taux d'agrégation des micelles de caséine et la fermeté du gel. Il n'y avait pas de différences entre les génotypes GH pour aucun des paramètres évalués dans le lait, ce qui pourrait être du à la faible capacité d'adaptation des brebis primipares à la traite mécanique. Les brebis plus légères alimentées avec du pâturage, du foin et de l'ensilage (groupe R) ont présenté des teneurs en protéines, en lait écrémé, et en solides totaux significativement plus élevés, de même que des valeurs plus élevées de l'AR et A40 et des valeurs inférieures de OK20, particulièrement pour les brebis des génotypes AA et AE.*

Mots-clés. *Hormone de croissance – Lait de brebis – Propriétés technologiques du lait.*

I – Introduction

Growth hormone (GH) is one of the main hormones involved in mammary development both in puberty and gestation (Sejrsen *et al.*, 1999) in ruminants. During lactation, GH takes part in the modeling of the mammary gland towards a higher milk synthesis rate and an increase of persistency of the lactation curve (Etherton and Bauman, 1998). The biological effects of the GH are mediated by GHR-JAK2-STAT-IGF-1 pathway (Carter-Su *et al.*, 2000). Signal transducer and activators of transcription (STATs) play an important role in the GH-regulated mammary modulation. Specific mammary activation of STAT5A regulates the development, function, and survival of mammary epithelial cells by inducing distinct subsets of target genes in mammary epithelial cells, including whey acid proteins and caseins (Clarkson *et al.*, 2006), that might lead to differences in milk composition, and thus in processing performance of the milk (Bencini and Pulina, 1997), i.e., its capability to be transformed into high quality dairy products.

In our previous work we also found significant associations between GH genotypes and milk production and composition in Serra da Estrela ewes (Marques *et al*., 2006). Differences in composition of milk, rather than influencing only the cheese making yield, may also influence the cheese quality by providing different milk clotting behaviour and thereby the subsequent stages, curd draining and cheese ripening. Decision makers should be aware of the milk clotting properties when deciding the introduction, in genetic programmes of selection markers, aiming to improve milk yield, and thus advising cheese makers of the need to adapt processing to overcome the differences that may influence the quality of the cheese (Martins *et al.*, 2009).

This work addresses the effect of the growth hormone (GH) polymorphisms and feeding regime at puberty (referred as growth rate) on milk production, composition and technological properties of Serra da Estrela sheep throughout the first lactation.

II – Materials and methods

Six SNPs [X12546: g.649C>G (F2L), g.668C>T (R9C), g.704C>G (L21V), g.1057A>G (S63G), g.1062G>C (K64N), g.1852G>A (G160S)] at the GH2-Z copy was genotyped by a single-base extension (SNaPshot) method (Marques *et al.*, 2012). Eighty-three ewe lambs carrying GH2-Z copy genotypes AA (R9R/S63S; n = 28), AB (R9C/S63S; n = 28), and AE (R9R/S63G; n = 27) were reared during pre-pubertal phase and gestation under two different feeding regimes to obtain a restricted growth rate of 79 g/day (group R - 42 ewe lambs) and a normal growth rate of 106 g (group N - 41 ewe lambs). The ewe lambs rotationally graze a pasture consisting of *Lolium perene*, *Festuca arundinacea*, *Tripholium* spp., and *Medicago* spp., and also received hay and corn silage. The lambs of group N had also access to a supplement of corn grain/sunflower meal. During lactation all sheep grazed the same pasture and received a supplement covering dairy sheep requirements to produce 1.5 L milk/day.

Sheep were milked twice a day after weaning of their lambs at 42 days of lactation. The daily production and milk properties were analysed at 42, 60 and 90 days of lactation. Proportionate samples representing the two daily milking were analysed for fat, protein, and total solids contents (Milko Scan 113B, Foss, Denmark), and pH (Metrohm 713, Switzerland). The evaluation of the cheese making yield (CY) was carried out according to Remeuf *et al.* (1989) and the milk technological properties were assessed by Optigraph (Ysebaert, France) as described by Martins *et al.* (2009), for the following parameters: R (clotting time, min), firmness measures (Volt) after 20 minutes (A20) or 40 minutes (A40) of trial, and after a 2R (2 x clotting time, AR) period and OK20 (rate of firming, min).

Data were analysed using the MIXED procedure of SAS for repeated measures (SAS, 2008) with sheep nested within genotype and growth rate, using an unstructured covariance matrix. A multiple comparison of means was performed using Tukey's test ($P<0.05$).

III – Results and discussion

There were no differences between the GH genotypes for any of the parameters evaluated (Table 1). The lack of differences between genotypes might be due to the low adaptability of primiparous sheep to machine milking since the value of 471 ml/day obtained at the first week after weaning, is well below the 1200 ml/day of suckled milk which, according to Degen *et al.* (2003) corresponds to the average growth of lambs of 230 g/day up to weaning.

The sheep raised at the lowest growth rate (R group) showed a significantly higher protein ($P<0.01$) and non-fat solids ($P<0.001$) contents in milk, which influenced its technological characteristics, i.e., significantly higher values of AR ($P<0.05$), A40 ($P<0.01$) and lower OK20 ($P<0.05$).

Throughout lactation, the milk of all primiparous sheep showed the expected significant increase in the values of their chemical composition ($P<0.001$), especially after 60 days of lactation. Technological parameters followed the evolution of the chemical composition, with higher values of cheese yield and firmness of the curd achieved in less time, as lactation day and the protein content of milk increased (Table 1).

Table 1. Effect of *GH* genotype (GH), growth rate (GR) and lactation day on milk yield, chemical composition and clotting properties in Serra da Estrela primiparous sheep

		Milk (ml/ day)	Fat (% w/w)	Protein (% w/w)	Non-fat solids (% w/w)	CY (g DM/ 100ml)	pH	R (min.)	AR (V)	A_{20} (V)	A_{40} (V)	0K20 (min.)
GH	AA	482	6.99	6.24	12.40	16.86	6.62	14.48	10.07	4.59	13.70	9.88
	AB	387	6.82	6.03	12.17	16.45	6.62	14.10	9.56	4.92	13.65	9.08
	AE	453	6.86	6.07	12.24	16.46	6.64	13.78	9.21	5.12	13.45	9.82
GR	R	420	6.87	6.30 ^{b}	12.46 ^{b}	16.60	6.62	14.11	10.45 ^{b}	5.34	14.88 ^{b}	8.45 ^{a}
	N	453	6.91	5.93 ^{a}	12.08 ^{a}	16.61	6.64	14.21	9.00 ^{a}	4.49	12.64 ^{a}	10.49 ^{b}
Day	42	471 ^{b}	5.62 ^{a}	5.77 ^{a}	12.20 ^{a}	14.59 ^{a}	6.65 ^{b}	13.36 ^{a}	7.69 ^{a}	4.34 ^{a}	11.55 ^{a}	12.53 ^{b}
	60	482 ^{b}	6.79 ^{b}	5.89 ^{a}	12.06 ^{a}	16.23 ^{b}	6.66 ^{b}	14.11 ^{ab}	8.75 ^{a}	4.46 ^{a}	12.74 ^{a}	9.76 ^{ab}
	90	370 ^{a}	8.26 ^{c}	6.69 ^{b}	12.54 ^{b}	18.95 ^{c}	6.56 ^{a}	14.89 ^{b}	12.40 ^{b}	5.83 ^{b}	16.51 ^{b}	6.48 ^{a}

Note: In each column, different letters mean significant differences ($P<0.05$).

Although interaction genotype × day was not significant for milk production (not shown), it was observed that sheep from AA genotype gave more milk at days 42 and 60 of lactation than at day 90. The decrease in milk production was less noticed in AB and AE genotypes, which might indicate an increased persistency of lactation for those genotypes.

The interaction genotype × growth rate tended to be significant for protein content ($P<0.10$), and was significant for AR ($P<0.05$) and 0K20 ($P<0.05$). Milk from R group sheep tended to be richer in protein content, in AA and AE genotypes; which is reflected in AR and OK20 parameters, namely for AA sheep where those differences are significant (Fig. 1).

It was also observed a slightly significant interaction genotype * day of lactation for protein content ($P<0.10$) and a significant one for total protein ($P<0.05$). At 42 days of lactation total protein was respectively 19.5, 25.8 and 30.7 g/day for AB, AE and AA sheep ($P<0.05$), having not varied throughout lactation except for the sheep of AA genotype in which decreased from day 60 to 90 of lactation (31.5 *vs* 24.6 g/day; $P<0.05$). These findings are in agreement with possible effects of GH in the expression of milk protein genes (Clarkson *et al.*, 2006).

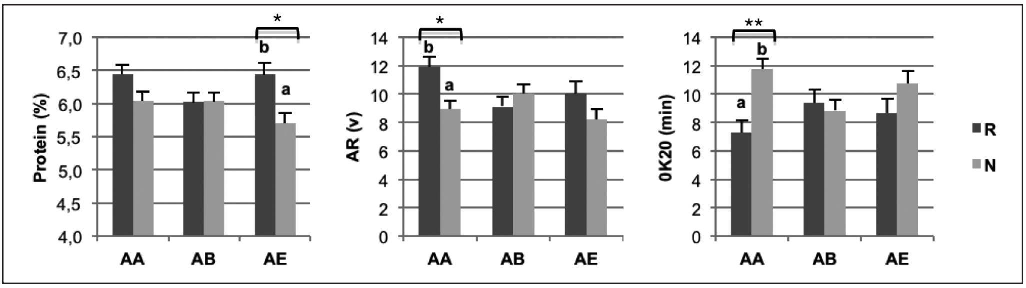

Fig. 1. Effects of the interaction genotype (AA, AB or AE) * growth rate (R or N) on milk protein content, firmness of the cloth (AR) and rate of firming (0K20) Serra da Estrela primiparous sheep. Note: * - P<0.05; ** - P<0.01.

IV – Conclusions

There were no differences between the GH genotypes for any of the milk parameters evaluated. Results indicate that the sheep of AA genotype produce more milk in early lactation while AB and AE seem to have greater persistency of lactation. However the assessment of milk production was affected by poor adaptability of primiparous sheep to mechanical milking.

The lighter sheep fed only pasture, hay and silage (group R) showed significantly higher protein and non-fat milk in higher solids contents, and also higher values of AR, A40 and lower OK20, especially evident in the genotypes AA and AE.

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Response of pregnant sheep to sadrinking water during early pregnancy

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Abstract. Seventy Barbarine sheep aged 5 years were used to evaluate the influence of high intake of salty water of grazing ewes on growth performance, metabolites blood concentrations and physiological parameters. The two groups were randomly allotted a high-salt water (10 g NaCl / 1 l of water) or control water (potable fresh water, 0.5 g/l). Twice weekly body weight was recorded for each individual animal. Blood serum was collected at 30, 60 and 90 days of pregnancy for metabolites contents. Rectal temperatures, pulse rates, and respiration rates were recorded on day 45, 75 and 105 of pregnancy for measure of physiological test. Body weight differed during gestation (P<0.05), resulting in lower weight gain in the high-salt group in the first third of gestation until 75th day of pregnancy (-0.05 v. -0.01 kg/day) and higher weight gain in the final third of gestation (0.13 v. 0.07 kg/day). Glucose concentrations were high significantly lower (67.44 v. 82.38mg/dL P<0.001) in response to high-salt drinking as well as total protein concentration (97.15 v. 90.89 g/l P<0.05), presumably to achieve salt and water homeostasis. Triglycerides, cholesterol, albumin, urea, acid, creatinine and γ-GT concentration was not significantly affected by the water quality (P>0.05). Neither at the first month of the pregnancy, nor at days 75 and 105 during pregnancy, pulse rate, respiratory rate and rectal temperature were affected by the quality of water.

Keywords. Salty water – Sheep – Pregnancy – Metabolites Blood.

L'effet d'un stress salin sur des brebis gestantes pendant le début de la phase de gestation

Résumé. *Dans le but d'étudier l'effet d'un stress salin pendant le début de la phase de gestation sur les performances de croissance, la concentration en métabolites sanguins et les paramètres fœtaux, soixante-dix brebis de la race Barbarine âgées de 5 ans ont été utilisées. Les animaux ont été répartis de façon aléatoire en deux groupes et ont reçu soit de l'eau enrichie de sel (10 g NaCl / l d'eau) (S) soit de l'eau potable (0,5 g / l) (C). Le poids corporel a été enregistré toutes les deux semaines. A la fin de chaque mois de gestation, le sérum sanguin a été collecté afin d'analyser les métabolites sanguins (triglycérides, cholestérol, glucose, albumine, protéines totales, urée, acide urique, créatinine et Gamma glutantransferase). La température rectale, le rythme cardiaque et respiratoire ont également été notés. La consommation d'eau et les paramètres fœtaux n'ont été pas affectés par la qualité de l'eau. Les brebis recevant de l'eau enrichie de sel ont eu un gain de poids moyen quotidien supérieur après le jour 75 de gestation. La concentration de glucose et protéine totale ont été significativement diminuées sous l'effet de sel pendant le début de la phase de gestation.*

Mots-clés. *Sel – Brebis – Gestation – Métabolites Sanguines.*

I – Introduction

Salinity is an increasing problem in agriculture worldwide and the use of halophytic plants such as saltbush represents one of the few options available to revegetate salinised landscapes and re-establish grazing systems (Masters *et al*., 2007). Some landholders in Tunisia are grazing sheep on saltbush to fill a summer/autumn feed gap, a period that coincides with the greater demands of late pregnancy for autumn- or winter-lambing sheep. However, feeding saltbush or drinking salty water may possibly have a negative impact on growth performance of the sheep as high salt intake may reduce intake and cause physiological changes associated with adaptation to the salt. High salt intake has been shown to reduce the efficiency of energy use for production (Blache *et al*., 2007) in sheep which is usually associated with a decrease in the concentration of metabolic hormones and metabolites blood (Chilliard *et al*., 2005). Thus, the objective of this work is to investigate the effect of drinking high-salt water during the first middle of pregnancy on the growth performance, the physiological parameters and the blood profiles in the pregnant-Barbarine sheep.

II – Materials and methods

Seventy Barbarine sheep, aged 5 years, and weighing on average 45 kg, were held at the Livestock Research Centre of National Institute of Agronomic Research at Ouslatia, Tunisia. After 15 days of adaptation from the day of mating, sheep were divided in two groups: experimental sheep drink high salt water (10 g/l NaCl; S- sheep; n = 35) or control sheep drink fresh potable water, normal salt (0.5 g/l NaCl; C-sheep; n = 35). About 0.4 kg barley grain per ewe was offered daily in the morning (09:00) and 0.8 kg hay was offered in the afternoon (18:00). During the day, sheep grazed pastures.

Animals were weighted twice weekly. Blood samples (9 ml) were collected from the jugular vein of each animal on days 30, 60 and 90 of pregnancy for metabolites blood analysis (triglyceride, cholesterol, glucose, albumin, total protein, uric acid, urea, creatinine and γ-GT). Plasma metabolites were analysed using BioSystem (Costa Brava, 30 Barcelone, Spain) kits. Rectal temperatures, pulse rates, and respiration rates were recorded on days 45, 75 and 105 between 9:00 and 11:00 h during data collection period.

Body weight, body condition score, metabolites blood concentrations and physiological parameters were arcsine-transformed prior to statistical analysis. All data were analysed by ANOVA. The C and S levels were regarded as fixed effect. Analysis of variance were undertaken using the proc GLM procedure of the SAS statistical package (SAS, 2004)

III – Results and discussion

Pregnant sheep that drunk high salty water during pregnancy show a difference in the daily live weight gain according to salt in water content especially on day 30 and 105 of pregnancy ($P<0.05$; Fig. 1).

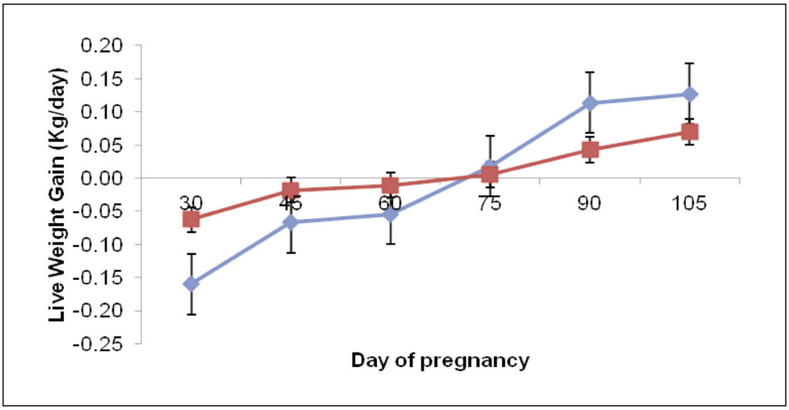

Fig. 1. Live weight gain of Barbarine ewes during the 105 days of pregnancy (Square shape: C-Sheep; Cubic shape: S-Sheep).

Sheep from the high-salt treatment showed an increased body weight elevated in ewes after day 90 of pregnancy. These results are similar to other studies in rats (Smriga *et al*., 2002) and humans (Curtis *et al*., 2004). Moreover, the high-salt sheep were 1 kg heavier than their control counterparts. Warren *et al*. (2001) found that by the end of pregnancy, an increase of 10 to 15% in total body water, which equates 3 to 5 kg more in weight when animals were fed saltbush.

Metabolites blood concentrations showed no significant change neither in C-Sheep nor in S-Sheep following either the water salt drinking until 90 days of pregnancy. Exceptionally for the glucose and γ-GT concentration which increased more after the salt drinking than the fresh water (P<0.05; Table 1).

Table 1. Metabolites blood levels of Barbarine ewe drinking potable water or salty water during early pregnancy

Metabolites blood	Day of pregnancy	Quality of water		SE	Effet of water
		Potable water	Salty water		
Triglyceride (mg/dL)	30	$17^{b} \pm 6$	$14^{b} \pm 6$	0.86	NS
	60	$17^{b} \pm 6$	$15^{b} \pm 8$	0.78	NS
	90	$54^{a} \pm 29$	$52^{a} \pm 35$	0.63	NS
Cholesterol (mg/dL)	30	$65^{b} \pm 12$	$66^{b} \pm 15$	0.25	NS
	60	$73^{b} \pm 15$	$67^{b} \pm 22$	1.34	NS
	90	86 ± 27	$87^{a} \pm 24$	0.22	NS
Glucose (mg/dL)	30	53 ± 17	53 ± 17	2.11	NS
	60	63 ± 23	59 ± 20	1.48	NS
	90	82 ± 45	67 ± 5	6.02	***
Albumin (g/l)	30	$32^{b} \pm 11$	$29^{b} \pm 11$	1.24	NS
	60	$34^{b} \pm 9$	$32^{b} \pm 10$	0.67	NS
	90	46 ± 16	$49^{a} \pm 18$	1.01	NS
Total protein (g/l)	30	$68^{b} \pm 20$	70 ± 19	0.69	NS
	60	$74^{b} \pm 13$	73 ± 20	0.45	NS
	90	$90^{a} \pm 9$	79 ± 15	3.02	*
Uric Acid (mg/dL)	30	1 ± 0	$1.1^{b} \pm 0.8$	0.13	NS
	60	1 ± 2	$1.3^{ab} \pm 1.2$	0.072	NS
	90	2 ± 1	$1.9^{a} \pm 1.3$	0.041	NS
Urea (mg/dL)	30	$19^{b} \pm 8$	$17^{c} \pm 10$	0.38	NS
	60	$31^{b} \pm 7$	$28^{b} \pm 11$	0.69	NS
	90	$68^{a} \pm 34$	$57^{a} \pm 26$	3.19	NS
Creatinine (mg/dL)	30	$1^{ab} \pm 0.9$	$1.3^{ab} \pm 0.7$	0.047	NS
	60	$1^{a} \pm 1$	$1.6^{a} \pm 0.7$	0.058	NS
	90	$1^{b} \pm 0.3$	$1.7^{b} \pm 0.3$	0.212	NS
Gamma	30	$25^{a} \pm 14$	$19^{a} \pm 8$	2.07	NS
glutantransferase	60	$21^{a} \pm 15$	$13^{b} \pm 5$	2.47	NS
(U/L)	90	$12^{b} \pm 5$	$10^{b} \pm 5$	0.98	*

SE, standard error of means; NS: P>0.05, *: P<0.05, ***: P<0.001; Data bearing the same superscript within a column are not different at P<0.05.

Balıkcı *et al*. (2005) showed that blood cholesterol and triglyceride levels increased with pregnancy compared to non-pregnant sheep. The plasma concentrations of glucose for both groups vary between 50 and 90 mg/dL which equal the normal values recorded for serum glucose founded by Radostits *et al*., (2000). The total plasma protein concentration increased significantly with pregnancy ($P<0.05$). This increase in plasma total protein may be ascribed to the fact that the pregnant sheep divert more protein into their fetus which uses amino acids derived from the mother's body protein Albumin (Yildiz *et al*., 2005). Creatinine, urea and γ-GT level increased in serum with pregnancy. These results were in general agreement with literature which quantify the biochemical indices in sheep during different stages of pregnancy (Khatun *et al*., 2011).

Neither at the first month of pregnancy, nor at days 75 and 105 during the pregnancy, pulse rate, respiratory rate and rectal temperature were affected by the salt content of drinking water ($P>0.05$; Table 2). Respiratory rates fluctuated throughout the study, ranging from 10 to 27 breaths per minute, and were higher than an average respiration rate of 19 breaths per minute in resting lambs (Tenney, 1977). Pulse rates fluctuated throughout the study, ranging from 26 to 38 beats per minute, and were lower than the expected range of 70 to 80 beats per minute (Dukes, 1964). Rectal temperatures were within the normal range (38.1 to 39.1) for S-sheep and C-Sheep (Anderson, 1977).

Table 2. Physiological parameters of Barbarine ewe drinking potable water or salty water during the early pregnancy

	Quality of water			
Day of pregnancy	**Potable water**	**Salty water**	**SE**	**Effet of water**
Pulse rate (Beats per min)				
45	27 ± 0.2	28 ± 0.1	0.26	NS
75	28 ± 1	29 ± 2	0.16	NS
105	35.5 ± 2	35.9 ± 1	0.21	NS
Respiratory rate (Respiration per min)				
45	18 ± 0.5	16 ± 0.4	0.55	NS
75	17 ± 2	16 ± 3	0.20	NS
105	18 ± 3	16 ± 2	0.43	NS
Rectal temperature (°C)				
45	38.3 ± 2	38 ± 1	0.025	NS
75	38.4 ± 0.1	38.5 ± 0.2	0.006	NS
105	38.5 ± 0.2	38.4 ± 0.2	0.029	NS

SE, standard error of means; NS, $P>0.05$.

IV – Conclusion

Barbarine ewes that drank high amounts of salt during early pregnancy did not show any adverse effects on metabolism, physiological parameters. It is most probable that ewes adapted to salted water by increasing gut water content to regulate osmolarity and may be to some extend their body protein mass.

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Lamb's growth and carcass characteristics as affected by herbaceous or woody pasture in Tunisian North West

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Abstract. The aim of this work was to study the effect of rearing system of two mountainous areas, Ain Draham of Woody Pasture (WP) and Fernana of Herbaceous Pasture (HP) on growth and carcass composition of lambs. The WP is characterized by an uneven distribution of plant biomass, with *Quercus suber* dominates the shrubby stratum which in turn dominates the herbaceous during the period of low rainfall, by cons HP is characterized by grasses and clover. Animals of both regions were fed exclusively on pasture which amount and value depends on the production potential of the rearing systems. They were weighted monthly from birth until 4 months age where 10 lambs from each region were slaughtered and the left shoulders were dissected. The final live weight and average daily gain were affected by pasture type. The slaughter body weight was 28.6 kg and 23.8 kg for HP and WP respectively. The carcass weight was higher (p = 0.003) on HP than WP (14.1 *vs* 10.9 kg). Consequently, the commercial yield was 49% for HP and 46% for WP. Fat content was 11 and 15% for WP and HP, respectively, while bone content was higher for sheep from WP. The WP group presents a higher quantity of muscle than HP group (64% *vs* 62%). This composition resulted from the difference in the slaughter body weight.

Keywords. Pasture – Forest – Lamb's growth – Carcass – Tissues importance.

Croissance et caractéristiques des carcasses d'agneaux pâturant des parcours herbacés ou ligneux dans le Nord ouest de la Tunisie

Résumé. *L'objet de cette contribution est d'étudier l'effet du système de production de deux régions montagneuses, parcours ligneux (WP) et Herbacé (HP), sur la croissance et la composition de la carcasse des agneaux. Le système WP est caractérisé par une distribution irrégulière de la biomasse du couvert végétal dominé par le chêne vert et une strate arbustive qui domine elle aussi le parcours herbacé durant les saisons à faibles précipitations. Le système HP est caractérisé par une strate herbacée particulière de graminées et de légumineuses. Le calendrier alimentaire des troupeaux des deux régions est constitué exclusivement de parcours avec des performances quantitatives et qualitatives variables. Les animaux ont été pesés mensuellement de la naissance à l'âge de 4 mois. Une dizaine d'agneaux de chaque système de production a été abattue et l'épaule droite a été disséquée. Nous avons observé des différences du poids final et du gain quotidien moyen entre les agneaux du système WP et HP. Le poids vif à l'abattage est différent (p = 0,007) avec 28,6 kg pour HP et 23,8 kg pour WP. Le poids de la carcasse était plus élevé (p = 0,003) pour les agneaux élevés sur HP que WP (14,1* vs *10,9 kg). Par conséquent, le rendement commercial, était de 49% pour HP et 46% pour WP. Le pourcentage de matière grasse était respectivement, de 11 et 15% pour WP et HP, alors que, la teneur en fraction maigre était plus élevée pour les agneaux du WP comparés à ceux du HP (64%* vs *62%). Cette composition résulte des différences du poids vif à l'abatage.*

Mots-clés. *Parcours herbacé – Parcours forestier – Croissance des agneaux – Carcasse – Importance tissulaire.*

I – Introduction

The parameters as lamb growth, carcasses characteristics and meat quality vary according to the production system (Moron *et al*., 1999). It was observed that lambs reared on pasture have generally more carcass muscle and bone and less fat than those of feedlot (Diaz *et al*., 2002; Santos-Silva *et al*., 2002). For feedlot there are many results concerning lamb's growth and carcass characteristics in relationship with feed level, protein level or resource, some additives, etc. However, to our knowledge within pasture there is no information concerning lamb's performance reared in different types, particularly the forest or woody pasture and land or herbaceous pasture. Livestock in the mountainous region of the Tunisian Northwestern is characterized by the use of different types of Mediterranean natural pasture. Lambs in this region are reared mainly with their dams on pasture until they reach 15 to 30 kg when they are slaughtered or weaned. The aim of the present contribution is to assess the effect of pasture type (herbaceous and woody) on the lamb's growth and carcass characteristics.

II – Materials and methods

Feeding system and animals. Sheep from local breed were fed on two rearing systems: (1) Woody pasture (WP) dominated by a stratum of trees as Aleppo pine, *Quercus ilex* and *Quercus suber* intercalated by shrubs as *Erica arborea*, Myrtre*, Asparagus aphyllus, Phillyrea latifolia* and *Olea europea* with herbaceous layer that depends on the seasonal rainfall, and (2) Herbaceous pasture (HP) based on mixed intercropping of grass and legume species as *Genera Lolium* (ryegrass), *Lotus* (trefoil), *Trifolium* (clovers) and *Medicago* (alfalfa). For the present study, 20 male lambs were randomly chosen, 10 from WP and 10 from HP. They were weighed monthly, from birth to slaughter.

Slaughter and dissection procedure. Lambs from each rearing system were slaughtered in two different days when they were weaned after 120 ± 20 days old. The animals were weighed before slaughter. After they have been slaughtered, they were skinned and eviscerated. After overnight stored at +4°C, carcasses were weighted and divided into halves. The left half-carcass was cut into six joints (leg, lumbar region, flank, thoracic region, neck and shoulder). The left shoulders were stored at -20°C. Frozen shoulder was thawed at ambient temperature (10-20°C) for approximately 18 h prior to dissection into muscle, bone, fat, and waste. Percentage of each component was calculated for tissue composition study given the shoulder composition is representative of the carcass composition.

Statistical analysis. The analyses of variance were performed using GLM procedure (SAS, 2004) to study the effects of rearing systems on the lamb growth performance, carcass characteristics and carcass composition.

III – Results and discussion

1. Growth performance

Table 1 reports growth performance analysis. With the design followed in our study, differences between the two groups essentially reflect differences between production systems. HP lambs tended ($P<0.10$) to have more important birth weight than WP lambs. The higher frequency of ewes to grass of the herbaceous pasture system may have improved their body conditions which are reflected in lambs as compared to the woody system. For the former the content of soluble carbohydrate, lignin cellulose and hemicellulose is higher than in herbaceous pastures consumed. This may cause lower intake and explain the difference in growth between HP lambs and WP lambs (Bocquier *et al*., 2002; Olafur 2001). It is most often the quantity rather than the quality of nutrition that is the limiting factor, as both protein and energy content are high in herbaceous pastures (Olafur, 2001). Nevertheless, differences (P< 0.05) were reported for the average daily gain and live weight even though the HP group showed higher values as compared to WP lambs. These results may result from the consumption of some grasses and clover feed by the HP lambs which improved the nutrient digestibility and the dry matter ingestion as compared to WP lambs that are affected by the tannin of forest vegetation (Faria *et al.,* 2012).

Table 1. Effect of rearing system on lamb's growth, carcass traits and composition

Production system	Woody pasture (AD)	Herbaceous pasture (F)	P	MSE
Birth weight (kg)	4.87	4.95	0.570	0.208
Average daily gain (g)	130	164	0.002	4.679
Slaughter body weight	23.87	28.62	0.007	1.085
Hot carcasse weight	10.95	14.10	0.003	0.608
Commercial yield (%)	45.75	49.00	0.001	0.570
Fat	10.54	14.65	0.019	1.101
Lean	64.55	62.35	0.227	1.233
Bone	23.47	21.88	0.023	0.443

2. Carcass characteristics

The effect of rearing system on carcass characteristics is presented in Table 1. The differences among rearing systems in terms of slaughter weight were significant (P<0.01). Lambs from HP system had higher values of hot carcass weight and commercial yield (P<0.01) than lambs from WP system. This is related to the slaughter body weight for HP lambs. These results are close to those observed by Sents *et al*., (1982) and Atti *et al*. (2003) who found that carcass weight and characteristics are correlated to slaughter body weight. In addition, Borton *et al.* (2005) observed, for forage-fed lambs, greater carcass weight compared to those complementation-fed.

3. Carcass composition

Table 1 reported the analysis of carcass composition. The rearing system did not affect (P > 0.05) lean proportion in shoulder; however, the fat and bone contents were different between groups (p<0.05). Compared to the herbaceous group, the woody group had higher proportion of bone (23.5 *vs* 21.9%) and lower proportion of fat (10.5 *vs* 14.7%). There was an augmentation in the percentage of fat for heavy lambs (HP) given this tissue have a late development. Fat depots depend on slaughter weight, nutritional level and nutrient utilization (Murphy *et al*., 1994; Mahouachi and Atti, 2005). In addition, lambs from woody system (WP) have more physical activity, which need more energy and result in less fat depot. While animals grazing herbaceous pasture did not accomplish a lot of displacement to find food, and they did not demand more energy to cover walking and climatic conditions requirements (Christopherson and Kennedy 1983; Smeti *et al*., 2014), so they may deposit more fat in their carcasses.

IV – Conclusions

The objective of this study was to investigate the effect of rearing system on the lambs' performances in terms of growth and carcass characteristics. The results show significant difference between the group of herbaceous pasture (HP) and woody pasture (WP).The HP lambs gained higher carcass weight (p = 0.003) and had higher (14% of fat) fat content compared to WP lambs.

However bone content was higher for WP lams. It could be concluded that although their higher fat proportion, the HP lambs are lean and more interesting in term of food supply, as WP lambs need food complementation. These first results suggest to analyze the chemical and sensory quality of the two lambs groups.

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Effect of grazing alfalfa on α-tocopherol content and FA composition in *Longissimus* and *Semitendinosus* muscles of light lambs

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Abstract. Grazing can increase α-tocopherol content in the lamb muscle without additional expenses compared with tocopheryl acetate supplementation and modify the fatty acid (FA) profile. The aim of the study was to compare the effect of alfalfa grazing on α-tocopherol and FA composition of *Longissimus thoracis* (LT) and *Semitendinosus* (ST) muscles. Twenty single reared male lambs of Rasa Aragonesa breed were used. A group of weaned lambs was indoors and fed concentrate and a group of suckling lambs was grazing alfalfa continuously with their dams. The LT and ST muscles were extracted to determine α-tocopherol content and FA composition. In both muscles, grazing lambs had more than 2-fold higher α-tocopherol content, C18:2n-6tt, C18:3n-3, C20:5n-3, C22:5n-3, C22:6n-3 and total n-3 FA contents ($P<0.001$) but lower n-6:n-3 ratio ($P<0.001$) than concentrate-fed lambs. In both muscles, grazing lambs had lower Monounsaturated FA than concentrate-fed lambs. Generally, grazing had a greater impact on n-3 FA and α-tocopherol content in ST than in LT muscle. Grazing improved the n-6:n-3 ratio and could increase the meat shelf-life. The α-tocopherol content and individual n-3 FA could be used to authenticate forage intake.

Keywords. Fatty acids – α-tocopherol – Meat – Light lamb.

Effet du pâturage de luzerne sur le contenu α-tocophérol et la composition en acides gras dans les muscles* Longissimus *et* Semitendinosus *d`agneaux légers

Résumé. *Le pâturage peut augmenter la teneur en α-tocophérol dans le muscle sans dépenses supplémentaires comparée avec la supplementation avec acétate de tocopherol et améliorer la composition des acides gras (AG). L'objectif de l'étude était de comparer l'effet du pâturage sur le teneur en α-tocophérol et la composition en AG des muscles Longissimus thoracis (LT) et Semitendinosus (ST). Vingt agneaux simples de la race Rasa aragonaise ont été utilisés. Un groupe d´agneaux sevrés a été nourri exclusivement au concentré à la bergerie et un autre groupe a eu accès continuellement à une parcelle de luzerne avec leurs mères. Dans les deux muscles, les agneaux au pâturage avaient plus de 2 fois plus d´α-tocophérol, C18:2n-6tt, C18:3n-3, C20:5n-3, C22:5n-3, C22:6n-3 et AG n-3 totaux (P<0,001), mais un rapport n- 6:n- 3 inférieur (P<0,001) que les agneaux nourris au concentré seul. Dans les deux muscles, les agneaux de pâturage avaient des teneurs en AG mono-insaturés inférieures à celles des agneaux nourris avec le concentré seul. Le pâturage a un impact plus important sur le teneur des AG n-3 et la teneur en tocophérol dans le ST que dans le muscle LT. Le pâturage de luzerne amélioré le rapport n-6:n-3 ce qui pourrait augmenter la conservation de la viande. La teneur en α-tocophérol pourrait être utilisée pour authentifier l'ingestion de fourrage avec les AG n-3 individuels.*

Mots-clés. *Acides gras – α-tocopherol – Viande – Agneau léger.*

I – Introduction

The α-tocopherol is a lipid-soluble antioxidant often fed to ruminants in the concentrate (in the form of tocopheryl acetate) due to its powerful antioxidant activity. It is an effective method to reduce the oxidative processes in meat and to increase meat shelf life (Liu *et al*., 1995). However the high cost of α-tocopherol requires accurate feeding and quantity of α-tocopherol must be adjusted to reduce the cost of the diet. Grazing increases the intake of α-tocopherol cheaply. Lambs finished on pasture had higher α-tocopherol content in meat than those fed high concentrate diets (Turner *et al.*, 2002). Besides, grazing also can improve of the fatty acid (FA) composition from a human health point of view (Wood *et al.*, 2004). But, the effect of grazing might be muscle-dependent. The objective of the study was to compare the effect of grazing on α-tocopherol and FA profile of *Longissimus* (LT) and *Semitendinosus* (ST) muscles.

II – Materials and methods

Twenty single reared Rasa Aragonesa male lambs were used. Twelve weaned lambs (49±0.2 days old) were indoors fed a commercial concentrate (C) (175 g crude protein (CP)/kg dry matter (DM), 180 g neutral detergent fibre (NDF)/kg DM, 45 g acid detergent fiber (ADF)/kg DM, 13.2 MJ metabolisable energy (ME)/kg DM, 27 mg dl-α-tocopheryl acetate/kg). A group of 8 unweaned lambs (29.5 ± 0.95 days old) grazed continuously on alfalfa pasture (154 g CP/kg DM; 326 g NDF/kg DM and 204 g ADF/kg DM, 154 mg α-tocopherol/kg DM) with access to their dam's milk and the commercial concentrate (Gr). When the lambs reached 22-24 kg of live weight (75 and 66 days old, C and Gr lambs respectively), lambs were slaughtered. After chilling for 24 h at 4 ºC, the LT and ST muscles were extracted to determine α-tocopherol content and FA composition.

The content of α-tocopherol in muscle was determined following the procedure of Molino *et al.* (2012). The extraction was performed in duplicate. One hundred mg of lyophilized meat were placed in a tube with 0.4 ml ethyl alcohol and vortexed. Afterwards, 1 ml of hexane was added to the tube, which was vortexed for 15 min and centrifuged (3.500 rpm for 5 min). The upper layer was collected and evaporated under nitrogen. The dry residue was dissolved in 0.5 ml of acetonitrile–dichloromethane–methanol (75–10–15). HPLC was run on a HPLC 1100 Agilent equipped with a DAD. The α-tocopherol was detected at 295 nm. FA was determined according to Bligh and Dyer (1959) method, with the following modifications: 2.5 g of lyophilized muscle were mixed with chloroform, methanol and KCl 0.88%. The lower phase (FA and chloroform) was extracted, dry evaporated and stored at -20 ºC. Meat FA composition was determined by GC-FID (Bruker 436-GC) of the fatty acid methyl esters (FAMEs) (Joy *et al*., 2012). These FAMEs were prepared by base-catalysed methanolysis of the glycerides with KOH according to the UNE-EN ISO 5509:2000 methods.

III – Results and discussion

The α-tocopherol content was affected by the interaction between the muscle and diet (P=0.007). Grazing increased 3.0 and 3.7-fold α-tocopherol content in LT and ST muscles in comparison with indoors concentrate-fed lambs (C) (Fig. 1). In studies with weaned lambs, grazing increased 4 times α-tocopherol content in LT muscle (Santé-Lhoutellier *et al.,* 2008; Turner *et al.*, 2002). The α-tocopherol contents in the abovementioned studies were greater probably because the feeding periods were longer than in the current experiment and α-tocopherol deposition in muscle increased with feeding length (Turner *et al*., 2002), In relation to that, Liu *et al.* (1995) concluded that age of lambs affects the α-tocopherol deposition, which can explain the differences among studies. In the current experiment Gr lambs were still lactating thus α-tocopherol intake could be different than in weaned grazing lambs. Regarding the muscle effect, In C lambs treatment, both muscles, LT and ST, presented similar α-tocopherol content, whereas in Gr lambs, ST muscle presented greater content than LT muscle (P<0.05) as reported in beef cattle (Lynch *et al*., 2000).The different proportion and size of fibres of muscles affects the membrane volume, which might affect the potential retention of α-tocopherol (Liu *et al*., 1995).

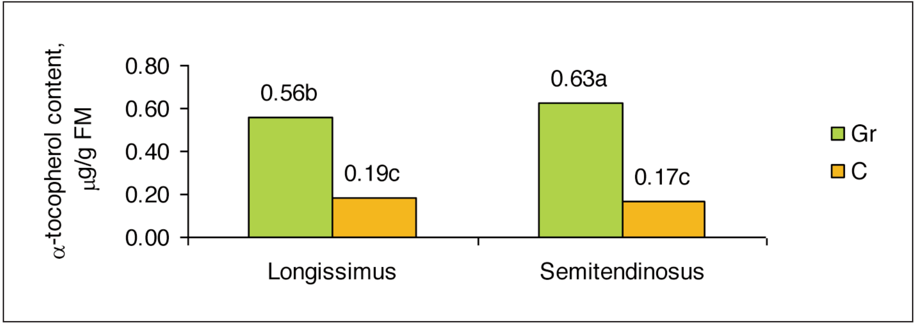

Fig. 1. The α-tocopherol content in *Longissimus* and *Semitendinosus* muscles of grazing (Gr) and concentrate (C) lambs. Different letters mean differences at P<0.05.

Table 1. Effect of diet (D) and muscle (M) on fatty acids profile *(g/ 100g FAME)*

	diet		muscle		P-value		
	Gr	C	LT	ST	D	M	DxM
C10:0	0.24	0.18	0.21	0.21	***		
C12:0	0.51	0.40	0.44	0.47	†	†	
C14:0	5.12	4.08	4.53	4.68	**		
C16:0	23.02	24.80	23.76	24.06	**		
C16:1	1.77	1.85	1.80	1.82			
C17:0	1.16	1.02	1.04	1.14	*	†	
C17:1	0.82	0.77	0.78	0.81			
C18:0	11.93	12.01	12.13	11.82		***	
C18:1n9	34.89	39.12	37.50	36.52	***	***	
C18:1n7	1.11	1.15	1.10	1.16			
C18:2n6tt	0.59	0.16	0.37	0.38	***		
C18:2n6ct	6.86	6.92	6.70	7.08		*	
C18:3n6	0.07	0.07	0.07	0.07			
C20:0	0.12	0.08	0.10	0.10	***	***	
C18:3n3	2.57	0.37	1.45	1.49	***		
CLA	0.83	0.48	0.67	0.64	***	*	
C20:1	0.08	0.09	0.09	0.08		***	
C22:0	0.20	0.19	0.18	0.21		**	
C20:4n6	2.11	2.71	2.25	2.57	†	**	
C20:5n3	1.11	0.17	0.55	0.73	***	***	**
C24:0	0.10	0.26	0.18	0.18	***		
C22:5n3	1.19	0.55	0.80	0.94	***	***	
C22:6n3	0.63	0.23	0.38	0.48	***	***	*
SFA	42.43	43.03	42.60	42.87			
MUFA	38.68	42.98	41.27	40.39	***	***	
PUFA	15.99	11.66	13.26	14.39	***	***	
n-6	9.63	9.86	9.39	10.10		**	
n-3	5.54	1.32	3.18	3.68	***	***	*
n-6:n-3	1.75	7.81	5.03	4.52	***	***	***
PUFA:SFA	0.38	0.27	0.31	0.34	***	**	

† P < 0.10 *P<0.05, **P<0.01, ***P<0.001.

The diet had effect on most of the FA studied (Table 1). Grazing lambs had greater contents of C18:2n-6tt, C18:3n-3, CLA, C20:5n-3, C24:0, C22:5n-3, C22:6n-3 and lower C18:1n9 than C lambs in both muscles ($P<0.05$). Consequently Gr lambs had greater total PUFA, PUFA n-3, lower MUFA contents and n-6:n-3 ratio ($P<0.05$), being in agreement with Santé-Lhoutellier *et al.* (2008). Grass-based diets can improve the FA composition of ruminant fat depots by increasing their C18:3n-3, CLA, C18:1n-7, and PUFA n-3 contents (Wood *et al.*, 2004). However, no effect of grazing was observed on C18:1n-7 what can be due to the pH of rumen and to the FA metabolic pathway (Joy *et al.*, 2014).

Regarding muscle effect, C18:0, C18:1n9, C18:2n6ct, C20:4n6, C20:5n3, C22:5n3, C22:6n3, MUFA and PUFA contents were different in LT and ST muscles ($P<0.05$). Grazing affected PUFA n-3 contents to a greater extent in ST (5.9 and 1.4 g/100 g in Gr and C lambs, respectively) than LT muscle (5.2 and 1.2 g/100 g in Gr and C lambs, respectively). The ratio n-6:n3 was also affected by the interaction between diet and muscle ($P < 0.001$). Unweaned grazing lambs had similar n-6:n-3 ratio in the LT and ST muscles (1.8 and 1.7, respectively) whereas concentrate-fed lambs had greater n-6:n-3 ratio in the LT than in the ST muscle (8.3 and 7.4, respectively; $P<0.001$). Differences in muscle fibre type between muscles are reflected in differences in FA composition (Wood *et al.*, 2004).

IV – Conclusions

In conclusion, grazing of unweaned lambs increased α-tocopherol content and improved the FA composition in muscle compared with concentrate-fed lambs. However, the magnitude of the effect of grazing in α-tocopherol and PUFA n-3 contents differed between muscles.

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Are bedding materials a source of useful microorganisms for dairy cow and ewe milk?

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Abstract. Milk microbial diversity contributes to the sensorial diversity of raw milk cheeses. The milking is an important step for milk inoculation through teat skin, biofilm on the milking machine, water, air and animal environment. This study aims at evaluating microbial count of bedding materials usual in dairy cow and ewe farms. Four bedding materials (straw, mat, grass, slatted floor) from 48 farms in four French mountain areas of PDO cheese production were studied. Bedding surfaces, teats and bulk milk were sampled in winter (housed full-time) and summer (pasture) for cows, and during the grazing season for ewes. Microbial groups were counted on five culture media. For housed animals the microbial count (95 to 99% of ripening bacteria) of bedding material for cow and ewe was similar. In ewe farms, all microbial levels were higher on straw bedding than on slatted floor, and ripening bacteria levels on teat surface and in milk were significantly the highest with straw. On cow pasture surface, the ripening bacteria were less dominant (62%) than in winter and Gram negative bacteria (22%), yeasts (9%) and moulds (7%) proportions were higher. The season and the type of bedding material had similar effect on the teat skin but not in the milk microbial counts. The microbial flows from bedding to teat and teat to milk must be better understood to advise dairy farmers suggesting microbial transfer between bedding and teats.

Keywords. Bedding material – Teat skin – Microbial community – Raw milk.

Les litières sont-elles une source de micro-organismes utiles pour le lait de vache et de brebis ?

Résumé. *La diversité microbienne du lait contribue à la diversité sensorielle des fromages au lait cru. La traite est une étape importante pour l'inoculation du lait par la peau du trayon, le biofilm de la machine à traire, l'eau, l'air et l'environnement. Cette étude vise à évaluer les niveaux microbiens des litières de fermes laitières bovines et ovines. Quatre supports de couchage (paille, tapis, herbe, caillebotis) issus de 48 fermes de quatre zones fromagères françaises de montagne en AOP ont été étudiées. Les litières, les trayons et le lait ont été échantillonnés en hiver (logement en bâtiments) et en été (pâturage) pour les bovins, sur une saison à l'herbe pour les brebis. Les groupes microbiens ont été dénombrés sur cinq milieux de culture. Les niveaux microbiens (bactéries d'affinage>95%) des litières des animaux logés en bâtiment, dans les fermes bovines et ovines étaient semblables. En exploitation ovine, tous les niveaux microbiens étaient plus élevés sur les litières paille que sur les caillebotis et les niveaux de bactéries d'affinage sur la peau des trayons et dans le lait étaient significativement plus élevés avec la paille. Sur la surface de pâturage, ces bactéries étaient moins dominantes (62%) qu'en hiver au profit des bactéries à Gram négatif (22%), des levures (9%) et des moisissures (7%). Les effets de la saison (en vache) et litières sont aussi significatifs sur les niveaux microbiens des trayons, mais pas sur ceux du lait, suggérant des transferts microbiens entre litière et trayons.*

Mots-clés. *Litière – Peau des trayons – Communauté microbienne – Lait cru.*

I – Introduction

Milk in udder cells of a healthy lactating female is sterile. The composition of the milk microbiota depends on microbial sources directly in contact with the milk: the animal's teat (Vacheyrou *et al*., 2011; Verdier-Metz *et al*., 2012) and dairy equipment such as milking machine (Laithier *et al*., 2004) and tank. It also depends on the composition of the microbial indirect sources (feed, litter, drinking and washing water, stable and milking parlour air, milker (Montel *et al*., 2014). As there is little literature about the role of bedding material as sources of milk inoculation, this study aims at evaluating microbial composition of bedding materials usual in dairy cow and dairy ewe farms as reservoir of micro-organisms for milk. Preserving microbial diversity in milk at sufficient level is an important goal for traditional cheese production, since it plays a major role in the making of taste and typicality of raw milk cheeses.

II – Materials and methods

The study was carried out from January 2011 to July 2012 in 36 cow and 11 ewe farms in four French mountain areas producing PDO cheese (Pyrénées for ewe; Auvergne, Franche-Comté and Alpes, for cows). The cow farms' were selected according to the housing type: tie (18 farms) or free stalls (18 farms) and the bedding material: with straw (24 farms) or without straw (12 farms) and they were sampled at two periods: in winter, when animals housed full-time and in summer, at the pasture. Ewe farms' were chosen only according to bedding material: with straw (7 farms) and stalled floor (4 farms). Ewes pastured all the year but housed in the sheepfold (open housing) during the night. Bedding materials and teat surfaces were taken before morning milking and bulk tank milk at the end of milking. Cow teat surfaces were sampled before cleaning with a sterile swab as described by Monsallier *et al*. (2012) and ewe teat surfaces with sterile tips. Sampling was repeated 4 to 6 times in each farm.

Samples were plated on Plate Count Agar (PCA) medium with milk for total bacterial count; on PCA with Gram-positive inhibitor (0.1% cristal violet, 0.05% vancomycin) added for presumed Gram negative bacteria; on Cheese Ripening Bacterial Medium (CRBM) for presumed ripening bacteria (Gram positive and catalase positive bacteria, G+C+ bacteria), on Man Rogosa Sharp medium (MRS) for lactic acid bacteria, on Oxytetracyclin Glucose Agar medium (OGA) for yeasts and moulds as previously described (Verdier-Metz *et al*., 2012). The results are expressed in $\log_{10}$ cfu/cm^2 for bedding, /2 teats for teat and /mL for milk.

The effects of season, the types of housing and bedding material on the microbial levels and their interactions were evaluated by analysis of variance using XLStat© and Statistica Softwares. The Fisher test was used to compare difference in the means. Relationships between microbial counts were studied using the Pearson's correlation coefficient.

III – Results and discussion

1. Microbial characteristics of bedding materials

For cow and ewe (Tables 1 and 2), microbial count of bedding material was dominated by ripening bacteria (95 to 99% of total population). Lactic acid bacteria (1 to 3%) and the Gramnegative bacteria (0.1 to 2%) were at lower level. The levels of yeasts and moulds were the lowest. For all microbial groups, except for lactic acid bacteria, in both cow and ewe, and for ripening bacteria in cow, counts were significantly higher on straw bedding than on mat or slatted floor. Straw bedding material presented significantly more total population (+0.6 $\log_{10}$ cfu/cm^2 and +0.9 $\log_{10}$ cfu/cm^2 respectively for cow and ewe), Gram negative bacteria (+0.6 $\log_{10}$ cfu/cm^2 and +0.7 $\log_{10}$ cfu/cm^2), yeasts (+1.1 $\log_{10}$ cfu/cm^2 for cow) and moulds (+0.8 $\log_{10}$ cfu/cm^2 for cow) than bedding material without straw.

Ripening bacteria were dominant on cows' pasture, but at a lower level than in winter (62% total population), whereas lactic acid bacteria were less than 1% of total bacteria and yeasts and moulds raised up to 9% of population (Table 1).

Table 1. Mean value (± standard deviation) of microbial count ($\log_{10}$ cfu/cm^2) of: (i) straw and mat bedding in winter; and (ii) winter bedding and pasture in summer for cow

Seasons	Winter				Summer	
Bedding materials	**Straw (n = 30)**	**Mat (n = 30)**	**Straw *vs* without straw**	**Winter bedding (n = 60)**	**Grass (n = 52)**	**Winter bedding *vs* pasture**
Total count	6.5 ± 0.8	5.9 ± 0.9	**	6.2 ± 0.9	5.1 ± 0.8	***
Lactic acid bacteria	4.3 ± 1.6	3.8 ± 1.2	NS	4.0 ± 1.4	2.3 ± 0.9	***
Ripening bacteria	6.3 ± 1.1	5.9 ± 1.0	NS	6.1 ± 1.1	4.1 ± 1.1	***
Gram negative bacteria	3.6 ± 1.0	3.0 ± 0.9	**	3.3 ± 1.0	3.6 ± 0.9	*
Yeasts	3.4 ± 1.3	2.3 ± 1.2	***	2.9 ± 1.3	3.2 ± 1.6	**
Moulds	2.6 ± 0.9	1.8 ± 0.9	***	2.2 ± 1.0	3.1 ± 1.0	***

*P<0.05, **P<0.01, ***P<0.001, NS: non significant.

Table 2. Mean value ± standard deviation of microbial count ($\log_{10}$ cfu/cm^2) straw and slatted floor ewes' bedding. Comparison between bedding materials counts was made

Bedding materials	Straw (n = 42)	Slatted floor (n = 24)	Straw *vs* stalled floor
Total count	4.8 ± 1.0	3.9 ± 0.9	**
Lactic acid bacteria	1.4 ± 0.6	1.2 ± 0.6	NS
Ripening bacteria	5.4 ± 0.6	4.8 ± 0.9	**
Gram negative bacteria	2.6 ± 0.6	1.9 ± 0.6	***
Yeasts and Moulds	1.9 ± 0.6	1.4 ± 0.6	**

*P<0.05, **P<0.01, ***P<0.001, NS: non significant.

2. Relationships between microbial characteristics of bedding, teat and milk

A. From bedding to teat

As for bedding material, teat surface was dominated by ripening bacteria; 95% of total bacterial count (6.58 $\log_{10}$ cfu/2 teats). Lactic acid bacteria (4.42 $\log_{10}$ cfu/2 teats) and the Gramnegative bacteria (3.82 $\log_{10}$ cfu/2 teats) were at lower level. Yeasts and moulds have the lowest level (3.00 $\log_{10}$ cfu/2 teats). As already observed on the bedding material, the levels of microbial counts on the teat surface were higher in winter (cows housed full-time) than in summer (grazing cows). The levels of total population, ripening bacteria and lactic acid bacteria on the teat skin were 0.7 to 1 $\log_{10}$ cfu/2 teats higher in winter than in summer. This result can be explained by the cow claustration in stall during winter.

In winter the level of ripening bacteria in bedding material specially in tie stall with straw was well correlated with those on teat surfaces (r = 0.80).The level of lactic acid bacteria on teat was correlated with that in tie stall (r = 0.77) and yeast level on teats and in free stall, especially without straw, was also correlated (r = 0.74). The microbial count on pasture and teat surfaces were weakly correlated (r<0.57) except that of yeasts (r = 0.66).

All the teat surface counts of ewes in farms with slatted floor were lower than those with straw, but only the difference in ripening bacteria level was significant ($p<0.05$). The ripening bacteria count on teat were correlated with that on straw ($r = 0.5$) and lactic acid bacteria level was correlated with that on slatted floors ($r = 0.5$).

B. From bedding to milk

On cow farms, there was no significant difference (<0.5 cfu/ml) between milk microbial counts in summer *versus* winter, in free stall *versus* tie stall and on bedding with straw *versus* without straw. The level of ripening bacteria in milk and teat surface was correlated in farms using straw ($r = 0.44$).

On ewe farms, milk from farms using straw as bedding had significantly higher ripening acid bacteria level ($p<0{,}001$) than that of farms using slatted floors. There was no significant correlation between the microbial levels of milk and of bedding surfaces. However, ripening bacteria levels for both material beddings were correlated with those of milk ($0.5<r<0.6$). The highest correlation was observed with the level of ripening bacteria on farms using straw ($r = 0.44$).

IV – Conclusions

Bedding materials are a source of ripening bacteria potentially useful in cheesemaking. Straw in cow farms, as well as in ewe farms, can be interesting since its microbial level was higher than mat or stalled floors. Levels of few microbial groups from bedding and teat surfaces were correlated, but no corelation between bedding surfaces and milk count was found. It remains to understand why microbial balance in bedding surface, source of ripening bacteria and milk differ and to determine if some strains from bedding transfer to milk. The role of microbial biofilm of milking for the enrichment of the milking should be deeper studied.

Acknowledgments

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Utilisation of whey by finishing beef cattle in alpine cheese production regions

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Abstract. In alpine cheese-production areas, whey represents an important source of available energy which is nevertheless little used, in addition to being perceived as an environmental problem. Consumption of whey by beef cattle might represent a profitable solution to this problem. Three groups – grass (G), grass+cereals (B) and grass+whey (W) – of 16 animals each with an average live weight of 478 ± 55 kg were put out to summer pasture in the Jura (1200 m altitude). Two kg of rolled barley granules with added molasses (B) and the energy equivalent of warm full-fat whey (W) were distributed daily. After 95 days, group B had consumed less grass on average ($p<0.01$), as assessed by a differential in grass height, than groups G and W. A substitution effect appears to exist with the barley but not with the whey, despite an average daily intake of 25.5 litres per animal. Average daily weight gain was 911 g, with the differences of +12% for B and +9% for W not being significant. Carcass quality (conformation and level of fattening) was not affected by the treatments. Although it is possible to utilise warm whey derived from alpine cheesemaking in beef-cattle production, this additional energy intake did not translate into higher performance under the conditions of our experiment.

Keywords. Beef cattle – Whey – Alpine pastures – Feed intake – Growth performance – Carcass quality.

Valorisation du petit-lait par des bovins à viande dans les zones de fabrication de fromage d'alpage

Résumé. *Le lactosérum ou petit-lait représente dans les zones de production de fromages d'alpage une source d'énergie disponible importante, peu valorisée et problématique pour l'environnement. Son ingestion par des bovins à viande pourrait représenter une opportunité intéressante. Trois groupes, herbe (G) - herbe+ céréales (B) - herbe+petit-lait (W), de 16 animaux d'un poids vif moyen de 478 ± 55 kg, ont été estivés dans le Jura (1200 m a.s.l.). Deux kg de granulés d'orge mélassée (O) et un équivalent énergétique de petit-lait non écrémé chaud (W) ont été distribués quotidiennement. Après 95 jours, le groupe B a consommé en moyenne moins d'herbe (p<0.01), estimé par un différentiel d'hauteur d'herbe, que les groupes G et W. Un effet de substitution semble présent avec de l'orge mais pas avec le petit-lait malgré une consommation moyenne de 25,5 l par jour. Le gain moyen quotidien s'est élévé à 911 g, les écarts de +12% pour B et +9% pour W n'étant pas significatifs. La qualité de la carcasse, la conformation et l'état d'engraissement, n'ont pas été affectés par les traitements. La valorisation par des bovins à viande du petit-lait d'alpage chaud est possible, mais cet apport supplémentaire d'énergie ne s'est pas traduit, dans nos conditions expérimentales, par des performances supérieures.*

Mots-clés. *Bovins à l'engrais – Petit-lait – Alpages – Ingestion – Croissance – Qualité de carcasse.*

I – Introduction

Mountain agriculture is faced with a substantial decrease in both the number of farms and livestock numbers, the encroachment of forest on farmland, the need to research viable economic alternatives, and society's growing demands for the upkeep of the landscape, the preservation of biodiversity and the provision of local quality products. In such a context, the PASTO project (Chassot A. and Deslandes K.A., 2009; Miéville *et al*., 2009) has shown that it is possible to reconcile alpine meat production with caring for the landscape, provided that a minimum feeding intensity can be guaranteed. In alpine-cheese production areas, whey represents an important source of available energy which is not only little used, but is also considered to be a problem for the environment. Currently, it is either fed to pigs, purified by passage through a bed of compost (Fiaux J.-J., 2004), or spread on pastures. Whilst use by pigs remains problematic owing to the mismatch of their intake capacity and the quantities produced at the start of the season, use of the purification system incurs a high cost, producing heat, CO_2 and ammonia. The feeding of whey to beef cattle could represent a worthwhile alternative. To our knowledge, no study combining the production of alpine cheese with the production of beef within a mixed production system has ever been carried out. On the occasion of a first study of the LACTOBEEF project, the effects of different grazing supplements on feed intake, animal performance and carcass quality were compared.

II – Materials and methods

The 95 day-long trial took place on a summering farm situated at 1200 m altitude in the Swiss Jura. Forty-eight animals aged 17.5 months and weighing 478 ± 55 kg, belonging to four genetic groups (Angus, Limousin, Angus x Limousin, Limousin x Red Holstein) and two sexes (castrated males and females) were used in the study. The cattle were randomly assigned to 3 experimental treatments (2 animals per genetic group and per sex in each treatment). One group had access to grazed grass only (group G), whilst the two other groups received an individually distributed daily isoenergetic supplement to grazing either in the form of 2 kg of rolled barley granules with added molasses (group B) or in the form of full-fat whey (6.68% DM) delivered once a day warm to the manger (group W).

Grazing was organised as a rotating system and comprised four paddocks for each group. The available area and stocking density were the same (5.6 ha and 1.8 LU/ha, respectively) for the three groups. All three groups were always moved simultaneously to different paddocks. In the event of differences in grass height when the herds were moved, a herd not currently involved in the trial (‘shuttle’ animals) was brought in to consume the excess grass, thereby ensuring comparable regrowth conditions (quality and quantity of grass) in the paddocks of all three groups. The height of the sward was measured with a herbometer before and after each use of a paddock. In a first approach, prior to observations made by means of wax-markers (alkanes), forage intake was estimated for each group on the basis of the differences in grass height measured at the beginning and at the end of each grazing period.

The animals were accustomed to the whey over a five-week pre-experimental period in the lowlands (650 m altitude). Whey intake was measured per group, except during three 5-day periods when the animals were brought into the stable daily for individual *ad libitum* bucket feeding. The animals were weighed at the beginning and end of the experiment as well as at the end of each rotation period, the last day before changing paddocks, *i.e.* about once a month. Conformation and level of fattening were evaluated in the live animal at the beginning and end of the experiment by professional experts. Carcasses were classified in the abattoir according to these same parameters.

III – Results and discussion

1. Grass intake

During the experimental period, the quantity of grass consumed by the animals of group B (5.5 kg DM/d) was lower ($p<0.05$) than that consumed by the animals of groups G (7.8 kg DM/d) and W (7.3 kg DM/d). The substitution effect caused by the intake of barley was not observed for whey (group W), despite the substantial quantities of this food consumed by the animals. Differences between the rotations also became evident, with the animals consuming significantly less grass in summer (July) than in late spring (June).

Over the entire season, the animals consumed between 6.6 and 9.0 kg of dry matter (DM) of grass per day on average. With respect to the reference values given in the Swiss feeding recommendations for cattle (Agroscope, 2013), viz. 8.9 kg DM, these values seem fairly realistic, especially bearing in mind the supplements for variants B and W.

2. Whey intake

The constraints of the experimental design (allocation criteria breed, sex) prevented the selection exclusively of animals which consumed whey. Despite the long adaptation period, only 13 animals of 16 consumed the whey distributed on pasture, which was limited to a maximum of 320 litres per day. So the average maximum amount consumed by each of the 13 animals was 24.6 litres per day (Fig. 1). The three peaks in intake which can be seen in this figure correspond to the *ad libitum* bucket-distribution periods in the stable with measurement of individual intake. After these *ad libitum* periods, negative peaks appear. These generally correspond to the day of entry in the new field, where the animals had access to plenty of young grass, and therefore neglected the whey to an extent. Over the entire experimental period (pasture restricted and stable *ad libitum*), average intake came to 25.5.litres per animal and per day, i.e. 1.7 kg DM, corresponding to 19% of the total DM intake. According to Schingoethe (1975), this share can reach 30%.

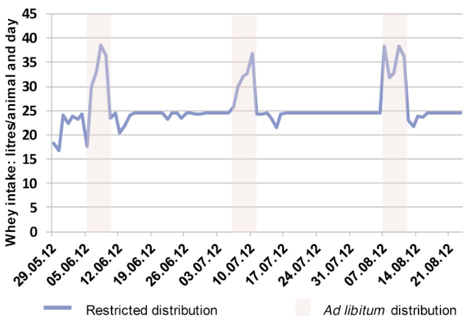

Fig. 1. Average whey intake per animal and day throughout the entire experiment.

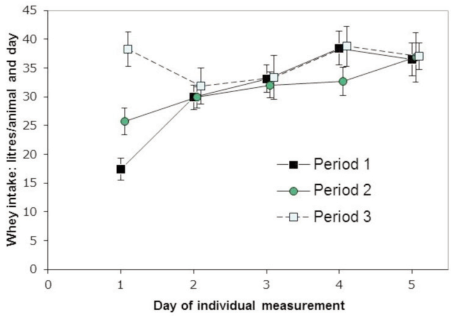

Fig. 2. Average whey intake per animal and day during the 3 *ad libitum* individual distribution periods.

The results of the individual-intake measurements (Fig. 2) indicate that there are few differences between the three periods. Only the first day of each period shows major differences, with an increase of over 20 litres between the first and third period. This may be due to an adaptation of the animals to bucket feeding in the stable. The average intake reached from the second day of each period lies between 30 and 35 litres per animal and day. The maximum intake per day reached 58.4 litres. According to Thivend (1978), ruminants are capable of consuming between 12 and 15 litres of fresh whey per 100 kg live weight.

3. Growth performance and carcass quality

With respect to control group G, the supplemented groups B and W achieved a daily growth of +12% and +9% respectively (Table 1) (n.s.).The effect of both breed and sex on the average daily gain (ADG) was significant, but will not be discussed here. In a trial with stabled beef cattle, the distribution of 40 litres of whey per day as a supplement to hay and beets contributed to a 16% increase in the ADG (Lehmann *et al*., 1993). Carcass quality (conformation and level of fattening) was not influenced by the treatments. The higher yield at slaughter for group W (P<0.05) can be explained by less filling of the digestive tract.

Table 1. Effect of the different treatments on growth performance and carcass quality

Trait		Treatment			P value		
		G	B	W	Group	Breed	Sex
No. of animals		16	16	13			
Live weight initial	kg	480 ± 52	475 ± 56	478 ± 60	0.949	**0.010**	**<0.001**
Live weight final	kg	560 ± 59	564 ± 62	565 ± 69	0.968	0.179	**<0.001**
Duration	d	94 ± 7	94 ± 7	93 ± 7	0.964	0.990	0.570
ADG	g/d	852 ± 163	957 ± 196	928 ± 290	0.271	**0.001**	**0.039**
Hot carcass weight	kg	307 ± 37	313 ± 37	324 ± 46	0.593	**0.024**	**<0.001**
Carcass yield	%	54.7 ± 2.5	55.5 ± 2.4	57.4 ± 2.6	**0.020**	**<0.001**	0.160
Conformation:							
Diff.score initial-final		0.70 ± 0.45	0.88 ± 0.44	0.75 ± 0.34	0.212	**0.024**	0.217
Score at slaughter[1]		4.22 ± 0.66	4.31 ± 0.83	4.42 ± 0.70	0.662	**<0.001**	1.000
Level of fattening:							
Diff.score initial-final		0.59 ± 0.59	0.89 ± 0.52	0.75 ± 0.65	0.231	**0.001**	0.074
Score at slaughter[2]		3.06 ± 0.68	3.19 ± 0.75	3.08 ± 0.86	0.641	**<0.001**	**0.019**

[1]Conformation: 1 (fleshless) to 5 (very good conformation); [2]Level of fattening: 1 (lean) to 5 (excessively fat); ADG=average daily gain

IV – Conclusions

Appreciable amounts of fresh warm whey may be consumed once daily by beef cattle without this causing any health problems. Animal performance indicators such as growth and carcass quality are not adversely affected by this practice.

The experiment will be pursued under the same conditions, but with an *ad libitum* distribution during the entire experimental period as well as under practical conditions for the techno-economic aspects, particularly in order to study joint use of fattening cattle with dairy cows on alpine pastures where cheese is produced. Finally, the possibility of setting up a quality-label beef production system will be validated.

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Safety status and physicochemical composition of Plaisentif Cheese

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Abstract. This is the first attempt to describe Plaisentif cheese. Plaisentif is a traditional cheese produced in the Western Alps and obtained from the raw milk of cows fed on pastures during the violet flowering period. This cheese has never been studied. The aim of this work was to evaluate the safety status of milk and cheese and some basic physical-chemical parameters. Samples of milk and cheese at the end of ripening (60 days) were collected from nine Alpine dairy farms. Content of dry matter, protein, fat and ash, as well as pH and water activity (Aw) were evaluated. The microbiological parameters considered were: coagulase-positive Staphylococci, *Enterobacteriaceae*, *Salmonella* spp and *Listeria monocytogenes*. The final mean values of pH and Aw for cheeses were 5.39 and 0.963, respectively. *Salmonella* spp was found neither in milk nor in cheese. *Listeria monocytogenes* was found in one sample of milk. *Enterobacteriaceae* varied between <10 and 3.26 x 10^4 CFU/ml in milk and between <10 and 8.1 x 10^4 CFU/gr in cheese. Coagulase-positive Staphylococci varied from <100 to 3.1 x 10^4 CFU/ml for milk. Three ripened cheeses from different producers showed counts higher than those permitted by the European Regulations. The rise in *Enterobacteriaceae* could be due to environmental contamination, because some cheese factories, located above 1400 m a.s.l., are used only during the summer period, when sufficient hygiene standards could be difficult to obtain.

Keywords. Plaisentif – Cheese – Microbiology – Chemical composition.

Qualité sanitaire et composition physico-chimique du fromage Plaisentif

Résumé. *Ce travail représente la première tentative de caractérisation du fromage Plaisentif. Le Plaisentif est un fromage traditionnel produit dans les Alpes occidentales et obtenu à partir de lait cru de vaches nourries sur les pâturages pendant la période de floraison des violettes. Il n'a jamais été caractérisé. L'objectif de ce travail était d'évaluer la qualité sanitaire microbiologique des laits et des fromages et de déterminer leur composition physico- chimique. Des échantillons de laits et de fromages à la fin de l'affinage (60 jours) ont été collectés dans neuf fermes laitières alpines. Les teneurs en matière sèche, protéines, graisses et cendres, ainsi que le pH et l'activité de l'eau (Aw) ont été mesurées. Les staphylocoques à coagulase positive, entérobactéries,* Salmonella *spp et* Listeria monocytogenes *ont été dénombrés. Les valeurs moyennes finales de pH et Aw pour les fromages ont été de 5,39 et 0,963, respectivement.* Salmonella *spp n'était détectée ni dans les laits, ni dans les fromages.* Listeria monocytogenes *n'était trouvée que dans un échantillon de lait. La charge en Entérobactéries était comprise entre <10 et 3,26 x 10^4 UFC / ml dans les laits et entre < 10 et 8,1 x 10^4 UFC/g dans les fromages. Dans les laits, la charge en Staphylocoques à coagulase positive a varié de <100 à 3,1 x 10^4 UFC/ml. Trois fromages affinés provenant de différents producteurs ont montrés des valeurs supérieures que celles autorisées par la Réglementation Européenne. Les valeurs élevées en entérobactéries pourraient être dues à la contamination de l'environnement, puisque certaines fromageries sont situées au-dessus de 1400 m d'altitude et ne sont utilisées que pendant l'été. Cela peut rendre difficile le maintient de forte pratiques d'hygiène.*

Mots-clés. *Plaisentif – Fromage – Microbiologie – Composition chimique.*

I – Introduction

Plaisentif cheese is a bovine cheese produced with raw milk and generally without using starters from cows fed on pasture grass. Pastures and cheese factories are located at a minimum height of 1400 and 1800 m a.s.l., respectively. The peculiarity of this cheese is the fact that it is produced from pastures during the violet flowering period (from June to July). Briefly, the cheese is produced by adding the milk obtained from the morning milking to that from the previous evening's milking and warmed to 33-36°C. Rennet is added and clotting time is established visually by the cheese-maker (usually takes around one hour). The curd is cut into blocks of varying sizes, depending on the producer's preferences. After 5-10 minutes, the curd is mixed, collected, pressed and drained for 12 hours. The cheese can be dry-salted or in brine, and then ripened for 60 days. The disciplinary contain no specifications regarding temperature and humidity for this phase. At the end of the ripening phase, the cheese is marked with the typical logo, the producer name and the day of marking. The aim of this work was to evaluate the microbial hygiene and safety status and bromatological composition of milk and Plaisentif cheese.

II – Materials and methods

Samples of pooled milk (sampled in the whole herd when it was in the vat) and 60-day ripened cheese were taken from nine producers. pH and water activity (Aw) were measured using an HI 99163 pH meter (Hanna instruments, Italy) and an Acqualab 3TE water activity meter (Decagon Devices, Inc., Pullman, WA), respectively. Milk and cheese samples were analysed to determine dry matter, ash by ignition to 550°C and crude protein content according to the AOAC method (AOAC, 2000) while the crude fat content was determined according to the method described by Hara and Radin (1978).

Regarding microbiology, *Enterobacteriaceae* were analysed using the AFNOR V08-054 protocol, Salmonella with the ISO 6579-1993 protocol, *Listeria monocytogenes* with ISO11290-1/Amd 1:2004E and Coagulase-positive *Staphylococci* with the AFNOR V08-14 protocol modified using Baird-Parker Agar with RPF in order to detect coagulase activity (Liophilchem, Italy). The other mediums were purchased from Oxoid (Oxoid, UK).

III – Results and discussion

A mean pH value of 6.77 ± 0.06 and 5.39 ± 0.19 was found for milk and cheese, respectively; cheese showed a mean Aw of 0.963 ± 0.009. The results of the bromatological composition are reported in Table 1. The analytical results showed that, even in the presence of a production regulation, there is a great difference between producers, as far as shape, cheese-making process, and ripening conditions are concerned. This may explain the high degree of variability observed in milk and cheese composition. For example, the use of partially-skimmed milk from the evening milking, mixed with milk from the morning milking, could affect the fat content of the ripened cheese. The same conditions have been found in other typical dairy products, such as Toma Piemontese cheese, which is produced in three different types according to fat content that can vary between 17% and 28% (Manzi *et al.*, 2007; Zeppa, 2004).

Regarding microbiological analysis, *Salmonella* was not found in the milk, while *Listeria monocytogenes* was only found once. Neither *Salmonella* nor *Listeria monocytogenes* were found in the cheese. *Enterobacteriaceae* varied from <10 to 3.26 x 10^4 CFU/ml (mean: 7.39 x 10^3) and from <10 to 8.1 x 10^4 CFU/g (mean: 1.65 x 10^4) in milk and in cheese, respectively. The *Enterobacteriaceae* count distributions in milk and cheese among producers are shown in Figures 1 and 3, respectively. Coagulase-positive *Staphylococci* varied from <100 to 3.1 x 10^4 CFU/ml (mean 5.26 x 10^3) for milk (Fig. 2). Only three ripened samples out of nine (one = 500 and two = 100 CFU/g) from different producers showed counts higher than those permitted by European Regulations (Fig. 4) (EC, 2007). Some producers had low EC counts in milk and high EC counts in cheese. This may be ascribed to the poor hygienic conditions of cheese factories located at high altitude, which determine the *Enterobacteriaceae* contamination of environment, water and milk (Bintsis *et al.*, 2008; Bhatt *et al.*, 2012; Coton *et al.*, 2012).

Table 1. Bromatological composition (% of fresh matter) of milk (n = 18) and Plaisentif cheese (n = 18) from nine Piedmont farms (mean ± SD†)

	Dry matter	Protein	Fat	Ash
Milk	12.74 ± 0.75	3.09 ± 0.31	2.62 ± 0.54	0.69 ± 0.03
Cheese	58.97 ± 2.87	22.55 ± 2.14	21.94 ± 3.46	2.47 ± 0.15

† SD: standard deviation.

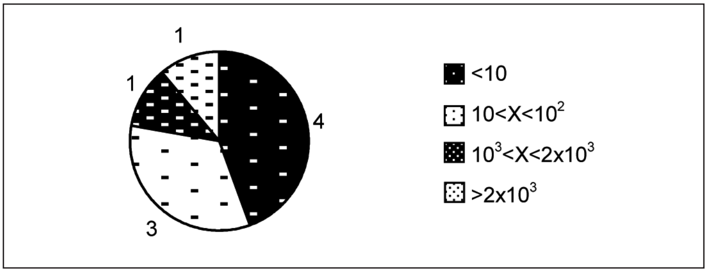

Fig. 1. *Enterobacteriacee* count in milk samples (CFU/ml).

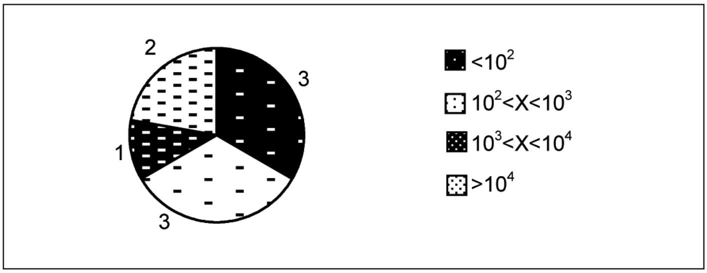

Fig. 2. Coagulase-positive *Staphylococci* count in milk samples (CFU/ml).

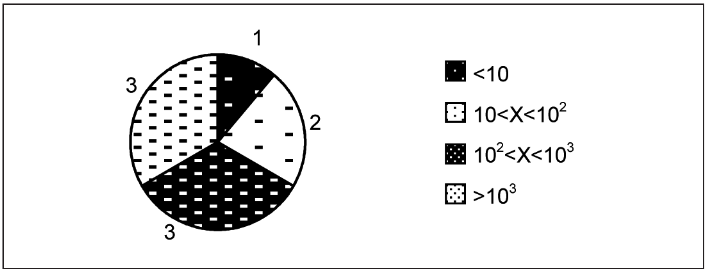

Fig. 3. *Enterobacteriacee* count in cheese samples (CFU/g).

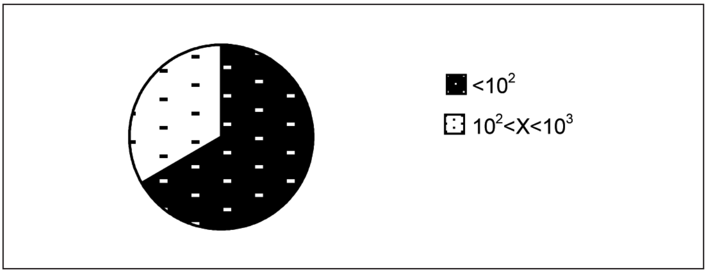

Fig. 4. Coagulase-positive *Staphylococci* count in cheese samples (CFU/g).

IV – Conclusions

Preserving typical food products provides valuable support for the natural environment and economic revitalization of local communities. In this sense, Plaisentif turns out to be a very interesting model. This work is thus the first attempt to evaluate the hygienic status of Plaisentif cheese and its chemical composition.

From these data, the cheese appears to be considered as safe. There is clearly, however, considerable variability in the data due to the craft-based nature and to the difficult conditions of the cheese-making process. This could be considered positive providing a proof in traditional and artisanal products.

From a microbiological point of view further investigations are necessary in order to clarify the source of *Enterobacteriaceae*.

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Prediction of fatty acids composition of annual forage clovers and serradella by near infrared spectroscopy

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Abstract. Near infrared reflectance spectroscopy (NIRS) was evaluated as an alternative method to gas chromatography for the quantitative analysis of fatty acids (FA) in samples of six annual legume species grown as winter crops in Galicia (NW Spain) and harvested at different dates in spring. Spectral data from both whole plant and morphological fractions (leaves, petioles, stems and inflorescences) samples of crimson clover (*Trifolium incarnatum* L.), balansa clover (*T. michelianum* Savi.), persian clover (*T. resupinatum* L.), ssp. *resupinatum* and *majus*, arrowleaf clover (*T. vesiculosum* Savi.) and French serradella (*Ornithopus sativus* Brot.) were collected in the wavelength range of 1100-2500 nm. Chromatographic data was regressed on spectral data to develop calibration equations for FA composition, sum of total FA (TFA), saturated FA (SFA), unsaturated FA (UFA), and polyunsaturated FA (PUFA). Equations showed good or excellent coefficients of determination (R^2) for calibration (0.80-0.93), except for C17:0. It can be concluded that NIRS analysis is a useful tool for the prediction of fatty acid composition of the annual legumes studied.

Keywords. Forage legumes – Fatty acids – NIRS.

Prédiction de la composition en acides gras de fourrages annuels de trèfles et serradelle par spectroscopie dans l'infrarouge proche

Résumé. *La spectroscopie dans le infra rouge proche (NIRS) a été évaluée comme une méthode alternative à la chromatographie en phase gazeuse pour l'analyse quantitative des acides gras au sein de six échantillons de légumineuses annuelles cultivées comme culture d'hiver en Galice (NO Espagne) et récoltées à différentes dates au printemps. Les données spectrales obtenues à partir soit de la plante dans son ensemble, soit de fractions morphologiques (feuilles, pétioles, tiges et inflorescence) de trèfle incarnat, trèfle Balansa, trèfle de Perse, trèfle vésiculeux et serradelle française, ont été acquises dans un intervalle de longueurs d'onde compris entre 1100 et 2500 nm. Les données chromatographiques ont été corrélées avec les données spectrales dans le but de développer des équations de calibration pour déterminer la composition en acides gras, la somme des acides gras totaux (AGT), saturés (AGS), insaturés (AGI) et polyinsaturés (AGPI). Les équations de calibration ont montré de bons voire d'excellents coefficients (R^2) de corrélation, sauf dans le cas de l'acide C17:0. L'analyse NIRS constitue une méthode très utile pour la prédiction de la composition en acides gras des légumineuses fourragères annuelles étudiées.*

Mots-clés. *Légumineuses fourragères – Acides gras – NIRS.*

I – Introduction

The dairy cow farms of Galicia (NW Spain) produce 2.2 million of tonnes of milk, accounting for about 40% of total dairy production and more than half of dairy cow producers in Spain (MARM, 2010). In recent years, the number of farmers interested about production of differentiate milk have been increased, with feeding system based on forage legumes, due to their potential for enhance the proportion of polyunsaturated fatty acids (PUFA) in milk fat (Dewhurst *et al.*, 2003).

Therefore for evaluation of profile fatty acids (FA) of some annual forage legumes species as winter crops for silage in Galicia, arising the need of having reliable methods for the routine evaluation of fatty acids composition for both research and advisory purposes.

Near infrared reflectance spectroscopy (NIRS) is an alternative to standard analytical methods for determining nutritive value of forages and has become widely recognized as a valuable tool in the accurate determination of the chemical composition of a wide range of forages (Shenk and Westerhaus, 1985). The key to successful use of the NIRS technique is to develop a calibration model, based in a large calibration database which adequately represents the characteristics of the forage problem samples to be predicted.

In the present study, it is evaluated the potential use of NIRS as a alternative method to gas chromatography for the quantitative analysis FA in samples of six annual legume species grown as winter crops in Galicia (Valladares *et al*., 2012) and harvested in different dates in spring for silage as the first step in providing a robust, fast and inexpensive laboratory method for estimating FA composition of these species.

II – Materials and methods

This work was carried out with samples of six annual legume species harvested at six different dates during the first and second spring growth of the year 2011 (15 March-24 May and 26 April-5 July, respectively) with 10 replications, in an experiment carried out at the Centro de Investigacións Agrarias de Mabegondo (A Coruña, Galicia, Spain). Moreover, the fresh whole plants of all legumes species, were harvested at five harvest dates (3 April-29 May) during the first spring growth of the same experiment in year 2012 (1 replicate), the legumes were separated by hand into morphological fractions: leaves, petioles, stems and inflorescences. The species studied were Crimson clover (*Trifolium incarnatum* L. cv. Viterbo), Balansa clover (*T. michelianum* Savi. cv. Bolta), Persian clover (*T. resupinatum* L. ssp. *resupinatum* cv. Kyambro and ssp. *majus* cv. Maral), Arrowleaf clover (*T. vesiculosum* Savi. cv. Zulu) and French serradella (*Ornithopus sativus* Brot. cv. Margurita), this specie was not harvested for separation into morphological fractions. Dry matter (DM) content of fresh samples was determined by oven-drying at 80ºC for 16 hours, ground in a Christy-Norris hammer mill to 1 mm and sample spectra were recorded in a Foss NIR Systems 6500 monochromator (spectofotometric NIRSystems 6500 (FOSS NIRSystems, Inc., Silver Spring, Washington, USA). Two aliquots of each sample were scanned in a spinning circular cup with a quartz window of 37.5 mm diameter, at 2 nm intervals in the wavelength range of 1100-2500 nm. The spectrum of each sample was the average of the two sub-samples. Initially, all spectral data were recorded as the log 1/reflectance (log 1/R values). Samples with extreme (i.e. outliers) or very similar spectra were excluded from the calibration data set, unless they were thought to provide relevant information (Shenk and Westerhaus, 1996). Data were processed using the software Win ISI Version 1.5 (Infrasoft International, Port Matilda, USA, 2000).

From total samples (n = 820) the most representative spectra were selected using the SELECT algorithm included in the WinISI software. Fatty acids of forage selected samples (n=190, 107 whole plant and 83 fractions) were extracted using a modified version of the direct transesterification method developed by Sukhija and Palmquist (1988) performing a simultaneous extraction and methylation with methanolic hydrochloric acid. The FA methyl esters were detected and quantified by gas chromatography coupled with a flame ionization detector. All parameters were reported on a DM basis and analysed in duplicate.

Calibration equations were obtained using a Modified Partial Least Squares Regression (MPLS) regression technique (Martens and Naes, 1987). This regression technique requires cross-validation to prevent over-fitting, obtaining validation errors by partitioning the calibration set into several groups and pooling them into a standard error of cross-validation. MPLS of reference values on the second derivative of standard normal variate and de-trended spectra (Barnes *et al*. 1989) was regression method for all the determinations. The statistics parameters used to test the performance of the calibration equations were the standard errors (SEC and SECV) and coefficients of determination (R^2 and r^2) obtained in the calibration and cross validation steps, respectively. The Range to Error ratio (RER) of cross validation, as defined by the range of the population's reference values divided by the corresponding SECV was also considered since it is a useful statistic to test the accuracy of the calibration models (Williams and Sobering, 1996).

III – Results and discussion

The characteristics of the reference values of the calibration data set and the statistics to describe the quality of NIRS calibration equations developed are shown in Table 1. The variability in their composition was found to be adequate for developing initial NIRS calibrations.

Table 1. NIRS statistics of the calibration equation used for the prediction of fatty acid (FA) composition, sum of total FA (TFA), saturated FA (SFA), unsaturated FA (UFA), and polyunsaturated FA (PUFA) of whole plant and morphological fractions of the annual forage legume species

Constituent	N	Mean	SD	Range	SEC	R^2	SECV	r^2	RER
C12:0	177	0.086	0.078	0.000-0.310	0.027	0.88	0.035	0.82	8.77
C14:0	175	0.028	0.025	0.000-0.098	0.012	0.75	0.016	0.65	6.22
C15:0	183	0.027	0.026	0.000-0.097	0.009	0.87	0.011	0.82	8.55
C16:0	183	1.822	0.783	0.117-4.193	0.009	0.87	0.419	0.82	9.72
C16:1	183	0.056	0.015	0.000-0.065	0.295	0.86	0.039	0.73	1.65
C17:0	158	0.026	0.019	0.000-0.082	0.009	0.64	0.010	0.16	8.15
C18:0	182	0.181	0.124	0.000-0.540	0.008	0.85	0.066	0.74	8.20
C18:1n9c	182	0.123	0.079	0.000-0.332	0.051	0.83	0.072	0.74	4.63
C18:2n6c	185	1.817	0.810	0.000-4.214	0.367	0.80	0.482	0.65	8.75
C20:0	163	0.139	0.068	0.000-0.295	0.023	0.88	0.052	0.66	5.63
C18:3n6	183	0.056	0.050	0.000-0.179	0.015	0.91	0.026	0.74	7.02
C20:1	181	0.024	0.017	0.000-0.074	0.008	0.80	0.010	0.70	7.62
C18:3n3	183	5.899	4.032	0.092-17.974	1.101	0.93	1.310	0.90	13.65
C22:0	181	0.106	0.073	0.000-0.323	0.031	0.82	0.039	0.73	8.23
C22:1n9	132	0.004	0.004	0.000-0.014	0.001	0.91	0.002	0.71	5.83
C20:3n3	190	0.038	0.028	0.000-0.121	0.013	0.78	0.016	0.68	7.44
C20:4n6	179	0.039	0.029	0.000-0.122	0.014	0.80	0.016	0.71	7.50
C24:0	180	0.150	0.098	0.000-0.435	0.035	0.88	0.050	0.75	8.75
TFA	188	10.677	5.504	1.873-25.784	1.854	0.89	2.170	0.84	11.02
SFA	182	2.623	1.214	0.264-6.218	0.409	0.89	0.581	0.77	10.24
UFA	189	8.055	4.504	1.153-20.825	1.431	0.90	1.717	0.85	11.46
PUFA	184	7.848	4.369	1.051-20.572	1.397	0.90	1.661	0.86	11.75

SD = standard deviation. SEC = standard error of calibration. SECV = standard error of cross validation.
R^2 and r^2 = coefficient of determination in calibration and cross validation. RER = Range/SECV.

The values obtained for the coefficients of determination (R^2) of calibration ranged from 0.64 to 0.93, according to the criteria proposed by Shenk and Westerhaus (1996), an R^2 value greater than 0.90 indicates an excellent quantitative precision, while a value between 0.70 and 0.90 is described as a good quantitative precision, therefore, the equations developed in this work showed good or excellent coefficients of determination for calibration, except for C17:0. On the other hand, according to the guidelines utilized by Williams and Sobering (1996) calibrations with RER>10, are acceptable for quantitative prediction, the RER values were greater than 10 for the more prevalent fatty acids (C18:3n3, TFA, SFA, UFA and PUFA). Ours results showed values for coefficients of determination of calibration and cross validation lower than those reported by Foster *et al.* (2006).

IV – Conclusions

This work demonstrates the possibilities to use NIRS for the prediction of fatty acid composition of the six annual legumes studied. It is nevertheless advisable to check the equation in blind tests on open sets into the future and to include new samples to increase the robustness of the predictions and expand it to other legume species.

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Cattle distribution under rotational grazing as affected by mineral mix supplements and traditional salt placement in Alpine environments

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Abstract. Effects of strategically placed mineral mix supplement (MMS) and traditional salt placement (TS) on cattle distribution were compared within Val Troncea Natural Park (Italy). Loose salt (TS) was placed on the rocks traditionally used by the farmers within flat and herbaceous areas. MMS blocks were strategically placed along 50-m transects in steep and shrub-encroached sites. Each TS and MMS treatment area was paired with a control site without supplements. Grazing period within each pasture was divided into two equal sub-periods during which TS and MMS were available. Eleven cows were tracked at 15 minute intervals with GPS collars. Both TS and MMS placement areas were used more ($P<0.001$) than associated control areas. No differences were detected ($P>0.05$) in the time spent near TS and MMS. During both periods, cattle preferred areas with gentler terrain, closer to streams, closer to TS or MMS points, and with higher forage pastoral value. During TS periods, cattle preferred ($P<0.01$) areas with higher percentage of large leaf grasses, whereas during MMS periods cattle avoided ($P<0.01$) areas with higher bare ground and rock cover. Since we did not detect differences in the time spent in MMS and TS placement sites, strategically placed MMS appears to be a very promising tool to increase the use of steep and shrub-encroached areas and to enhance cattle distribution within large pastures.

Keywords. Beef cows – Feed blocks – Cattle distribution – GPS-tracking – Rotational grazing system.

Influence de l'emplacement de blocs minéraux à lécher et de sel traditionnel sur la répartition des animaux au pâturage dans les milieux alpins

Résumé. *Les effets de l'emplacement de blocs minéraux (MMS) et de sel en vrac (TS) sur la répartition des animaux au pâturage ont été comparés dans le Parc Naturel Val Troncea (Italie). TS a été placé sur des rochers traditionnellement employés par les éleveurs dans des milieux plats et herbacés. MMS ont été stratégiquement placés le long de transepts de 50 m en milieux abrupts et embroussaillés. Chaque aire avec TS et MMS a été associée avec une aire témoin sans aucun supplément. La période de pâturage des animaux à l'intérieur de chaque parcelle a été partagée en deux périodes pendant lesquelles TS et MMS étaient disponibles. La position des vaches a été enregistrée à l'aide de colliers GPS toutes les 15 minutes. Les aires de placement de TS et de MMS ont été exploitées par les animaux d'une façon plus fréquente que les aires témoin ($P<0,01$). Aucune différence n'a été relevée ($P>0,05$) parmi les aires à TS et à MMS. Pendant les deux périodes, les vaches ont préféré les milieux avec des terrains doux, près des ruisseaux et des points avec TS ou MMS, et caractérisés par une valeur pastorale de la végétation plus élevée. Pendant les périodes TS, les vaches ont préféré ($P<0,01$) les milieux avec des pourcentages élevés de graminées à feuilles larges, tandis que pendant les périodes MMS les vaches ont évité ($P<0,01$) les milieux avec des couverts importants de sol nu et de rochers. Puisque aucune différence de temps passé près des aires MMS et TS n'a été relevée, le placement stratégique de MMS pourrait être un moyen efficace pour augmenter l'exploitation des milieux raides et embroussaillés et pour améliorer la distribution des animaux au pâturage.*

Mots-clés. *Vaches allaitantes – Blocs nutritionnels – Répartition des animaux – Collier GPS – Pâturage tournant.*

I – Introduction

Grazing distribution is a critical component of cattle management on mountainous rangelands (Del Curto *et al.,* 2005). Strategic supplement placement has been used to manipulate cattle grazing patterns in the United States (e.g., Bailey and Welling, 2007), Brazil (Goulart *et al.,* 2008) and Western Italian Alps (Probo *et al*., 2013). During the 20th century, socio-economic transformations have led to a large-scale decline in livestock farming and agriculture in the Alps. People moved to the cities in the plains, and the number of traditional agro-pastoral activities has diminished. The ecological consequences of undergrazing or complete elimination of domestic animals grazing are usually evident where conditions are suitable for tree and shrub growth. Targeted livestock grazing using rotational grazing systems (RGS) and strategic supplement placement to lure the cattle towards underused and shrub encroached areas may be effective to avoid or slow down this process. The goal of this study was to evaluate how the strategic placement of mineral mix supplement (MMS) and traditional salt (TS) placed by farmers can affect the grazing patterns of beef cows managed under RGS. Our hypothesis was that TS would be more attractive than MMS because it is traditionally placed in flat areas, which are more accessible and often offer better quality forage. In contrast, MMS was placed in underused, steep and shrub encroached sites, which are less accessible. The specific objectives were: (i) to identify the most important geomorphological and vegetation factors affecting cattle grazing patterns in sub-alpine and alpine pastures managed under RGS with large paddocks and MMS or TS available; and (ii) to determine if MMS is an effective tool to increase the use of undergrazed areas.

II – Materials and methods

The study was conducted in the Val Troncea Natural Park (44°57’ N, 6°57’ E), which is a protected area representative of the socio-economic changes that occurred on Western Italian Alps. A total of 119 Piedmontese beef cows, including heifers and non-lactating cows, grazed from 20 June to 26 August 2013 in four paddocks in rotation according to a pastoral plan. Only three paddocks were monitored because the first one was used to familiarize cows to MMS blocks. Pastures were 6 ha (not monitored), 27 ha, 45 ha and 60 ha in size. Although the paddocks differed in size, each of them was used for about 20 days, because their carrying capacity was similar. Fourteen randomly selected cows were tracked with Global Position System (GPS) collars (GPS Model Corzo, Microsensory SLL, Fernán Núñez, Andalusia, Spain). Positions were recorded every 15 min, with an average accuracy of 6 meters. The grazing period within each pasture was divided into two equal sub-periods. The two supplements (i.e. MMS or TS) were randomly assigned to the two sub-periods in order for cattle to have access to both supplements in each pasture. TS (NaCl, 25 kg) was placed in traditional locations 2-3 times by the farmer during the sub-period. MMS was placed *ad libitum* at five steep, undergrazed, and shrub-encroached locations along a 50 m transect on poles (5 kg blocks). MMS blocks were arranged to gradually attract cows from gentle to moderate herbaceous dominated sites to steep and shrub dominated sites. In contrast, TS was placed on flat rocks within flat herbaceous areas to simulate the traditional use by farmers (i.e. to concentrate cattle for periodic herd counts and health inspections within accessible sites). The average slope of MMS sites was 26.6° ± 4.12, whereas TS was 16.9° ± 2.28. A paired control area with similar geomorphological and vegetation conditions was identified for each supplement (TS or MMS) placement site. Pastures were subdivided into 50 x 50 m grid cells in order to study the spatial patterns of the grazing cows. Starting from the center of each cell, the cover of shrubs, herbaceous species, bare ground, and rocks were visually estimated within a 20 m buffer area. The ratio among thin leaf, medium leaf, and broad leaf herbaceous species (including grasses and sedges) was assessed by a visual estimation. Moreover, vegetation composition was visually estimated to identify the vegetation type (Cavallero *et al*., 2007) and to estimate the Forage Pastoral Value (Daget and Poissonet, 1971). Distance to the nearest water was calculated from the center of each grid cell. A 20 m buffer area was created around the center of each grid cell. Average slope of each 20 m radius buffer was calculated from a Digital Terrain Model (DTM, 5 m resolution) and GIS software (Quantum Gis 2.0.1, Quantum Gis Development Team 2012 and ArcMap 10, ESRI 2010). For the evaluation of spatial grazing patterns during the two MMS and TS sub-periods, only positions recorded (27259) when cattle are generally most active and grazing (0600 to 2200 hours) were considered (Probo, unpublished data). Spatial locations were recorded by 11 out of 14 GPS collars, because 3 of them failed. Relationships between environmental variables and spatial use of pastures when supplemented with MMS and TS were analyzed with a Generalized Linear Mixed Model (GLMMs, Zuur *et al.*, 2009). The number of positions recorded in each 20 m buffer were modeled using 9 environmental predictors. Predictors were standardized (Z-scores) to allow for analysis of effect size by scrutinizing model parameters (β coefficients). A correlation analysis was used to exclude predictors with high collinearity (r>|0.80|). Time spent by cows near MMS and TS was defined considering the number of GPS fixes within 10 m of the supplement (Bailey and Welling, 2007). To evaluate the time spent within MMS and TS placements and their corresponding control areas, the number of GPS positions to placement and control sites was counted. To compare the time spent near MMS and TS placements we used a GLMM. The model included cow and paddock as random effects and supplement type (MMS or TS period) as a fixed effect. To evaluate if MMS and TS areas were frequented more than related control areas, we used the same type of analysis and the model included cow and paddock as random effects and treatment (control or supplement placement area) as a fixed effect. Because the dependent variable in all models was based on count data, a poisson distribution was initially assumed, but the test of overdispersion prior to model fitting showed that a negative binomial distribution was more appropriate. Statistical models were fitted in R version 3.0.1. (R Development Core Team 2012) via the glmmAMDB R package using a negative binomial distribution.

III – Results

During the study, 10 of 11 collared cows (90%) visited MMS sites, while 11 of 11 cows visited TS sites. The GLMM β coefficients were used to assess the importance of environmental variables affecting spatial use of pasture by cattle under MMS and TS sub-period (Table 1).

Table 1. GLMM with environmental variables affecting spatial use of pasture by cattle under MMS and TS supplement period

	MMS grazing period			TS grazing period		
	β[1]	SE[2]	*P* value	β[1]	SE[2]	*P* value
Shrub cover	-0.10	0.076	n.s	-0.16	0.09	P<0.10
Thin leaf grass cover	0.03	0.082	n.s	0.05	0.09	n.s
Medium leaf grass cover	0.10	0.065	n.s	0.14	0.08	P<0.10
Broad leaf grass cover	0.06	0.055	n.s	0.27	0.07	P<0.001
Bare ground + Rocks	-0.35	0.103	P<0.001	-0.13	0.12	n.s
Forage pastoral value (PV)	0.11	0.048	P<0.05	0.17	0.05	P<0.01
Distance to TS or MMS points	-0.39	0.048	P<0.001	-0.20	0.06	P<0.001
Distance to water source	-0.18	0.051	P<0.001	-0.39	0.07	P<0.001
Slope	-0.40	0.042	P<0.001	-0.44	0.05	P<0.001

[1]Stand β indicates that each coefficient of the variables (β) has been standardized, that is, measured from their means in units of standard deviations.

[2]SE is of standardized coefficients (β).

[3]ns indicates not significant (P>0.05).

With both MMS and TS placements, cattle preferred gentler terrain ($P<0.001$), areas closer to streams ($P<0.001$), MMS or TS placements ($P<0.001$), and areas with higher forage pastoral value ($P<0.05$). During TS periods, cattle preferred ($P<0.01$) areas with more broad leaf grasses and with low shrub cover, whereas during MMS periods cattle avoided ($P<0.01$) areas with higher bare ground and rock cover. Thin leaf and medium leaf cover were not important predictors of cattle use in either the MMS or the TS periods. Time spent by each cow near (within 10 m) MMS sites (22.89 ± 0.48 min/week, mean ± SE) was greater ($P<0.001$) than that spent in paired control areas (4.2 ± 0.12 min/week). Cows also spent more time ($P<0.001$) within 10 m of TS sites (32.48 ± 0.61 min/week) than at paired control areas (19.11 ± 0.61 min/week). However, we did not detect any difference in the time cows spent within 10 m of MMS and TS placements.

IV – Discussion and conclusion

Similar to other research, cows in this study preferred gentler slopes over steeper slopes (Bailey *et al*., 1996). Cattle preferred to graze in areas closer to water, with higher forage quality and more palatable species in both sub-periods. Nevertheless, cows tended to select areas with steep terrain close to MMS placement to the same degree as gentle terrain. In TS periods cows selected sites with higher broad leaf cover, which are typically associated to flat areas. In TS periods, cows avoided sites with higher shrub cover suggesting a preference for open pastures, while in MMS periods there was no evidence of cows avoiding shrub encroached locations. The MMS blocks were placed within steep slopes, shrub encroached, and historically underused areas. In contrast, TS was supplied by the farmer on flat rocks within sites with gentle slopes several years before and during the study. Correspondingly, it is not surprising that cattle used TS sites because of the ease of access. In addition, cows likely remembered the TS placement sites since cattle have accurate spatial memory (Bailey *et al.,* 1996). With both MMS and TS placements, cows spent more time near supplement than in corresponding control sites. Although historical cattle use likely differed in TS and MMS treatment areas, no differences in the time spent within a 10 m buffer of placement sites were detected during the study. The similarity in the time spent in MMS and TS placement sites suggests that cows grazed steep and shrub dominated areas when MMS was placed nearby at the same intensity than flat and herbaceous areas with salt available. This result indicates that strategic placement of MMS may be effective in changing cattle grazing patterns. Although more research is needed, strategically placed MMS appear to be a promising tool to enhance grazing distribution within large pastures and increase cattle use of shrub dominated areas. Grazing in steep, shrub encroached areas by cattle facilitates trampling, defoliation, and fecal deposition which may help to restore vegetation structure and composition around supplement sites, reducing shrub abundance and increasing fertility of soil and forage quality and quantity in the years to come (Probo *et al*., 2013).

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Milk production without wet forage for Saint-Nectaire PDO cheese

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Abstract. In a few years the new specifications of the Saint-Nectaire PDO cheese will prohibit the use of wet forage like grass silage, forcing a number of producers to change their winter feeding. Therefore, INRA and Saint-Nectaire inter-profession association implemented an experiment to optimize milk production during a complete lactation with an 'all hay' winter diet, in comparison with a silage diet, associated with the maximum amount of concentrate permitted (30% over the year). Two groups of 15 autumn calving cows were compared for 305 days of lactation: a Silage group fed during winter with a '50% grass silage-hay-concentrate' diet; a Hay group fed with a 'hay-concentrate' diet. At pasture, the 30 cows were kept together on a rotational grazing system. During the first 14 weeks of lactation, Silage cows ingested more forage than Hay cows (12.3 *vs.* 10.9 kg/d on total winter period). The lowest milk production of Hay cows (-343 on 7740 kg/y, *ns*) took place essentially during winter. The difference is less pronounced for multiparous than for primiparous (-113 *vs.* -801 kg/y), penalized by the lower energy density of the hay diet, their limited intake capacity and their growth needs. Finally, the experiment was enriched by simulations with the Dynamilk model, which allowed extrapolating the results to other harvesting or grazing conditions.

Keywords. Milk production – PDO cheese – Mountain areas – Grass-based system – Hay.

Production laitière permise par le cahier des charges sans fourrage humide de l'AOP Saint-Nectaire

Résumé. *Le futur cahier des charges du fromage AOP Saint-Nectaire, sans fourrage humide, va obliger de nombreux producteurs à modifier leur alimentation hivernale. L'Inra et l'interprofession du Saint-Nectaire ont donc mis en place une expérimentation visant à optimiser la production laitière sur une lactation complète (305 jours) d'animaux recevant une alimentation hivernale "tout foin", associée à la quantité maximale de concentré autorisé (30 % sur un an). Deux lots de 15 vaches vêlant en automne ont été comparés : un lot témoin Ensilage recevant un régime hivernal "50% ensilage d'herbe-foin-concentré" ; un lot Foin recevant un régime "foin-concentré". L'été, les 30 vaches ont été conduites ensemble en pâturage tournant. Pendant les 14 premières semaines de lactation, les vaches Ensilage ont ingéré plus de fourrage que les vaches Foin (12,3 vs 10,9 kg/j sur l'ensemble de la période hivernale). La plus faible production laitière des vaches Foin (-343 kg/an, ns) a eu lieu essentiellement l'hiver. La différence est moins marquée chez les multipares que chez les primipares (-113 vs -801 kg/an), pénalisées par la densité énergétique plus faible de la ration foin, par leur capacité d'ingestion limitée et par leur besoin de croissance. Enfin, l'expérimentation a été enrichie par des simulations effectuées avec le logiciel Dynamilk, qui ont permis l'extrapolation des résultats à d'autres conditions de récolte ou de pâturage.*

Mots-clés. *Production laitière – Fromage AOP – Zone de montagne – Système herbager – Foin.*

I – Introduction

Since 2007, the specifications for the production of Saint-Nectaire PDO cheese indicate that forage preserved by wet process should not exceed 50% of total winter forages and limit concentrate to 30% of the total annual diet of dairy cows. The use of this type of forage will be completely forbidden in 2020, forcing number of producers to change their winter feeding.

Therefore, in cooperation with Inra, the Saint-Nectaire inter-profession wished to implement an experiment as a «local demonstration» at the Monts d'Auvergne Experimental Unit, with 3 objectives: (i) to optimize, on a complete lactation, milk production (in quantity and quality) permitted by a winter diet "all hay", associated with the maximum annual intake of concentrate permitted by the PDO specifications; (ii) to compare this production (in quantity, quality and distribution over the year) with that permitted by a winter diet "50% grass silage", associated with an equivalent amount of concentrate (30%); and (iii) to extrapolate the responses obtained during the experiment with other harvesting or grazing conditions, by simulations performed with the Dynamilk model (Jacquot *et al.*, 2012).

II – Materials and methods

Two identical groups of 15 Holstein cows were constituted prior to calving on expected calving date (05/12), rank of lactation (33% of primiparous), live weight (654 kg) and previous dairy production (7 836 kg/y) or milk index for primiparous (+669): one called 'Silage' group and the other 'Hay' group. The experiment was divided into 3 periods: a 4-week period before calving (from wk-4 to wk-1) when the animals began to receive the winter diet corresponding to their group; a winter period (from the 1st day of lactation until pasture) when the animals received their corresponding winter diet; a summer period (from the 1st day at pasture to the 305th day of lactation) when all the animals grazed together but received individually their concentrate.

The winter forages came from 5 plots of semi-natural grassland, divided in two equivalent parts, one for Silage group harvests and the other for Hay group harvests. The characteristics of the 4 types of forage harvested on these plots, the two winter diets and the two concentrates are summarized in Table 1. During the winter period, each cow received ad libitum a mixed diet corresponding to its group and, during the 3 periods, a fixed amount of concentrate corresponding to its group, rank and stage of lactation. Due to a 4-week delay between silage and hay harvests, the energy value of the latter was 18.6% lower. Nevertheless with the same duration of regrowth, the two "2nd cut" hays had close compositions. Thus, compared to the Silage diet, the Hay diet differed only by -9.1% in energy value and +11.7% in crude fiber during winter.

Table 1. Composition and nutritive values of the feeding components

	Crude Protein *(%)*	Crude Fiber *(%)*	Ashes *(%)*	Feed Unit	Fill Unit
A = Grass silage *(1st cut on 29 May, 35% DM)*	13.2	26.1	11.7	0.86	1.08
B = Hay *(2nd cut, 10.3 wk. after grass silage cut)*	13.9	25.1	12.3	0.76	1.03
C = Hay *(1st cut on 23 June)*	8.8	31.8	9.1	0.70	1.10
D = Hay *(2nd cut, 11.0 wk. after 1st cut hay)*	13.2	25.9	12.4	0.80	1.02
Silage diet = 50% **A** + 35% **B** + 15% **C** *(on DM basis)*	12.8	26.6	11.5	0.80	1.06
Hay diet = 65% **C** + 35% **D** *(on DM basis)*	10.3	29.7	10.3	0.73	1.07
Winter concentrate *(cereal and by-products pellets)*	15.0	7.7	5.8	1.00	
Summer concentrate *(barley pellets)*	11.6	5.2	2.6	1.09	

The strategy for concentrate distribution was established before the beginning of the experiment. It was adjusted at mid-winter and at turn-out to pasture, to fit better the target of 30% of concentrate over the year in each group, with 34.5% for the primiparous and 27.8% for the multiparous, due to their respective needs. The maximum amount of concentrate was limited to 10 and 12 kg/d respectively, with 3 distributions by day in order to avoid acidosis troubles.

All experimental measurements were individual: milk production (at each milking), milk composition (fat content, protein content and somatic cell count, on 4 consecutive milkings each week), intake of forage and concentrate (quantities offered and consumed, on 3 consecutive days each week), live weight (every 2 weeks), body condition score (on a 0 to 5 scale, once a month) and health problems. The statistical analysis was performed with a mixed model including the group, the lactation rank, the calving date and, when it exists, a representative covariate (SAS, 2008).

The characteristics of the two "systems" and the results of the experiment were used to parameterize and calibrate the Dynamilk model. This allowed to simulate milk production of the Hay group, during winter with 3 qualities of hay and during summer with 3 weather conditions.

III – Results and discussion

We observed no difference between groups on health status, but we had to remove 2 cows from the statistical analysis: one Hay primiparous (actinomycosis of the digestive tract) and one Silage multiparous (accident with the automatic cleaning system of the cowshed).

Intakes of winter forages and concentrates are presented in Fig. 1. Up to the 14th week of lactation, Silage cows ingested more forage than Hay cows. Beyond, values became statistically identical and it should be the same at pasture, with two groups of same weight and same milk production (see below), grazing together on same plots. During winter, concentrate intakes are identical between the two groups (1 485 *vs.* 1 488 kg DM/cow, *ns*), due to the protocol limitation. During summer, in order to reach the same annual percentage of concentrate for the two groups, a higher amount of concentrate was distributed to the Silage group (423 *vs.* 368 kg DM/cow, *P*<0.001) because it had ingested previously more forage than the Hay one (1 807 *vs.* 1 626 kg DM/cow, *P*<0.001). This difference is due to the bulky and coarser forage that quickly saturates the capacity of ingestion of the Hay cows, particularly for two-year-old primiparous (-230 kg DM *vs.* -157 kg DM for multiparous). Furthermore, we estimated the percentage of concentrate over the year to 28.4 and 28.7% for Silage and Hay groups, close to the maximum of 30% allowed, with the assumption of 14 kg/d DM of grass ingested at pasture (and +50 kg of concentrate for Silage cows over the season).

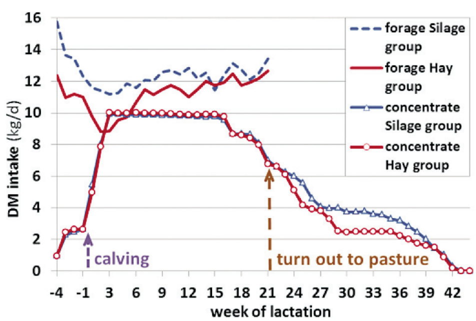

Fig. 1. **Controlled intakes of Silage group and Hay group over the complete lactation.**

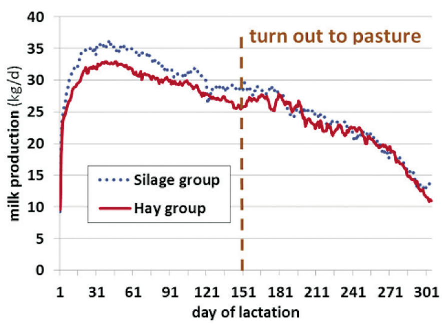

Fig. 2. **Individual milk production of Hay and Silage cows during 305 days.**

We can see in Fig. 2 and Table 2 that the higher annual milk production of Silage cows (+343 kg, *ns*) took place essentially during the winter period (+383 kg, *P*<0.05), when animals received identical quantities of concentrate. This moderate difference is the result of an addition of a small difference of milk production between multiparous of the 2 groups (+113 kg, *ns*) and an important one between primiparous (+801 kg, P<0.001). It seems therefore entirely due to the higher ingestion of best quality forages as seen before, in particular for two-year-old primiparous. During the experiment, milk composition, LW and BCS were not significantly different between the two groups (Table 3), except for BCS at the end of winter that tended to be higher for Silage cows (+0.31, P<*0.10*).

Table 2. Individual milk productions of Silage and Hay cows *(in kg)*

	Silage	Hay	*P*
Winter milk	4 713	4 330	*
Summer milk	3 369	3 410	*ns*
305 days milk	8 083	7 740	*ns*
Primiparous milk	7 532	6 731	***
Multiparous milk	8 358	8 245	*ns*

*: P<0.05, ***: P<0.001, ns: non-significant.

Table 3. Milk composition, LW and BCS of Silage and Hay cows

	Silage	Hay	*P*
Milk fat content *(g/kg)*	36.9	37.3	*ns*
Milk protein content *(g/kg)*	29.1	29.4	*ns*
LW at 44 wk. *(kg)*	624	612	*ns*
End of winter BCS *(0-5)*	1.68	1.37	+
BCS at 44 wk. *(0-5)*	1.70	1.50	*ns*

+: P<0.10, ns: non-significant.

One of the limitations of the results obtained during this experiment is that they closely depend on weather conditions during harvesting and grazing periods. To go further, we simulated the winter milk production of the Hay group with 3 energy values of hay, corresponding to a more or less favorable weather at harvest: one harvested at heading stage (0.73 UFL/kg DM, usual in the Saint-Nectaire area), one harvested 2 weeks before (0.82 UFL) and one harvested 2 weeks later (0.63 UFL). Compared to the intermediate situation, the differences calculated by Dynamilk are respectively +323 and -292 kg/cow of winter milk production (Fig. 3). We also simulated the summer milk production with "typical" weather conditions (2010), with a hot spring (2011) and with a summer drought (2005). Surprisingly, even if the distribution is different, the summer milk productions are not really different (+9 and -19 kg/cow for 2011 and 2005, compared to 2010).

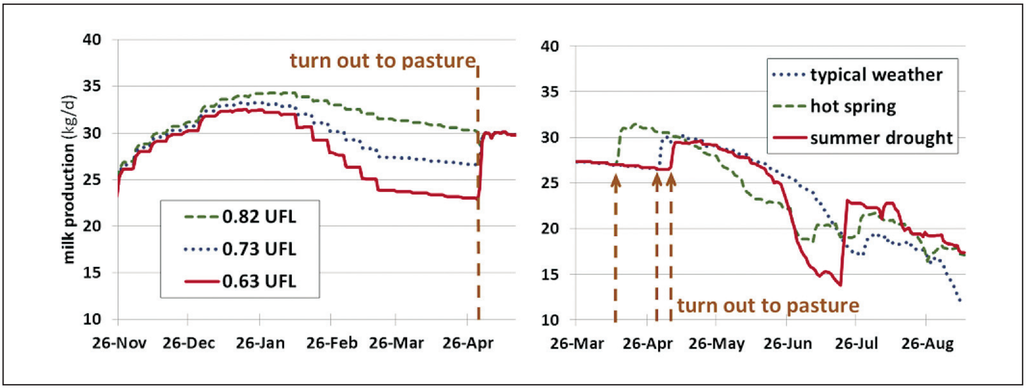

Fig. 3. Simulation by Dynamilk of the Hay group milk production *a)* with 3 energy values of hay *b)* with 3 contrasted weather conditions at pasture.

IV – Conclusions

The weak difference in milk production (-343 kg/cow with -50 kg of concentrate) observed in the experiment with the new Saint-Nectaire specifications reflects mainly the important percentage of two-year-old primiparous. Concerning feed, the role of silage is not as important as expected because its proportion represents only 16% of the annual diet, replaced by hay. For this reason, as shown by the simulations, Saint-Nectaire producers should especially focus on the best date to harvest their hay (or invest in a hay drier because of the weather) and on the management of their pastures (e.g. with an earlier turning-out), which represent 40% of the annual intake.

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Genetic polymorphism study of the Tunisian Barbarine breed

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Abstract. Tunisia is well endowed with a wealth of native sheep breeds. The Barbarine, also called "Nejdi"or "Arbi", remains the main Tunisian sheep breed and it is raised in all regions with an abundance in the central region (43.3%). Although this breed has benefited from a programme of monitoring of performances for quite a long time, its productivity remains low. Thus its genetic management requires more attention. In this context the objectives of this study were to determine the genetic polymorphism in the Barbarine breed of the central region of Tunisia and to calculate genetic distances between genotyped animals. The genomic DNA of 24 purebreds Barbarine individual was extracted. These animals belong to the Tunisian Public Lands's Office (OTD) herds which are located in the governorates of Kairouan and Sidi Bouzid (centre of Tunisia). These samples were amplified by the PCR using four microsatellite molecular markers. Genotyping analysis was performed by Bio-Capt, NTSYSpc and GENAlex6.2 softwares. The value of the PIC was 0.92, showing the effectiveness of the use of the microsatellite markers in the diversity analysis. The genetic diversity's study has detected an average number of 11 alleles per locus. The allele frequencies were close and all loci were in disequilibrium compared to the act of Hardy-Weinberg equilibrium. The values of the observed heterozygosis (Ho) and the expected heterozygosis (He) were 0.23 and 0.88 respectively. Based on multi loci, the unbiased heterozygosis was 0.86 and was greater than the observed heterozygosis (0.12). The fixation index found, which reflects the deviation of the observed heterozygosity and the expected one, was positive in the range of 0.85 explaining an heterozygosis deficiency in the studied population. This means that the structure of these two farms showed an increased homogeneity between herds and management of genealogies in the mating strategy seems to be missing in the Tunisian central region, which could lead to a loss of genes.

Keywords. Sheep – Diversity– Genotyping – Polymorphism.

Etude du polymorphisme génétique au sein de la race Barbarine de Tunisie

Résumé. *La race Barbarine, appelée « Nejdi » ou « Arabi », demeure la principale race ovine tunisienne et colonise toutes les régions avec une abondance dans la région centrale (43.3%). Bien que cette race ait bénéficié d'un programme de contrôle de performances, sa productivité reste faible et sa gestion génétique nécessite encore plus d'intérêt. Les objectifs de cette étude sont de déterminer le polymorphisme génétique au sein de la race Barbarine de la région centrale de la Tunisie et de calculer les distances génétiques entre les animaux génotypés. Les ADN génomiques de 24 animaux de race Barbarine, appartenant aux troupeaux de l'OTD localisés dans les gouvernorats de Kairouan et de Sidi Bouzid, sont extraits. Ces échantillons sont amplifiés par 4 marqueurs moléculaires de type microsatellites. Le génotypage est réalisé par deux logiciels statistiques (Bio-Capt et NTSYSpc) pour la construction de dendrogramme et de la matrice de similarité entre les animaux. L'étude de la diversité génétique est faite par le logiciel GENAlex6.2. L'étude de la diversité génétique a permis de détecter un nombre moyen d'allèles par locus de 11. Les valeurs de l'hétérozygotie observée (Ho) et de l'hétérozygotie attendue (He) sont respectivement de 0,23 et 0,88. Sur la base de multi loci, l'hétérozygotie non biaisée est de 0,86 et dépasse la valeur de l'hétérozygotie observée (0,12). L'indice de fixation (F), qui traduit l'écart entre les individus trouvé à l'état hétérozygotie et l'état d'hétérozygotie attendu, est positif de l'ordre de 0,85. Ces résultats expliquent un déficit en hétérozygotie dans la population étudiée. La valeur moyenne du PIC est de 0,92 montrant l'efficacité de l'utilisation des marqueurs microsatellites dans l'analyse de la diversité. Le coefficient de similarité est très important de 0,8 soit une distance génétique très faible de 0,2. La structuration de ces deux fermes révèle une homogénéité entre les troupeaux et la gestion de la généalogie dans les stratégies d'accouplement semble être manquante dans la région centrale de la Tunisie, ce qui pourrait entrainer une perte de gènes.*

Mots-clés. *Ovin – Diversité – Génotypage – Polymorphysme.*

I – Introduction

Biodiversity defines life on earth and provides human beings with the most important services, primarily by ensuring the sustainability of vegetable production systems, and therefore by maintaining populations in their area of origin (Djemali *et al.,* 1995). Livestock contributes 30% to 40% to overall agricultural production worldwide. Among the most important genetic livestock resources, the sheep population that counts over 1064 million head, of which 18% are localized in the Mediterranean region (FAO, 2004). Tunisia is a rich country in animal resources, especially its large sheep industry, which represents an important diversity that is worth preserving and managing rationally. Among the four major sheep breeds identified in Tunisia, Barbarine remains the main breed perfectly adapted to the harsh conditions and is able to take advantage of poor land and to withstand summer heat; thereby it is raised in very different natural environments that reflect the country climatic diversity. Nevertheless Barbarine is more abundant in the Tunisian semi-arid zone, that corresponds to the central area, where it acounts for 43.3%, compared to 38% in the north and only 18.7% in the south (OEP, 2010). Unfortunately Tunisian Barbarine breed is suffering nowadays and undergoing significant diversity threat (Ben Gara, 2000; Bedhiaf-Romdhani, 2006). In this context, this work was conducted to calculate genetic distances between genotyped animals and study the genetic polymorphism in the Babarine breed of the Tunisian central region.

II – Materials and methods

Twenty-four blood samples were collected in EDTA tubes from different sheep herds that belong to the Office of State Lands (OTD) farms located in the governorates of Kairouan and Sidi Bouzid, in the Tunisian Semi-Arid Central West. Each sample contained 5 ml of blood stored at -20°C. Genomic DNA was extracted according to the standard saline protocol (Sambrook *et al.,* 1989), and was stored at -20°C in TE solution (Tris-EDTA). The DNA purity was appreciated by using the spectrophotometer. DNA quality was further verified by electrophoresis on agarose gel (0.8%) that contains 1µg/ml of Ethidium Bromide (Sambrook *et al.,* 1989), after that diluted to 50ng/µl in 100µl.

Four molecular markers *Ovis Aries* microsatellite were used to study the breed genetic diversity namely: BM1824, DYMS1, HUJ616 and ILSTS11. For each primer, PCR reaction was optimized using different concentration of MgCl2 (1.5, 2, 2.5 and 3 mM) at a temperature gradient ranged from 50 to 65°C. PCR amplification has been developed in a thermocycler (C1000, BioRad). The PCR products were migrated by electrophoresis on agarose gel (2%) for 60 mn under 90 volts with a 100bp ladder (Promega, USA), then the electrophoretic profile were reveled under UV by using a transilluminator. Estimation of genetic diversity was carried out through two statistical softwares GENALEX6.2 and NTSYS 2.0e. Six parameters were calculated to describe the population genetic variability namely Average number of allele per locus, Allele frequencies, Rate of the observed heterozygosity (Ho), Rate of the expected heterozygosity (He), Rate of the unbiased heterozygosity (HNB), Fixed index (F) and Level of polymorphism (PIC).

III – Results and discussion

DNA concentrations varied between 42.11 g/ml and 1020 g/ml. A diluted DNA was fixed to 50ng/µl for all samples.

The optimization step has allowed to determine the PCR parameters for each primer while viewing the electrophoretic profiles of the amplified products (Table 1).

After optimization, genomic DNA was amplified using the four primers according to their appropriate parameters. The genotyped product was viewed under UV (Figs 1, 2, 3 and 4).

Table 1. The PCR parameter for the primers

Locus	Range	[$MgCl_2$]mM	Temperature°C
BM1824	171-194	2,5	59.5
DYMS1	152-221	2	53
HUJ616	114-178	2,5	59.5
ILSTS11	256-300	2,5	62.5

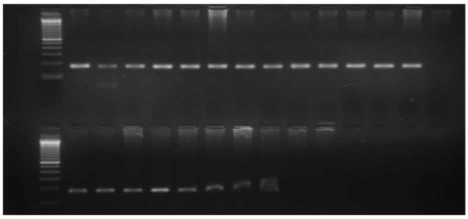

Fig. 1. Amplified DNA using BM1824.

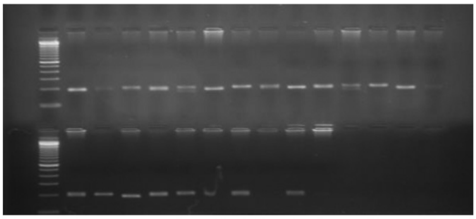

Fig. 2. Amplified DNA using DYMS1.

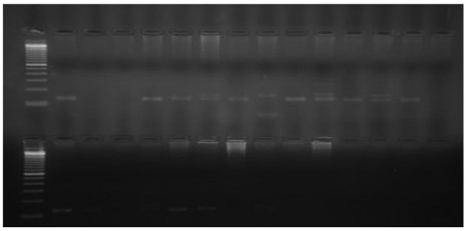

Fig. 3. Amplified DNA using HUJ616.

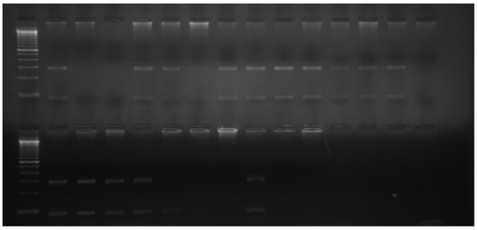

Fig. 4. Amplified DNA using ILSTS11.

Profiles were processed by BioCapt software (BioCapt, version 12.3.00, vilbert lourmat) in order to calculate the generated bands size and to construct a binary matrix. NTSYS2.0e software was used to transform the binary matrix into a similarity matrix and to schematise also the sampled individual dendrogram. The similarity matrix analysis has demonstrated high coefficients that varied between 0.78 and 0.97. The dendrogram showed two distinct groups with 0.2 genetic distances. The first group included 22 animals, whose similarity coefficients were very close and ranged between 0.81 and 0.87 suggesting that only 8% of differences were observed between the individuals. This explains a strong genetic relationship between animals although samples were taken from different farms located on two remote governorates. The second group was constructed by only one individual.

For all the studied loci, the genetic diversity analysis has revealed an average observed allele number (Ho) of about 10, 12, 14 and 7 for the locus BM1824, DYMS1, HUJ616 and ILSTS11 respectively; that exceeded the average expected allele number in the balanced population (He), in the order of 7.11, 9.13, 10.70 and 4.92 respectively. Furthermore, the fixed indexes were very high and varied between 0.77, 0.89, 0.74 and 1 for BM1824, DYMS1, HUJ616 and ILSTS11 respectively with an average of 0.85. These results indicate that the studied population is deviated from the panmictic law, whence it is in disequilibrium compared to the act of Hardy-Weinberg equilibrium.

The allele number generated per locus was about 21, 22, 17 and 16 for BM1824, DYMS1, HUJ616 and ILSTS11 respectively. Allele sizes ranged between 173 pb and 219 pb, 186 pb and 239 pb, 118 pb and 165 pb and 268 pb and 322 pb. Allele frequencies varied from 0.04 to 0.26, from 0.02 to 0.15, from 0.02 to 0.17 and from 0.06 to 0.25 respectively. The allele frequencies were very close and mostly similar for all the studied loci. Besides, the average observed heterozygosity (Ho) were remarkably exceeded by the average expected heterozygosity (He) explaining a deficit of heterozygosity and reflecting a high inbreeding rate (Table 2). For ILSTS11 locus zero was obtained meaning that all individuals are homozygous for this marker.

Table 2. Heterozygosity rates

Locus	(Ho)	(He)	Unbiased H
BBM1824	0.19	0.85	0.88
DYMS1	0.09	0.89	0.91
HUJ616	0.23	0.90	0.93
ILSTS11	0	0.79	0.82
Means	0.12	0.88	0.86
Standard deviation	0.05	0.02	0.02

The average PIC (Polymorphic Information Content) was 0.92 proving that microsatellites are effective to study the genetic diversity. The most polymorphic microsatellite were ILSTS11 (PIC = 0.97), followed by DYMS1 (PIC = 0.95), HUJ616 (PIC = 0.94) and finally BM1824 (PIC = 0.85).

IV – Conclusions

The results of this study provide a molecular characterization of a Barbarine breed sample from the Central Region of Tunisia and gave a rough idea about the breed genetic diversity in this region. Considering the abundance of this breed in the central area, the ultimate similarity found reflects that herds belonging to the OTD farms seem to be threatened by a lack of genealogies management and an increased rate of inbreeding that is ultimately due to mating between ascendants and descendants. Such a process may alter gene frequencies that may lead to genetic variability loss in governmental stations over the generations and even a decreasing in animal performance and hence the biodiversity of this breed across the country will be questioned. Thus, for sustainable management of this breed, it is recommended to perform selection and to use the most genetically distant animals in mating strategies in order to reduce inbreeding. However, because of the sample size which is relatively small and not representative enough, it may be assumed that the results found may be explained by the fact that samples are from only two governmental stations. Moreover, this study opens a door for a biodiversity study of the breed across the whole country with animals from different geographical areas.

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Recent results supporting the Montasio PDO cheeses labelled "Mountain product" and "Only Italian Simmental breed"

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Abstract. Montasio is one of the most important PDO cheeses in North-East Italy. Despite its mountain origin, it is mainly produced in lowlands. Recently, in order to differentiate mountain products and to link them to the breed more present in the territory, the PDO Montasio specification allows to labell products as 'Mountain Product' and 'Only Italian Simmental breed'. A project is in progress with the aim of assessing the economic and technical frame of a possible production system and studying the range of variability of the product qualitative characteristics. In the first phase of the project, one cheese factory with 20 associated dairy farms and one alpine farm, for a total of 350 Italian Simmental cows, were involved. A survey at farm level provided data useful to support a marketing strategy. A first experimental trial focused on the quality of cheese produced from cows grazing on alpine pasture or kept indoors. A more recent study aimed to define the quality of the Montasio cheese in relation to pasture type and level of supplementation. The results of the project within the framework of the increase of product value will be discussed.

Keywords. Montasio PDO cheese – Mountain product – Italian Simmental cows – Alpine pasture.

Résultats récents supportant les fromages AOP Montasio étiquetés «Produit de montagne» et «Seulement de race Simmental italienne »

Résumé. *Le fromage Montasio est l'un des plus importants fromages AOP dans le Nord-Est de l'Italie. Malgré son origine de montagne, il est principalement produit en plaine. Récemment, afin de différencier les produits de montagne et de les associer à la race la plus présente sur le territoire, la spécification AOP Montasio permet d'étiqueter le produit comme «Produit de montagne» et «Seulement de race Simmental italienne». Un projet est en cours dans le but d'évaluer le cadre économique et technique d'un système de production possible et d'étudier l'étendue de la variabilité des caractéristiques qualitatives des produits. Dans la première phase du projet, une usine de fromage avec 20 fermes laitières associées et une ferme alpine, pour un total de 350 vaches Simmental italiennes, ont été impliquées. Une enquête au niveau des fermes a fourni des données utiles pour soutenir une stratégie de marketing. Un premier essai expérimental a été axé sur la qualité du fromage produit à partir de vaches qui paissaient sur des pâturages alpins ou étaient gardées à l'intérieur. Une étude plus récente visait à définir la qualité du fromage Montasio en fonction du type de pâturage et le niveau de supplémentation. Les résultats du projet dans le cadre de l'augmentation de la valeur du produit seront discutés.*

Mots-clés. *Fromage Montasio AOP – Produit de montagne – Vaches Simmental italiennes – Alpage.*

I – Introduction

The added value of mountain cheese is linked to the ability to evoke the production area and its environmental, historical and cultural values, as well as objective nutritional and sensorial characteristics (Piasentier and Martin, 2005; Bovolenta *et al.,* 2011).

The livestock sector in the mountain area of Friuli Venezia Giulia Region (FVG) follows the general trends of the Alps (ISTAT, 2013). A gradual reduction of pastures and meadows from over

30,000 ha in 1990 to about 12,000 in 2010 (-60%) was observed. This is due to a drastic reduction of the total number of farms, from nearly 1600 in 1990 to 406 in 2010 (-75%), and in particular to the reduction of the farms that use the summer pastures. Cattle breeds reared in the mountain area of FVG are mainly Simmental, followed by Brown and Holstein.

Montasio cheese is a semi-hard and semi-cooked cheese made from raw or thermized cow milk and is the unique Protected Designation of Origin (PDO) cheese in the Region. Although Montasio belongs to the group of alpine cheeses and takes its name from a mountain plateau, it is produced mainly in lowlands. Recently, in order to improve the value of the mountain cheese and to link it to the breed more present in the area, two additional labels: 'Mountain Product' (PDM – *Prodotto della montagna*) and 'Only Italian Simmental breed' (PR – *Solo di Pezzata Rossa Italiana*) were proposed.

The PDM Register was founded by a national law (L. 289/02, Art. 85, Mipaf 30/12/03) to further characterize the PDO products, if the entire production chain, from milk production to cheese ripening, takes place in the mountain area. Since 2008, the National Association of Cattle Breeders of Italian Simmental breed (ANAPRI) gives the label PR for dairy or meat products from animals recorded in the Herd Book. Regarding dairy products, the product specification provides that they must be obtained exclusively from raw milk with the only addition of rennet and salt. Recently, on the basis of a legal agreement, the Consortium of Montasio cheese has recognized this monobreed label and allows to pair it with own. The production of monobreed cheese will therefore be subjected to more restrictive constraints of the two product specifications.

A project is in progress with the aim of assessing the economic and technical frame of a possible production chain and studying the range of variability of the cheese characteristics. This paper aims to present the first results obtained.

II – Production chain of Montasio PDO-PDM-PR

For this purpose 20 livestock farms, one cheese factory located in the bottom valley (*Caseificio di Ugovizza*), and one alpine farm provided with dairy factory (*Malga Montasio*) were chosen in the mountain area of FVG.

A survey on livestock farms, concerning buildings, utilized agricultural area (UAA), milk production, livestock management, forage self-sufficiency, animal welfare, and other useful information was performed. Vertical transhumance of cattle is adopted: during winter the animals are kept indoors in tie-stall barns, while, during summer, cows graze on mountain pastures for a total of about 100 days. The UAA was 35.6 ha on average, used mainly for pastures and meadows. The forage self-sufficiency, related to the winter period, ranged between 66% (farms with over than 20 cows) to 100% (farms with less than 10 cows). The average number of dairy cows per farm was 15, 89% of which belongs to the Simmental breed. The cheese factory (*Caseificio di Ugovizza*) annually processed 800 tons of milk (fat: 3.9%; protein: 3.2%).

The Welfare Quality Consortium (Welfare Quality, 2009) and the ANI-35L (Bartussek, 1999) methods were considered for animal welfare assessment. With the first method, 30% of the farms were classified as “enhanced” and the other 70% as “acceptable”. This is due to the housing system (tie-stall), which is particularly penalized by the method. With the second method the overall value (22.2 points) corresponds to an evaluation of “average suitable”.

Malga Montasio includes nearly 500 ha of pastures, facilities for animal housing, milk processing and cheese ripening. About 120 dairy cows (mainly Simmental) are kept on pasture day and night. On the basis of preliminary studies, pasture vegetation can be divided into three principal areas. The lower part of the pasture, flat or slightly inclined, is characterized by several species with a good forage value –*Phleum alpinum*, *Festuca pratensis* and *Poa alpina*– and other species typical of a medium fertile pasture, such as several species of clover (*Trifolium badium*, *T. repens*, *T. pratense*), *Lotus corniculatus*, *Alchemilla vulgaris*, *Crepis aurea* and *Leontodon hispidus*. The upper areas of the pasture are characterized by species such as *Sesleria coerulea*, *Koeleria pyramidata* and *Nardus stricta*. In many areas close to the stables, in the presence of a strong eutrophication of the soil, there are nitrophilous phytocoenoses characterized by *Deschampsia caespitosa*, *Veratrum lobelianum*, and *Rumex alpinus*.

III – Experimental results

The first trial was aimed to study the qualitative characteristics of Montasio PDO cheese made from milk of Italian Simmental cows. The main results, previously published (Romanzin *et al.,* 2013) are reported here. Cheeses obtained from two cow breeding systems (grazing on high altitude pasture or kept indoors with a hay-based diet), in two periods (early-July and late-August) and ripened for two times (two or six months) were considered (Table 1). Pasture-derived cheese presented higher fat and lower protein content, and was yellower (b* index) than hay-derived ones. Textural parameters (hardness, gumminess, chewiness) were highest in pasture-derived cheese, which presented also a more favorable fatty acid profile. Indeed it showed lower saturated fatty acids, higher n-3 polyunsaturated fatty acids and CLA content. Conversely, only limited effects of period and ripening time were observed on cheeses.

Table 1. Chemical composition, ripening index, colorimetric parameters and fatty acid content of cheeses (n = 48) (Romanzin *et al.,* 2013)

	Rearing system		Period		Ripening time		SEM
	Pasture	Indoor	July	August	60d	180d	
DM† (%)	69.7^{A}	67.8^{B}	68.3^{b}	69.2^{a}	66.6^{B}	70.8^{A}	0.16
Fat (%DM)	54.2^{A}	50.9^{B}	52.3	52.7	52.6	52.5	0.21
Protein (%DM)	38.6^{B}	42.3^{A}	40.9	40.0	40.7	40.2	0.25
Ripening index†	13.5	14.8	14.3	14.1	12.1^{B}	16.2^{A}	0.31
L*	75.6^{B}	77.8^{A}	76.9	76.6	77.4^{a}	76.1^{b}	0.27
a*	2.2^{A}	0.6^{B}	1.2^{B}	1.5^{A}	1.4	1.4	0.04
b*	25.1^{A}	16.1^{B}	20.1^{b}	21.1^{a}	19.7^{B}	21.5^{A}	0.16
C18:3 n-3	1.21^{A}	0.41^{B}	0.78	0.84	0.80	0.82	0.017
cis9trans11-CLA†	1.53^{A}	0.46^{B}	0.96^{b}	1.03^{a}	0.94^{B}	1.06^{A}	0.013
SFA†	64.61^{B}	71.72^{A}	68.55^{a}	67.78^{b}	67.45^{B}	68.88^{A}	0.120
MUFA†	31.71^{A}	27.13^{B}	29.13^{b}	29.70^{a}	30.22^{A}	28.62^{B}	0.100
PUFA†	3.68^{A}	1.16^{B}	2.32^{b}	2.52^{a}	2.33^{B}	2.51^{A}	0.032

Significance: $^{a,\,b}$: $P < 0.05$, $^{A,\,B}$: $P < 0.01$; † DM: dry matter, Ripening index: WSN/TN (x100), WSN: water soluble nitrogen TN: total nitrogen, CLA: conjugated linoleic acids, SFA: saturated fatty acids, MUFA: monounsaturated fatty acids, PUFA: polyunsaturated fatty acids.

With the aim to understand if consumers were able to distinguish the cheeses, a sensory test was performed. Although consumers perceived the cheeses different in terms of colour and holes, they expressed a similar overall liking, 27 ± 1.1 (mean ± SE) which, in a LAM (Labelled Affective Magnitude; from -100 to +100) scale, corresponds to a judgment of moderately like (Cardello and Schutz, 2004).

Afterwards, in order to assess whether the information about breed and rearing system may modify the consumer liking, two kind of cheeses, monobreed and monobreed from pasture, were tasted (Romanzin *et al.* 2012). Consumers evaluated the cheeses in two sessions. In the first one they assessed the cheeses in blind condition (perceived liking). Then they were asked to read information about the breed and rearing system and to give their liking expectation (expected liking). In the second session, the same consumers tasted cheeses with the linked information (actual liking). Mean scores of perceived liking were not statistically different. Expected liking and actual liking scores were higher for pasture than only monobreed cheese. For both cheeses the expected liking was higher than the perceived one. Consumers have assimilated their liking for both cheeses in the direction of expectations, completely for monobreed and partially (87%) for monobreed from pasture cheese.

Finally, a third trial was aimed to characterize Montasio cheese produced from milk of cows grazing on two alpine pastures with different botanical composition and receiving different levels of supplementation (1.5 *vs* 3.0 kg/day/head). Pasture composition and supplement level had a limited effect on physical and chemical characteristics of cheeses, while an effect of pasture on volatile profile, with particular regard to ketones, phenolic and monoterpenes compounds, was found. A total of 61 volatile compounds were identified.

IV – Conclusions

The project evaluated a possible production chain of the Montasio DOP-PDM-PR cheese. The producers identified are firmly rooted in the territory and able to guarantee an adequate production, ensuring the necessary cooperation. In the future it is hoped to involve other local producers. The product is generally liked by potential consumers. However, this liking can be further enhanced if properly linked to correct information about the product origin that can highlight its peculiarities such as the strong link with the territory of production (use of local fodder, use of local cattle breed, maintenance of traditions and alpine landscape).

It will be necessary in the future to assess the variability factors of product quality in relation to technological and microbiological aspects. Last but not least, even with the help of data concerning the environmental and social sustainability of farms, it will be useful to set an appropriate marketing campaign to support the product in order to ensure economic sustainability for producers.

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Use of wrapped hay silage to fatten Charolais bulls in grassland territories

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Abstract. Four homogeneous groups of young Charolais bulls have been fattened between 360 and 700 kg with contrasted diets based either on wrapped hay of semi mountain permanent grassland (GW) or corn silage (CS) distributed at two levels of intake (H or L).To be slaughtered at a common carcass weight of 420 kg, the GWH animals needed (in average) 33 more days of fattening than CSH and GWL group 38 days more than CSL group. The average daily gain reached 1660 g (CSH), 1570 g (GWH), 1600 g (CSL) and 1400 g (GWL), respectively. Whatever the intake level, the intake of GW was lower (*vs* CS) at the beginning of the test (-1kg DM/d *vs* CS) and higher at the end (+1.5 kg DM/d). Adipose tissues of the carcass (67.4 kg) and the 5th quarter (23.8 kg) of CSH were higher than the depots of other groups (58 and 17 kg, respectively). Differences in growth rate had more impact on the dynamics of depots for CS than for GW. The use of haylage (DM=60%) properly complemented allows fattening bulls. But at iso-energy intake, this diet seems to be less efficient than a diet of corn silage. Its use must be reasoned considering all other fattening conditions.

Keywords. Breeding – Young bull – Fattening – Wrapped hay silage – Charolais.

Utilisation de l'enrubannage de prairie naturelle pour l'engraissement de taurillons Charolais

Résumé. *Quatre lots homogènes de taurillons Charolais ont été engraissés entre 360 et 700 kg avec des rations contrastées à base d'enrubannage de prairie permanente de moyenne montagne (GW) ou d'ensilage de maïs (CS), distribuées chacune à deux niveaux d'apports (H ou L). Pour être abattus à un poids de carcasse commun de 420 kg, le lot GWH a eu besoin de 33 jours d'engraissement de plus que CSH et GWL 38 jours de plus que CSL. Les gains moyens qutidiens ont atteint respectivement 1660 (CSH) 1570 (GWH) 1600 (CSL) et 1400 g/j (GWL). Quel que soit le niveau d'accroissement, l'ingestion des rations GW était plus faible (*vs *CS) au début de l'essai (-1 kg MS/j *vs *CS) et plus élevée à la fin de (+1.5 kgMS/j). Les dépôts adipeux de la carcasse (67,4 kg) et du 5ème quartier (23,8 kg) de CSH ont été supérieurs à ceux des autres lots (58 et 17 kg). Les écarts de vitesse de croissance ont eu plus d'effet sur la dynamique des dépôts des lots CS que GW. L'utilisation de l'herbe enrubannée correctement complémentée permet d'engraisser des taurillons mais, à même apports énergétiques mesurés, cette ration semble moins efficace en termes de gains de poids vif et de poids carcasse qu'une ration ensilage de maïs. Son utilisation doit être raisonnée selon les conditions des ateliers d'engraissement.*

Mots-clés. *Conduite – Taurillon – Engraissement – Enrubannage – Charolais.*

I – Introduction

In France, 25,000 farms produce fat young cattle at the rate of 444,000 tonnes of carcases/year. Farmers are looking for new strategies to reduce cereals in ruminant diets and to optimize profitability of finishing cattle when use of corn silage is not feasible. Several previous experiments have shown the consequences of grass silage diets (Geay *et al.,* 1997) on the amount of fat depots compared to corn silage diets. Corn silage seems a better promoter of fat deposition at different growth rates as reported by Vasconcelos *et al.* (2009) with finishing Angus steers. However very good wrapped hay silage could be highly ingestible (INRA, 2007) and bring sufficient metabolizable energy to ensure an acceptable daily lipid depot. A study was conducted at INRA Clermont Ferrand / Theix experimental unit (UERT) to measure the effects of the nature of the diet ingested on performance and tissue depots (proteins *vs* lipids) in finishing Charolais bulls. Our experiment aimed at distinguishing the effects of the nature of the diet from those of intake level. Diets based on wrapped grass, little explored till now, were compared with the more common corn silage diets.

II – Materials and methods

The experiment involved 36 young Charolais bulls weaned at 360 ± 33 kg and eight-month-old. Calves received only milk and grass before weaning. Animals were divided in 4 homogeneous groups. They were housed in free-stall on semi-mulched area with electronic cornadis to measure individual intake. A 4 week transition period was applied to accustom animals to their experimental finishing diet. Diets were based on corn silage (CS) (40% DM, 0.88 UFV, 69 g and 52 g PDIE PDIN (INRA 2007)) or grass wrapping (GW) (60% DM, 0.71 UFV, 82 g and 66 g PDIE PDIN), and distributed at two energy density High (H) or Low (L) (Table 1). Low groups were only limited by concentrate amounts. These diets allowed theoretical growth of 1400 and 1600 g/d (INRA, 2007). Wrapping GW came from semi-permanent mountain grassland, 1st cut harvested in fine weather at early heading stage completed by citrus pulp and wheat malts (49-57%). The CS diets were supplemented with a cereal mixture (2/3 wheat, 1/3 corn), rapeseed meal and urea (35 to 48% of concentrate). Forages were distributed once a day and concentrate twice a day.

Bulls were slaughtered at a target weight of 700 kg, at the experimental slaughterhouse to obtain a target carcass weight of 420 kg. Ages of bulls at slaughter varied from 15 to 18 months. Throughout the experiment, offered and refused feeds were measured individually. Animals were weighed every two weeks. Rate of fat deposition was measured once monthly by BCS (Agabriel *et al.,* 1986) and three measurements of subcutaneous adipose cell sizes (Robelin and Agabriel, 1986) at beginning, mid-fattening, and slaughter. Feeding behaviour was monitored with electronic troughs and animals' activities with a 24 hour scoring video, which took place at week 2, 12, 24. At slaughter, organs, viscera and separable fats (KPS) were weighed. Carcass yields were calculated, and carcass compositions were estimated from dissection of the 6th rib (Robelin and Geay, 1975). From ME intake and initial live weight (LW), rates of gain of viscera and carcass of each group were simulated using MECSIC model (Hoch and Agabriel 2004). We modulated sensitive parameters (α: rate of protein synthesis and aMW: efficient use of metabolizable energy) to fit measurements of empty body weight (EBW), hot carcass weight (HCW) and total fat deposition (TFD). For statistical analysis, we used the SAS linear model procedure (proc GLM, Tukey test).

III – Results and discussion

From the beginning, CS groups ate more than GW (+1 kg DMI/d) and had a better ADG. But intake of CS groups showed a curvilinear evolution whereas intake of GW was more linear. When adjusting DM intake to a power of LW, a power of 0.45 best fitted the CSH group and 0.9 the GW group. Finally during the last month of feeding, intake of CSH was lower than GWH (-1.5 kg DMI/d). Due to a longer fattening period, GW groups ingested respectively 321 kg (H) and 472 kg (L) DM more than CS which represents 233 and 377 more UFV, and 44 and 61 more kg of PDI (Table 1). When quantities of net energy intake were identical between groups counterparts, the GWH animals weight by 43 kg less than the CSH ones, and the GWL weighed 36 kg less than the CSL. The general activity of bulls did not differ according to the diets. Nevertheless feeding behaviour differed between groups: intake time on corn silage was lower (CS 72 *vs* GW 160 min/d) with fewer meals (10 *vs* 14) and higher intake rate (120 *vs* 60 kg DM/mn).

Table 1. Nutritional values of experimental diets and intakes

	Concentrate %	Net energy (UFV/kg DMI)	CP (g/kg DM)	Starch, g/kg DM	NDF g/kg DM	DMI (kg/d)	Total DMI (kg)
CSH	47.5	0.97	139	403	322	9.1	1839[a]
GWH	57.2	0.94	150	27	462	9.2	2160[b]
CSL	35.2	0.92	134	370	348	8.3	1766[a]
GWL	48.6	0.90	146	25	484	8.9	2238[b]

On the same column, two means indexed by different letters (a, b and c) are significantly different at α = 5%.

To reach the target weight of 700 kg, animals of GWH needed 33 more days than CSH, while GWL required 38 more days than the CSL (Table 2). After a significantly slower growth period of 60 days (GW *vs* CS -0.6 kg/d), GW groups maintained their growth rate still the end of fattening. Growth targets of 1.6 kg ADG for high groups and 1.4 kg for low groups were achieved for GW groups and exceeded for CS groups.

Table 2. Weight and average daily gain at different stages of the fattening period

Group	Fattening period (d)		Initial weight (kg)		Slaughter weight (kg)		ADG (0-60d) (kg/d)		ADG (60-120d) (kg/d)		ADG total (kg/d)	
	Mean	SD†	Mean	SD†	Mean	SD†	Mean	SD†	Mean	SD†	Mean	SD†
CSH	202[b]	34	362	43	708	27	1.760[a]	0,303	1.780	0.230	1.660[a]	0.242
GWH	235[ab]	32	362	37	708	15	1.090[b]	0,223	1.680	0.164	1.570[ab]	0.146
CSL	213[b]	20	357	34	694	26	1.640[a]	0,254	1.790	0.148	1.600[a]	0.163
GWL	251[a]	28	368	20	711	16	1.110[b]	0,164	1.520	0.215	1.400[b]	0.139

On the same column, two means indexed by different letters (a, b and c) are significantly different at α = 5%
† SD: standard deviation.

The feed conversion ratio, ADG/DMI, showed that CS groups were more efficient than GW with no effect of diet density (+24 g CSH/GWH and +37 g CSL/GWL). But when efficiency was expressed in ADG/UFV, CSL was more efficient than the 3 other groups (p<0.01). GWL had a lower protein efficiency (307 g *vs* 380 g for CSH) whatever the ratio (fixed protein/UFV or /PDI).

Carcass composition was not different between groups. The CSH group had significantly higher total adipose tissue (total (TFD): +2%; 5th quarter (DA5Q) +1%). Adipose tissues of the carcass (DACA), significantly differed between CSH and GWH only (1.4%) (Table 3). Group CSH was fatter than the other groups, but the animals of 4 groups had deposited the same quantities of protein. In fact, since the middle of fattening, the size of the adipocytes was significantly greater for CSH (97 μ^2) compared to GW (81 and 74 μ^2) for GWH and GWL, respectively and (89 *vs* 74 μ^2) for CSL compared to GWL. At slaughter, CSH was different from all other groups. CSL was also different from GWL. Simulations underlined a different carcass gain in CSH animals relative to the other groups. They also reflected a rapid gap in the total fat tissue depots between corn silage groups (2.0 kg/week *vs* 1.7 kg), which was not observed with GW (1.3 kg/week).

It is possible to modulate the fat deposition by changing the nature of the diet (starch *vs* fiber) and by choosing adapted feeding levels. At a determined amount of net energy supply (UFV), the type of diets modifies the nature of carcass depots as in Micol *et al.* (2007) or Geay *et al.* (1997). In the latter, where three diets (corn silage, grass silage and hay) were compared, the “hay” diet produced significantly leaner carcasses than corn silage. The diet based on grass silage directly induced more

Table 3. **Slaughter results and fat distribution in the carcass**

Group	EBW (kg)		Carcass weight (kg)		Carcass yield %		DA5Q kg/100 kg EBW		DACA kg/100 kg EBW		TFD kg/100 kg EBW	
	Mean	SD†	Mean	SD†	Mean	SD†	Mean	SD†	Mean	SD†	Mean	SD†
CSH	648	34	425	14	61.3	0.7	3.67^{a}	0.78	10.4^{a}	0.79	14.2^{a}	1.5
GWH	649	59	419	11	60.9	1.6	2.70^{b}	1.95	8.9^{b}	2.56	11.6^{b}	4.5
CSL	635	40	412	11	60.8	0.1	2.77^{b}	0.18	9.9^{ab}	0.39	12.6^{b}	0.5
GWL	640	35	424	8	60.7	1.1	2.59^{b}	0.83	9.5^{ab}	1.59	12.2^{b}	2.4

On the same column, two means indexed by different letters (a, b and c) are significantly different at α = 5%
† SD: standard deviation.

yellow fat. In our work, wrapped hay silage diets seem to behave like hay diets, differing from corn silage diets. GWH and CSL had the same growth rate but CSL deposited more fat, and the difference (5 kg DAT) could be directly related to the nature of the diet. Our study also revealed that the difference in ADG of groups H and L seems more noticeable in GW than in CS groups. However, total protein depots are not different, although we strongly dissociated energy inputs from starch and cell walls. It is hypothesized that a more glucogenic diet favours directly through glucose precursor supply or indirectly through hormonal status intramuscular fat depots (Sharman *et al.,* 2013).

Feed intake in the finishing phase shows an almost linear increase in ingestion for group GWH (1.68 kg/100kg PV/day) and a lower ingestion rate for CSH, as shown by Micol *et al.* (2007) with corn or hay diets. Evolution of feed intake capacity of bulls receiving grass silage is similar to those which have lower growth rate (the allometry coefficient to LW was 0.9, like that for heifers in INRA 2007). It is not the case for both corn groups, where the power was 0.45, close to the 0.6 value used for fattening animals. The decrease in intake within corn group at end of fattening could be explained by a rapid negative feedback on intake and satiety. Diets also induced differences in intake behaviour (intake rate, number of meals) but not enough to cause alimentary pathologies like sub-acidosis that could affect animal welfare.

Corn groups have been more efficient, especially the low level group whose restrictions of concentrated feed have led to a better conversion ratio of energy intake (206 g/UFV). The slight restriction could reduce the rate of transit and improve digestibility. The energy value of the diets, recalculated on the basis of recorded performances (ADG), was 0.96 and 0.94 UFV/kg DMI for the two GW diets, slightly higher than the values calculated from chemical analysis (0.94 and 0.90). This suggests no loss of energy value related to digestive interactions. However corn silage diets were much better used (1.00 and 1.06 *vs* 0.97 and 0.92 UFV/kg DM). UFV value of corn silage in the 2007 INRA tables is reduced by 5% in order to take account of these digestive interactions. It seems that, as in Micol *et al.* (2007), this reduction is too important. Finally, for the corn diets, the ratio PDI/UFV (94), although in the standards, is 11% lower than that of wrapped hay diets (105). It could be considered that in GW groups, protein growth is optimized for energy intake. If this energy level is sufficient for this protein growth, the excess of energy in the CS groups would be oriented towards lipid synthesis.

V – Conclusion

This study has shown that high growth rates, near 1600 g/d, can be reached with diets devoid of starch and based on wrapped hay. However diets based on wrapped hay required a longer transition period before animals reached their highest level of intake (relative to their body weight). Growth in the first 60 experimental days was affected. If the delay is not overcome, it can be a strong constraint which reduces profitability in specialized fattening. Conversely it can be an opportunity for low-mountain farms that only fatten a few animals each year. The use of this type of diet, based on fodder (grazed or preserved) and produced on the farm, is an interesting alternative to corn silage in grasslands regions.

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Reticuloruminal pH values in dairy cows during the transition period from barn to pasture feeding

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Abstract. The effect of the transition from barn to pasture feeding on the pattern of reticuloruminal pH values in 8 multiparous dairy cows was studied with a validated indwelling wireless data transmitting system over a period of 42 days. After 7 days of barn feeding (period 1), all of the animals were pastured with increasing grazing times from 2 to 7 h/d over 7 days (period 2). From day 15 to day 21 (period 3), the cows spent 7 hours/d on pasture. Beginning on day 22, the animals had 20 h/d access to pasture (day and night grazing; 7 day periods 4-6). Despite a mild transition period from barn feeding to pasture, significant effects on reticuloruminal pH values were observed. During the periods of feed transition from barn to pasture feeding, reticuloruminal pH values were lowered significantly. After the beginning of grazing, it took 28-35 days for the reticuloruminal pH value to recover to the level of barn feeding.

Keywords. Rumen acidosis – Indwelling pH measurement – Dairy cattle – Feed transition.

Variations du pH du* reticulo-rumen *au cours de la période de transition alimentaire lors de la mise à l'herbe des vaches laitières

Résumé. *L'effet de la mise à l'herbe sur les variations du pH dans le* reticulo-rumen *a été étudié sur 8 vaches laitières multipares pendant une période de 42 jours, grâce à un système de mesures du pH à demeure avec transmission sans fil des données. Les 7 jours d'alimentation à l'étable (période 1), ont été suivis de 7 jours d'une mise à l'herbe progressive avec 2 à 7 h/j passées au pâturage (période 2). Du 15ème au 21ème jour (période 3), les vaches ont passé 7 h/j au pâturage. Le 22ème jour, les bêtes avaient accès à l'herbe 20 h/j (pâturage jour et nuit, périodes 4 à 6, de 7 jours chacune). Malgré une mise à l'herbe progressive, des effets significatifs ont été observés sur les valeurs du pH dans le* reticulo-rumen*. Les valeurs de pH étaient significativement plus basses et les écarts à court-terme de la concentration en ions H_30^+ plus élevés pendant la période de transition alimentaire. Il a fallu 28 à 35 jours à compter du premier jour de la mise à l'herbe pour que le pH du* reticulo-rumen *retrouve le niveau du début de l'expérience à l'étable.*

Mots-clés. *Acidose ruminale – Mesure du pH à demeure – Vache laitière – Transition alimentaire.*

I – Introduction

Sub-acute rumen acidosis (SARA), is a widespread problem not only in indoor fed dairy cows (Duffield *et al.*, 2004) but also in grazing dairy cattle (Bramley *et al.*, 2008; O'Grady *et al.*, 2008). SARA is difficult to diagnose in the field. The examination of rumen fluid is the most meaningful criterion for evaluating fermentation conditions, and determination of the ruminal pH value is the definitive test for SARA (Krause and Oetzel, 2006). In the present study, a novel indwelling pH sensor was used to continuously monitor reticuloruminal pH during feed transition from barn to pasture feeding.

II – Materials, animals and methods

The data of the present study were collected at the experimental organic dairy farm of the Agricultural Research and Education Centre Raumberg-Gumpenstein, Trautenfels, Austria (680 m altitude, 7°C average annual temperature, 1,014 mm (±63) precipitation per year; latitude: 47° 31‘ 03“ N; longitude: 14° 04‘ 26“ E). The trial was performed with 4 multiparous lactating Holstein Friesian cows and 4 multiparous lactating Brown Swiss cows (milk yield 26.5 kg/d ± 4.0 kg; parity 3.25 ± 1.4; DIM 110 ± 37; BW 556 kg ± 55.3). The pH measurement and wireless data transmitting units (pH bolus) were given orally to each cow on March 21st 2012, and after one week of barn feeding (period 1), the grazing period began on March 28th. A gradual transition from barn to pasture feeding was arranged. During trial days 8 to 14, the time cows spent on pasture increased constantly from 2 to 7 h/d (period 2). From day 15 to day 21 (period 3), the cows spent 7 hours/d on pasture. Beginning on day 22, the animals had 20 h/d access to the pasture (day and night grazing) and were brought to the barn twice daily for 2 hours each for milking and supplemental feeding. Feeding and milking times during all of the periods were 6:00 - 8:00 a.m. and 4:00 - 6:00 p.m., respectively. To investigate the animals' rumen adaptation during continuous grazing, the time span from day 22 to day 42 was sub-divided into another 3 weekly periods (periods 4-6). Rations fed in the barn were provided by Calan gates, and individual feed intake during barn feeding was measured twice daily (Table 1). Individual milk yield was recorded twice daily and samples for determination of milk composition were analysed three times a week. During the entire study period, all 8 cows received the same dietary treatment. On pasture, cows had free access to a continuously grazed (set stocking) sward, pasture intake was not measured. Sward height during the pasture period was measured weekly using a Filip's Folding Plate Pasture Meter; the mean sward height increased from 3.5 to 5.0 cm during periods 2-6. The botanical composition on the continuous grazed permanent grassland was dominated by *Poa pratensis* (21%), *Lolium perenne* (20%) and *Trifolium repens* (17%). Pooled feed samples were collected weekly for chemical analyses. The concentrate consisted of 30% maize grain, 56% barley, 10% oat and 4% of mineral supplementation. The average nutrient and energy content of the feed is shown in Table 2.

Table 1. Daily dry matter intake of dietary components from barn feeding to pasture

Period	1	2	3	4	5	6
Hay (kg DM/cow/d)	4.25	3.81	3.66	2.57	1.24	1.12
Grass silage (kg DM/cow/d)	9.83	7.67	4.57	0	0	0
Concentrate (kg DM/cow/d)	2.90	2.70	2.65	1.12	0.90	0.62
Time on pasture (hours/d)	0	2-7	7	20	20	20

Table 2. Average nutrient and energy content of feedstuffs

	Grass silage	Hay	Concentrate	Pasture
DM (g/kg FM)	437	841	880	173
CP (g/kg DM)	145	113	116	201
NDF (g/kg DM)	479	521	175	407
ADF (g/kg DM)	319	306	65	244
NEL† (MJ/kg DM)	5.8	5.4	7.7	6.8

† Net energy for lactation (GfE, 2001).

For continuous measurement of the reticuloruminal pH value, an indwelling wireless data transmitting system (SmaXtec Animal Care, Austria) was used (Gasteiner *et al.*, 2009). The measurement interval was 600 seconds. Due to its dimensions this indwelling system can orally be administered to an adult cow. The pH values are expressed as daily means (mean pH/d). Means of daily minima and maxima are denoted "min pH/d" and "max pH/d". The time for which reticuloruminal pH value was below specific thresholds (pH < 6.0-5.8) is given as "min/d < pH". Using reverse logarithmic calculus, the pH values were re-transformed into primary H_3O^+ ion concentrations. The maximum short-term fluctuation of the H_3O^+-ion concentrations is given for 2 and 12 hours (1×10^{-8}). Experimental data (daily means per animal) were tested for adherence to the normal distribution and for homoscedasticity using analysis of variance via visual testing of the fit diagnostics in SAS 9.2 (SAS Institute, 2002). The statistical analyses were implemented with PROC mixed of SAS 9.2 (SAS, 2002). The model contained breed (HF, BS), period (1-6) and day of period (1-7) as fixed effects (DDFM = Kenward-Roger). The day within the period was included as a repeated measurement for the subject animal. The results of this analysis were displayed as LS-means and residual standard error (s_e). P values < 0.05 were considered to be statistically significant. Tests of pairwise differences were performed using the Tukey-Kramer method.

III – Results and discussion

Milk yield and milk protein content increased at the beginning of the grazing season (P<0.001), whereas milk fat content decreased numerically (Table 3). Despite a mild transition period from barn feeding to pasture, significant effects on reticuloruminal pH values were observed (Table 4). During barn feeding, the mean reticuloruminal pH value for all of the cows was 6.44 ± 0.14, and the pH values decreased significantly (P<0.001) during period 2 and 3 to 6.24 ± 0.17 and 6.21 ± 0.19, respectively. During periods 4, 5 and 6, the reticuloruminal pH values increased again (pH 6.30 ± 0.22; pH 6.33 ± 0.17; pH 6.37 ± 0.16). Even though average min. pH/d were constantly above 5.8 minima of single animals (nadir) were below this threshold and min/d pH<5.8 ranged from 6 (period 1) to 85 min/d (period 3). The lowest pH value (nadir) decreased from pH 6.0 (period 1) to below pH 5.5 (periods 2, 3 and 4) and rose to pH 5.7 and pH 5.8 over periods 5 and 6 (Fig.1). Short-term deviations in the H_3O^+ -ion concentration were highest during period 4.

Table 3. Daily milk yield and milk composition

Period	1	2	3	4	5	6	s_e	P-value
Milk (kg)	25.2^{b}	25.5^{b}	26.5^{a}	27.0^{a}	26.5^{a}	26.0^{ab}	1.72	<0.001
Milk protein (%)	2.78^{c}	2.84^{bc}	3.00^{ab}	3.21^{a}	3.26^{a}	3.26^{a}	0.13	<0.001
Milk fat (%)	3.82	3.75	3.97	3.58	3.57	3.58	0.47	0.799

Table 4. Reticuloruminal pH values, time (minutes/day) of pH values below specific thresholds and maximum short-term fluctuation of H_3O^+-ion concentration ($x10^{-8}$) during 2 and 12 hours per day

Period	1	2	3	4	5	6	s_e	P-value
Mean pH/d	6.44^{a}	6.24^{cd}	6.21^{d}	6.30^{bc}	6.33^{b}	6.36^{b}	0.11	<0.001
Min. pH/d	6.09^{a}	5.89^{cd}	5.84^{d}	5.86^{d}	5.95^{bc}	6.02^{ab}	0.15	<0.001
Max. pH/d	6.77^{a}	6.64^{b}	6.64^{b}	6.76^{a}	6.73^{a}	6.74^{a}	0.15	<0.001
Min/d pH<5.8	6^{c}	43^{ab}	85^{a}	38^{ab}	13^{b}	9^{b}	91	<0.001
Min/d pH<6.0	28^{b}	273^{a}	333^{a}	226^{a}	100^{b}	89^{b}	198	<0.001
Max. fluct. H_3O^+-ion 2 h	65^{b}	91^{ab}	101^{ab}	113^{a}	83^{ab}	66^{b}	67	0.003
Max. fluct. H_3O^+-ion 12 h	75^{b}	114^{ab}	132^{a}	140^{a}	100^{ab}	83^{b}	71	<0.001

There have been few studies investigating the ruminal effects of the transition from dry diets to fresh vegetative pastures. Lippke *et al.* (2000) showed that ruminal acetate:propionate (A:P) ratios were variable during the first week that beef steers were placed in a wheat pasture, and they suggested rumen acidosis as a possible cause for poor performance during the early grazing period. In the present study, the mean reticuloruminal pH value significantly decreased in all 8 cows (P<0.001) from period 1 to period 3. The mean reticuloruminal pH values steadily increased during periods 4-6, which can be interpreted as an effect of the rumen's microbial adaptation to grazing conditions. Gasteiner *et al.* (2012) demonstrated that the additional feeding of concentrate decreased reticuloruminal pH values in grazing dairy cows significantly and that these cows were at high risk for SARA. In the present study, the amount of additional feed (hay, grass silage and concentrate) was reduced significantly during pasture periods. It can be concluded that the feed transition to grazing may be less harmful for dairy cows when the additional feeding of concentrates is less than 2.5 kg/cow/d. However, in this study, no clinical health problems in any animals were observed.

Information on the daily mean reticuloruminal pH values may not adequately represent the highly variable characteristics of this trait (DeVeth and Kolver, 2001). While the daily mean reticuloruminal pH value could remain relatively high, the daily fluctuations of reticuloruminal pH value might lead to the nadir being < 5.8 for more than 180 minutes, which is often considered to represent SARA. Gozho *et al.* (2005) addressed the issue of the duration of SARA. They defined SARA as a rumen pH threshold of between 5.2 and 5.6 for > 176 min/d. Data from Alzahal *et al*. (2007) suggest that a period of ruminal pH lasting longer than 283 and 473 min/d below 5.6 or 5.8, respectively, indicates SARA. In the present study, the times the reticuloruminal pH value during periods 1-6 was below 5.8 were 6, 43, 85, 38, 13 and 9 min/d, respectively. Based on the SARA definition of Alzahal *et al*. (2007), it can be concluded that pH values were higher in this study and that the animals were not at risk of SARA. According to the definition of Nordlund and Garrett (1994), who recommended a pH of 5.5 as the cut-off point between normal and abnormal, the cows in the present study were at risk of SARA during phases 2, 3 and 4 (Fig. 1).

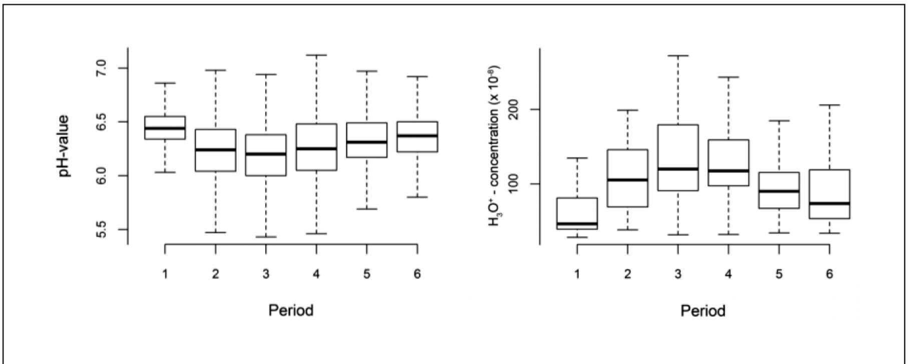

Fig. 1. Box-whisker plots of the reticuloruminal pH values (left) and short-term fluctuation of H_3O^+-Ion concentration (x10^{-8}) during 12 hours per day (right).

IV – Conclusion

The animals in present trial showed significantly lowered reticuloruminal pH values and higher short-term deviations in the H_3O^+-ion-concentration during the periods of feed transition from barn to pasture feeding. After the beginning of grazing, it took 28-35 days for the reticuloruminal pH value to recover to the stage of barn feeding. In literature different definitions for pH-thresholds on SARA can be found. Depending on the applied definition of SARA cows in present study where at a beginning risk on SARA or not. The indwelling pH measurement and data transmitting system is a helpful and proper tool for long-term and continuous measurement of reticuloruminal pH value in grazing cows.

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Effect of post-milking treatment on teat skin and milk microbial diversity of dairy cows

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Abstract. Microbial diversity is one of the specificities of traditional raw milk cheeses. It depends on both milk microbiota and microbial dynamics during manufacturing and ripening. The microbial composition of milk is not clearly understood yet; it depends on direct and indirect sources which vary according to herd management (feed, herd size, lactation rank, etc.), farm environments (litter, dung) and milking management (udder microbial community). The surface of cow teats has been described as a source of microorganisms for milk. Thus, it can be hypothesized that practices modifying the teat skin microbiota could be a lever to increase qualitatively and quantitatively the microbial diversity in milk. To check this hypothesis, the composition of microbial species of the teats of dairy cows that received three post-milking treatments (iodine, glycerol, no products) over the lactation was compared. Teat microbiota was also compared to the microbial composition of the corresponding milk. Teat microbiota was highly dominated by ripening bacteria whereas that of milk was well balanced between the different microbial groups. Forty-three microbial genera were identified on the surface of the teat against 34 in milk: 20 genera were common. The post-milking treatment affected mainly the count of ripening bacteria of teat surface whereas it had no effect on milk microbiota. The count of other microbial populations was not modified whatever the treatment.

Keywords. Microbial diversity – Microbial flow – Milk – Teat surface.

Effet du post-trempage sur la diversité microbienne de la peau des trayons et du lait de vaches laitières

Résumé. *La diversité microbienne est une des spécificités des fromages traditionnels au lait cru. Elle dépend du microbiote du lait et de la dynamique microbienne au cours de la transformation fromagère et de l'affinage. La composition microbienne du lait n'est pas encore clairement comprise. Elle dépend de sources directes et indirectes dépendantes de la gestion du troupeau, de l'environnement et de la traite. Les trayons des vaches ont été décrits comme une source de micro-organismes pour le lait. Il a donc été émis l'hypothèse que les pratiques susceptibles de modifier le microbiote des trayons peuvent être un levier d'action pour favoriser la diversité microbienne du lait. Pour vérifier cette hypothèse, la composition des espèces microbiennes des trayons de vaches laitières ayant reçu trois traitements de post-traite sur l'ensemble de la lactation a été comparée. Elle a aussi été comparée à celle des laits correspondants. Le microbiote des trayons était dominé par les bactéries d'affinage alors que celui du lait était bien équilibré entre bactéries d'affinage, bactéries lactiques, bactéries Gram- et levures-moisissures. Quarante-trois genres microbiens ont été identifiés sur le trayon contre 34 dans le lait : 20 genres étaient communs au lait et aux trayons. Le post-trempage influe sur les bactéries d'affinage du trayon alors qu'il n'a eu aucun effet sur celle du lait. Les niveaux des autres populations n'ont pas été modifiés.*

Mots-clés. *Diversité microbienne – Flux microbien – Lait – Surface des trayons.*

I – Introduction

Traditional cheeses are mainly produced with raw milk in the south of Europe in particular in mountain areas. The specificity of raw milk cheeses relies, among other things, on the preservation of microbial diversity *in situ*. To manage this microbial diversity through all the process from milk production to ripened cheeses, it is important to have a better understanding of the microbial reservoirs and how the milk production practices affect the microbial counts and how technological process modifies the milk microbiota dynamics. The composition of the milk microbiota depends on the composition of the microbiota of sources directly in contact with the milk: the animal's teats and dairy equipment such as milking machine, milk line and tank. Concerning indirect sources, teat care, washing, and disinfection of the milking equipment are of primary importance (Vacheyrou *et al.*, 2011). As the surface of cow teats has been described as a source of microorganisms for milk, it can be hypothesized that practices that can modify the teat skin microbiota could be a lever to increase qualitatively and quantitatively the microbial diversity in milk. The objectives of this study, conducted in controlled conditions, were i) to evaluate if the post-milking treatment affects the teat and milk microbiota and ii) to compare these microbiota.

II – Materials and methods

This study was carried out at the experimental farm of INRA-UEMA Marcenat in an upland area of central France using 48 dairy cows, divided into three equivalent groups. At the end of each milking, throughout the whole lactation, the three groups received respectively: an iodinated product (I), commonly used in dairy farms with disinfecting action; a 85% glycerol product (G), selected for its lack of antiseptic activity and its power of regenerating the lipid layer; no product (O). Once a month the total surface of the four teats of each cow and the individual (harvested just after milking without refrigeration) milk were sampled. The individual milk samples (the total surface of the 4 teats) were pooled within groups of post-milking treatment. The microbial flora of each teat and milk pool (I, G, O) was counted on several culture media to enumerate: total mesophilic bacteria on Plate Count Agar medium (PCA); facultative heterofermentative *Lactobacilli* on agar medium FH; lactic acid bacteria on de Man, Rogosa and Sharpe (MRS) medium; *Enterococci* on Slanetz and Bartley agar medium (SB); yeasts and moulds on Oxytetracyclin Glucose Agar medium (OGA). The ripening flora was counted on Cheese Ripening Bacteria Medium (CRBM) and the presumed Gram negative flora (Gram -) on PCA medium with vancomycin and purple crystal added (PCAi). Two hundred fifty-three milk isolates and 319 teat isolates were picked up on culture media (mainly CRBM and PCA) inoculated with milk and teat pools at different sampling time. They were there identified by 16S rRNA amplifying-sequencing (Verdier-Metz *et al*., 2012).Results of microbial counts at each sampling time were expressed as cfu/mL of teat juice or milk. The share of each microbial population in the total population was calculated as the ratio of the count of this population to the sum of the counted populations (CRBM + PCAi + SB + FH + OGA). The microbial counts were transformed to decimal logarithm to be analysed by univariate (post-milking treatment) analysis of variance using sampling times as replicates.

III – Results and discussion

The counts of lactic acid bacteria, Gram negative bacteria, yeasts and moulds were similar on teats, whatever was the post-milking treatment (Table 1). The lack of effect on these bacterial counts was also observed in milk. Teats treated with I and G post-milking product had a significantly lower count of ripening bacteria [less than 5.4 log(cfu/ml teat juice)] and consequently of total mesophilic bacteria [5.71 log(cfu/ml teat juice) than those without treatment [about 6 log (cfu/ml teat juice)]. On the contrary, such treatment had no effect on the count of these bacteria in milk. Thus, it can be hypothesised that the microbial count in milk is not directly affected by change of microbial count on teats. Even if the results are not expressed in the same units the levels of Gram- bacteria [about 3.25 log(cfu/ml milk)] and lactic acid bacteria [about 3.5 log(cfu/ml milk)] in milk were at higher levels than on teats whereas ripening bacteria were at lower levels. Interestingly the levels of yeasts, moulds, and heterofermentative *lactobacilli* in milk were at higher levels than on teats, whereas ripening bacteria were at lower levels. The microbial balance between teat and milk was quite different. On teat skin, ripening bacteria represented more than 96% of total population counted in different media, whereas they represented the same percent than lactic acid bacteria (31%) in milk. In milk the percentages of Gram-negative bacteria, yeasts and moulds were higher (14%) than on teat skin. This change in microbial balance between teats and milk suggests that the transfer of micro-organisms from teats to milk is hampered.

Table 1. Effect of post-milking treatment on teat (log cfu/ml teat juice) and milk (log cfu/ml milk) microbial counts over the lactation period

	Teat			Milk		
	I	G	O	I	G	O
Total mesophilic bacteria (PCA)	**5.71**^{b}	**5.71**^{b}	**6.17**^{a}	4.83	4.74	4.83
Ripening population (CRBM)	**5.30**^{c} (98.1)	**5.38**^{b} (96.5)	**6.08**^{a} (99.0)	3.51 (27.0)	3.44 (28.8)	3.50 (31.1)
Presumed Gram negative bacteria (PCAi)	3.22 (0.8)	3.21 (0.6)	3.16 (0.1)	3.36 (19.1)	3.23 (17.7)	3.17 (14.5)
Lactic acid bacteria (MRS)	3.33 (1.0)	3.84 (2.8)	4.00 (0.8)	3.55 (29.6)	3.45 (29.4)	3.50 (31.1)
Enterococci (SB)	1.31	1.53	1.26	1.13 (0.1)	0.81 (0.1)	0.81 (0.1)
Heterofermentative facultative *Lactobacilli* (FH)	1.52	1.82	1.79	3.06 (9.6)	2.95 (9.3)	2.96 (8.9)
Yeast (OGA)	1.79	1.59	2.00	3.02 (8.7)	2.92 (8.7)	2.95 (8.8)
Mould (OGA)	1.54	1.55	1.71	2.84 (5.8)	2.76 (6.0)	2.75 (5.5)

Results with different letters (a>b>c) are significantly different by the statistical Newman-Keuls test. Number in brackets is the percentage of this population in the (CRBM + PCAi + MRS + SB + FH + OGA) count.

Table 2. Microbial diversity of teat surface and milk

		Teat	Milk
Gram+ Catalase-	*Aerococcus, Enterococcus, Lactobacillus, Lactococcus, Leuconostoc, Streptococcus*	x	x
	Desemzia, Pediococcus, Trichococcus	x	
Gram+ Catalase+ (ripening bacteria)	*Arthrobacter, Brachybacterium, Brevibacterium, Corynebacterium, Kocuria, Microbacterium, Micrococcus,Plantibacter, Rhodococcus,Staphylococcus*	x	x
	Deinococcus, Propioniciclava, Rothia		x
	Agrococcus, Bacillus, Cellulomonas, Citrococcus, Clavibacter, Curtobacterium, Dietzia, Exiguobacterium, Jeotgalicoccus, Macrococcus, Paenibacillus, Planococcus, Salinococcus	x	
Gram- Catalase-	*Erwiniia, Roseomonas*	x	
Gram- Catalase+	*Ochrobactrum, Pseudomonas, Raoultella, Stenotrophomonas*	x	x
	Agrobacterium, Chryseobacterium, Citrobacter, Comamonas, Delftia, Hafnia, Klebsellia, Phyllobacterium, Rahnella, Serratia, Yersinia		x
	Achromobacter, Aminobacter, Enterobacter, Escherichia, Pantoea	x	

Sequencing of the 16S rDNA of the picked-up colonies on culture media (mainly CRBM and PCA) according to their morphotype showed a wide diversity of microbial populations. Indeed, in the dominant population 43 microbial genera were identified on the teat skin, compared to 34 in the milk. Twenty genera in milk were in common with teat skin (Table 2). The teat skin microbiota differed mainly from that of milk by 13 microbial genera belonging to the ripening population (Gram+ Catalase+, CRBM). Fourteen genera found on teat skin have been detected in milk by other authors (Montel *et al*., 2014). Eight genera found on teat skin in our study had not previously been identified, neither in milk, nor on teat skin: *Agrococcus*, *Aminobacter*, *Cellulomonas, Citrococcus, Desemzia, Erwiniia, Planococcus, Roseomonas.* Two genera found in milk (*Propioniciclava* and *Phyllobacterium*) have never been previously described in milk.

These results confirmed that the teat skin can be considered as a reservoir of microbial biodiversity for raw milk. Nevertheless differences between teat and milk microbiota argue for other sources of milk inoculation (environment, milking machines). These results are in agreement with the composition of teat and milk microbiota in the literature (Montel *et al*., 2014).

IV – Conclusions

Our study showed that the post-milking treatment impacts only the ripening bacterial count (and consequently the total mesophilic bacteria count) on teats, but without modification of this count in milk. Teat and milk microbiota composition differed. The number of species belonging to the Gram+ Catalase+ group (ripening bacteria) was higher on teat skin than in milk. In milk percentages of lactic acid bacteria and ripening bacteria were similar to those of yeasts and heterofermentative lactobacilli. Our results confirmed that there are breaking points between animal and milk at a farm level. Further researches are needed to identify precisely these breaking points and to better understand how microbial strains flow through the different ecosystems surrounding the animals and milk. The high throughput sequencing will facilitate such studies.

Acknowledgments

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Effect of transhumance and the use of a native breed on infection of sheep with pasture borne parasites

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Abstract. Pasture borne parasites, particularly gastrointestinal nematodes (GIN), substantially impact on animal health and production of sheep. For several decades GIN control relied on anti-parasitic drugs (anthelmintics). Because of the rapid evolution of nematode resistance to these compounds, new strategies to control these parasites are being developed. Here we report on a study which aimed at combining transhumance and the use of a native, less susceptible sheep breed (i.e. Red Engadine Sheep, RES) in order to control GIN. One-hundred and seventeen lambs infected with GIN (69 RES and 48 Swiss White Alpine, SWA) were blocked by the number of excreted GIN eggs (FEC) and breed and were distributed to either an alpine or a lowland pasture group. The 2 groups were grazed on the respective sites for approximately 12 weeks. For both groups individual FEC were performed at weeks 5, 7 and 12. All animals with FEC > 1000 eggs per gram of faeces were treated with an anthelmintic at week 7. The lambs of the transhumant flock had a lower FEC at week 7 ($p = 0.001$) and no transhumant lamb needed anthelmintic treatment, whereas 55 % of the lowland lambs needed treatment ($p = 0.001$). Irrespective of the grazing site, RES had lower FEC than SWA throughout the trial ($p < 0.001$). It is concluded that the incorporation of transhumance into the grazing management may keep the GIN infection level at an acceptable level. Furthermore, the native RES controlled GIN more efficiently than SWA lambs and therefore this breed, at least in Switzerland, may be of importance as an element of GIN control in the future.

Keywords. Sheep – Gastrointestinal Nematodes – Integrated control.

Effets de la transhumance et de l'utilisation d'une race rustique sur le niveau d'infestation des ovins par les strongles gastro-intestinaux

Résumé. *En systèmes herbagers, les parasites, et particulièrement les strongles-gastro intestinaux (SGI) ont des effets majeurs sur la santé et la production des ovins. Jusqu'à présent, le contrôle de ces parasites a reposé sur l'utilisation de produits chimiques de synthèse, les vermifuges. L'utilisation fréquente de ces substances ayant provoqué l'apparition de fortes résistances de la plupart des populations de parasites, de nouvelles stratégies non-chimiques de contrôle sont en cours de développement. Nous présentons ici une étude où la transhumance et l'utilisation d'une race d'ovins (Rouge d'Engadine, RE) naturellement moins susceptible aux SGI ont été combinées pour contrôler ces parasites. Cent-dix-sept agneaux (69 RE et 48 Blanche Alpine de Suisse, BAS) infestés naturellement avec des SGI ont été allotés sur la base de la race et du niveau de parasitisme par les SGI (nombre d'œufs de SGI par gramme de fèces) puis ont pâturé soit en estive soit sur des pâturages en plaine. Les deux lots ont pâturé sur les sites respectifs (estive, plaine) pendant environ 12 semaines. Des comptages d'œufs de parasites (OpG) ont été effectués pour chaque agneau aux semaines 5, 7 et 12. Tous les animaux présentant une valeur d'OpG > 1000 en semaine 7 étaient vermifugés. Les agneaux pâturant en estive ont présenté des OpG plus faibles en semaine 7 ($p = 0,001$) et aucun d'entre eux n'a nécessité un traitement antiparasitaire, alors que 55 % des agneaux pâturant en plaine ont dû être vermifugés ($p = 0,001$). Indépendamment du site de pâture, les agneaux RE ont excrété moins d'œufs de SGI que les agneaux BAS pendant la période d'étude ($p < 0,001$). Il est conclu que l'utilisation d'une estive dans la gestion du pâturage peut aider à maintenir le niveau d'infestation avec les SGI à un niveau acceptable. En outre, la race rustique (RE) contrôle les SGI plus efficacement que la race BAS Pour cette raison au moins en Suisse, cette race peut être importante comme élément de contrôle des SGI dans le futur.*

Mots-clés. *Ovin – Strongles gastro-intestinaux – Contrôle intégré.*

I – Introduction

Resistance of gastrointestinal nematodes (GIN) to anthelmintic drugs threatens small ruminant husbandry worldwide (Kaplan and Vidyashankar, 2012). This situation as well as the demand for reduced chemical inputs by organic farmers and consumers has stimulated the search for alternatives, such as the use of bioactive forages, the use of sheep breeds with lower susceptibility as well as nutritional and grazing management strategies to control GIN (Hoste and Torres-Acosta, 2011).

Compared to the high performing Swiss White Alpine Sheep (SWA), the native Red Engadine Sheep (RES) has shown to be less susceptible to GIN infection in previous studies (unpublished results). On the other hand, the use of alpine pastures (transhumance) would allow a reduced stocking density that hypothetically leads to a lower infection pressure on alpine pastures and furthermore to a lower infection level of transhumant sheep with GIN. Hence, the objectives of this study were to assess if the use of a less susceptible breed on alpine pastures reduces the reliance of synthetic anthelmintics due to additive effects.

II – Materials and methods

Sixty-nine RES and 48 SWA lambs were grazed on common pastures for 52 days (preparation period). The age of the lambs at grazing start ranged from 74 to 116 days and there was no difference between the breeds. Prior to the preparation period all lambs were artificially infected with 5000 *Haemonchus contortus* and 2200 *Trichostrongylus colubriformis* third stage larvae. Individual faecal samples were drawn from every lamb at the end of the preparation period. According to the number of nematode eggs per gram faeces (FEC) and breed, the lambs were distributed to either an alpine or a lowland pasture group. Thirty-seven RES and 25 SWA were assigned to the alpine flock and 32 RES and 23 SWA to the lowland flock. Due to animal welfare reasons, all lambs with a FEC > 1000 were treated with a commercial anthelmintic before the animals were moved to the corresponding pastures. The experimental animals were subsequently grazed on alpine or lowland pastures for a period of 82 days. Faecal samples were drawn on day 37 (FEC 1), 50 (FEC 2) and 82 (FEC 3) during this period. Anthelmintic treatment was again applied to those lambs that had a FEC > 1000 at day 50 (FEC 2). The alpine pastures were located in the Valley of Misox, Switzerland. The alpine pastures were at 1800 – 2750 m above sea level. Except for the grazing period from day 50 to 64, the alpine flock was always pushed to pastures which were never grazed before in the trial year. The stocking density of the grazing range could not be quantified due to the geographically complex situation on these alpine pastures. The lowland pastures were located close to the research facilities of the Research Institute of Organic Agriculture, Switzerland. The lowland pastures were at 350 – 600 m above sea level. During the preparation period, the lowland pastures were grazed by the entire flock for the first time in the corresponding trial year. During the 82 days after the preparation period, the lowland flock was rotated two times on the same pastures. The stocking density of the lowland pastures was 1.6 livestock units per hectare.

Data analysis was performed with the statistical computing environment R (R Development Core Team, 2012, version 2.15.1). The development of the FECs (1 – 3) was analysed using a linear mixed model. For the stabilisation of the variances all FEC data were log(x +1) transformed. Post-hoc tests were performed for the identification of differences between the sampling events. P-values were corrected for multiple testing by the Bonferroni method. Chi-square-tests were applied for the analysis of the difference of the anthelmintic treatment frequency between the two breeds.

III – Results and discussion

1. Anthelmintic treatment

The first anthelmintic treatment directly after the preparation period concerned 43.5% RES and 64.6% SWA (chi2, $p = 0.025$). A second anthelmintic treatment at trial day 50 was solely applied to lambs of the lowland flock, as no lamb of the transhumant flock exceeded the threshold of 1000 FEC. Within the lowland flock 37.5% RES and 82.61% SWA received the second drench (Chi2, $p = 0.001$). In total, 55% of the lowland lambs were treated with anthelmintics.

2. Faecal egg counts

There was no FEC difference between the alpine and the lowland flock at trial start ($p = 0.290$). The analysis of the repeated FEC revealed no difference between the alpine and lowland flock over the entire trial ($p = 0.277$). Post-hoc tests indicated, however, that the FEC of the alpine flock was lower at day 50 ($p = 0.001$) and higher at day 82 ($p < 0.001$) compared to the lowland flock. The RES showed a significantly lower FEC compared to the SWA throughout the trial ($p < 0.001$) (Table 1). Lambs that were treated with anthelmintics at day 50 had a considerable lower FEC at trial end ($p < 0.001$). There was no effect of other parameters such as age, weight or gender of the animals on the repeated FEC.

Table 1. Mean faecal egg counts (FEC) of the Red Engadine Sheep (RES) and the Swiss White Alpine (SWA) grazing either on alpine (ALP) or lowland (LOW) pastures

Trial days	RES x ALP		SWA x ALP		RES x LOW		SWA x LOW	
	Mean	SE†	Mean	SE†	Mean	SE†	Mean	SE†
1	285	55	156	51	303	56	193	61
37	241	37	325	88	317	115	848	115
50	224	35	226	31	1183	206	2776	346
82	1097	119	1876	284	253	52	209	55

† Standard error of the mean.

As all experimental lambs with a FEC > 1000 were treated with an anthelmintic at day 50 due to animal welfare reasons, we could not demonstrate an effect of the grazing site over the entire trial. But it has been shown that 55% of the lowland animals exceeded the threshold of 1000 FEC at trial day 50. In contrast, no alpine animal exceeded this threshold at this time of the trial. Therefore, the infection level of the alpine pastures must have been low compared to the lowlands for the first half of the trial. Depending on the environmental conditions in Switzerland, sheep are set out for grazing in April on lowland pastures. In contrast, grazing on alpine pastures usually starts in early July. This shift of the grazing start impacts on the epidemiological pattern of infection on alpine pastures towards a lower infection level compared to the lowlands (Eckert and Hertzberg, 1994). Farmers might incorporate the use of alpine pastures as a strategic grazing management tool to avoid periods with high nematode larval challenge on lowland pastures.

Compared to the lowland lambs, the alpine lambs had significantly higher FECs at the end of the trial on day 82. It is known that the number of infective nematode larvae increases with proceeding vegetation period on alpine pastures (Gruner *et al.,* 2006). Except for the period from trial day 50 to 64, the experimental lambs on alpine pastures were routinely pushed to pastures that were never grazed before in the same season. For the period from day 50 to 64, the experimental lambs were introduced to a pasture that was grazed by another sheep flock for several weeks before. We assume that this grazing period caused the increased FEC of the alpine lambs at trial end (day 82). This would emphasise the need for a pasture management to control the infection with GIN on alpine pastures with proceeding vegetation period.

The repeated measurement analysis revealed a significantly lower FEC of the RES compared to the SWA throughout the trial. As a consequence, the frequency of anthelmintic treatments applied to this breed was considerably lower compared to the treatment frequency of the SWA. We assume that the breeding progress of the high performing SWA took place when anthelmintics were available on the market. We hypothesise that the susceptibility against infection with GIN was not an important trait when selecting the animals for breeding during the last decades. The RES, however, persisted without much genetic modification since the middle of the last century. When breeding progress took place in that breed, resistance to GIN infection must have been a natural trait when animals were selected for breeding, as no anthelmintics were available during those times.

IV – Conclusions

The native RES has shown to be less susceptible to GIN infection compared to the high performing SWA. The use of the native RES could therefore reduce the number of applied anthelmintics treatments and might decrease the resistance development of GIN to anthelmintics. At least for the first half of the vegetation period the strategic use of alpine pastures resulted in significantly reduced FEC compared to lambs grazing on lowland pastures. We consider the effect of the breed and the grazing site as additive. Thus, the grazing of RES on alpine pasture may result in a considerably reduced number of anthelmintic treatments compared to a conventional grazing system.

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Session 2

Ecosystem services, prevention of risks

Keynote articles

Multifunctionality and dynamics of silvopastoral systems

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Abstract. Silvopastoral systems (SPs) are present all around Europe, being still important elements of cultural identity of many marginal, stress-prone regions. They are managed mostly as extensive, low-input farming. SPs are used for multiple purposes which generate timber and non-timber forest products, high-quality foods, livestock and game products, recreational and cultural services. SPs have the potential to be an outstanding High Nature Value farming system, however, they are currently facing both environmental and economic threats that might compromise their long-term persistence either by agricultural intensification or by abandonment. In recent decades, needs and challenges emerged in the modern society have led to a new concept of land use. Bioenergy, carbon sequestration, control of nutrient leaching, halting of biodiversity loss and recreational uses could increase economic profitability of SPs. To cope with these new functions, there is a need of innovative techniques and specific policy measures to solve those threats and reinforce their social and ecological roles.

Keywords. Biodiversity – Carbon sequestration – Fire risk control – Soil fertility – Habitat mosaic.

La multifonctionnalité et la dynamique des systèmes sylvo-pastoraux

Résumé. *Les systèmes sylvo-pastoraux (SPs) sont présents partout en Europe. Ce sont des éléments importants de l'identité culturelle de nombreuses régions marginales. Ils sont gérés la plupart du temps extensivement avec de faibles intrants. Les SPs sont utilisés à des fins multiples, pour la production de bois, de fruits, d'aliments de haute qualité, de produits de l'élevage, de gibier, pour les loisirs, et ils fournissent des services culturels. Les SPs ont un fort potentiel pour devenir des systèmes agricoles à haute valeur naturelle, cependant, ils sont actuellement confrontés à des menaces environnementales et économiques qui pourraient compromettre leur persistance à long terme, soit par l'intensification agricole soit par leur abandon. Au cours des dernières décennies, de nouveaux besoins et défis sont apparus dans la société moderne. Bioénergies, séquestration du carbone, contrôle du lessivage des nutriments, arrêt du déclin de la biodiversité et des fonctions de loisirs pourraient augmenter la rentabilité économique des SPs. Pour faire face à ces nouvelles fonctions, il est nécessaire de développer des techniques innovantes et des mesures spécifiques pour résoudre ces menaces et renforcer les rôles sociaux et écologiques des SPs.*

Mots-clés. *Biodiversité – Séquestration du carbone – Contrôle des incendies – Mosaïque de l'habitat.*

I – Introduction

Accordingly to the Bergmeier *et al.* (2010) the silvopastoral systems (SPs) started 7,500 years ago in Southeastern and central Europe. These SPs can be defined as a combination of trees, pastures or crops and/or livestock on the same plot of land (Mosquera-Losada *et al.,* 2012). In more marginal, stress-prone regions and mountains, where agriculture was hardly viable, extensive pastoralism has been the most common and traditional land use. Across Europe, different pastoral landscapes are still dominated by silvopastoral systems that include grazed forests, anthropogenic savannas, wood pastures (trees as fodder), grazed plantations, but also grazed fruit orchards. In

Iberian Peninsula, SPs cover 4.5 million ha, mainly represented by Dehesa and Montados. Similar systems are present in many other Mediterranean regions (Sardinia, Corsica, Crete, Greece, Albania, northern Africa and Western Asia) and in less extension in many other European biogeographic regions (Riguiero-Rodríguez *et al.,* 2009). SPs cover ca. 17 M km^2 in the world (Zomer *et al.,* 2009). Depending on the region, SPs occurs as vanishing relic of historical land-use, or still more or less widespread as multiple-use rangeland (Bergmeier *et al.,* 2010). SPs are frequently diffuse transitions from agriculture to forest lands, and there is still a lack of reliable maps of distribution or any official statistics of their extension (Van Doom and Pinto-Correia, 2007).

SPs have been harvested and/or managed in different ways in the different European socio-economic, political, cultural and environmental scenarios. Somewhere, there has been a deliberate and purposeful integration of woody vegetation (trees or shrubs) with crop and/or animal production systems to benefit from the resulting ecological and economic interactions. However, in many cases woody vegetation has been hardly managed and/or management did not follow underwent ecological and economical changes. Some of them are suffering declining processes as lack of regeneration and exhaustion of resources (Riguiero-Rodríguez *et al.,* 2009). In other cases, especially in mountain areas, abandonment is the harsh reality. Also, the low value of the traditional silvopastoral products in the actual markets is a common concern for all of them.

Despite the well-known socioeconomic and ecological importance of SPs across Europe, only in 2006 this land use system was considered as a specific agroforestry practice in the Common Agricultural Policy (CAP), namely under the Pilar 1 and 2 of the CAP 2007-2013. However, adoption of this financial support schemes has been limited and no relevant impacts on the future sustainability of this land use systems was observed. To achieve this propose many efforts have been conducted in last three years to ensure the full recognition of the silvopastoral systems as an eligible land use for Basic Farm payments in the CAP 2014-2020 period. One of the most interesting windows of opportunity to maintain in a sustainable way the silvopastoral systems across Europe is the new greening architecture of the CAP 2014-2020 diploma. However, some rules concerning the effective application/adoption of this measure will be determined by each member state, representing thus an important moment to highlight the specificities and relevancies of the silvopastoral systems that occurs in each country.

Therefore, this paper will review and discuss in detail the concept of multifunctionality of the European silvopastoral systems in order to provide an overview of their socioeconomic, ecologic and cultural relevance. Thus, section 2 and 3 present the goods and services provided by this ecosystem highlighting their importance to achieve a more sustainable agroforestry activity in Europe. Section 4 assesses the current state of the silvopastures dynamics knowledge, in relation to their main patterns and processes over the space and time. Section 5 outlines the importance in reorienting the public perception and management schemes based in a more scientific knowledge and innovative management tools for a more sustainable agroforestry production and ecosystem conservation. Finally, the section 6 provide a global view of what are the main needs and steps to be done to promote the SPs across Europe as an important traditional rural areas to be supported due to their recognized ecological importance but also due to their specific social, economic and cultural requirements.

II – Goods provided by silvopastoral systems

Although SPs are multifunctional systems, and provide a series of products, they are mainly used for animal breeding or tree-derived products. Owners maintain trees either because they barely compete with pasture understory and pasture productivity is not affected by the tree cover, as the case of oaks and many deciduous hardwoods (Fig. 1), or because trees are used as forage supplement. Good examples are oaks in Iberian dehesas that provide leaves and acorns, shrubs in many Mediterranean and mountains pastures, and pollarded trees (Fig. 2). In some cases, trees constitute the main source of fodder as in the Iranian Galazarini (Zabiholahi and Haidari 2013).

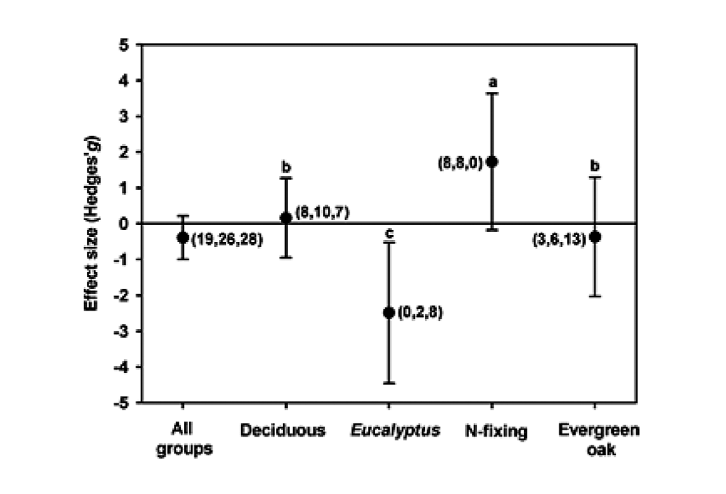

Fig. 1. Mean effect size (Hedges'g) of scattered trees on pasture yield among four functional groups and across all groups (bars = 95% confidence intervals). Adapted from Rivest *et al.,* (2013).

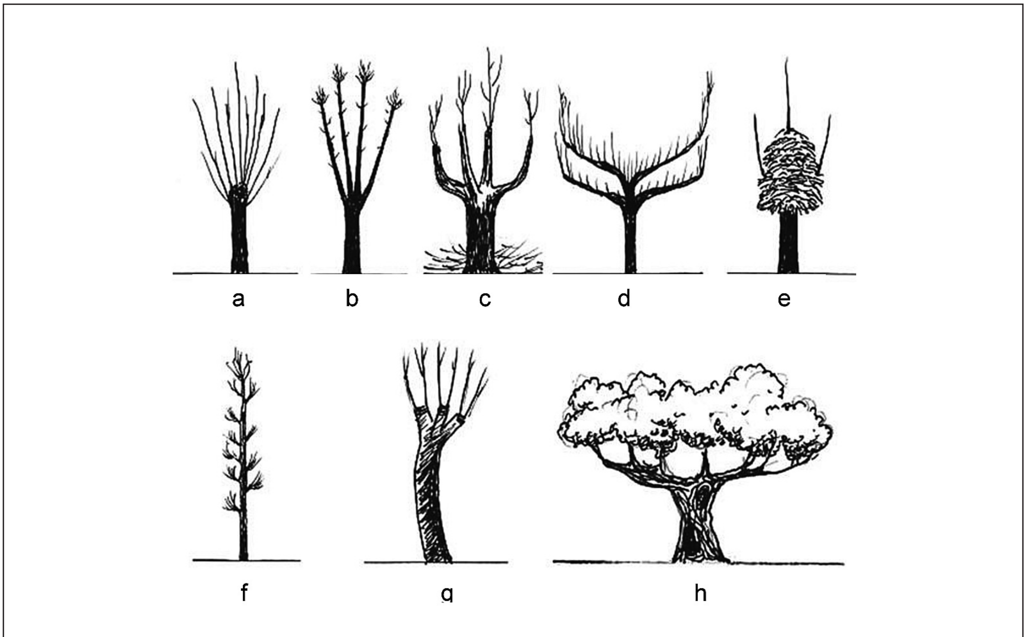

Fig. 2. Traditional management of fodder trees in Greece: (a) pollarded tree of any species, (b, c) pollarded oak trees (d) pollarded mulberry tree, (e) pollarded tree for storage of fodder, (f) shredded oak tree (g) grafted tree for fruit production and (h) lopped olive tree for olives and fodder production (Papanastasis *et al.,* 2009).

In addition to the pastoral component of the trees, SPs traditionally provided many other goods, especially timber, firewood and charcoal. Although the use of this energy has almost disappeared, this could have a new chance with the EU target of renewable energy. New opportunities are also open for high quality timber for which new plantations are being managed as silvopastoral systems. Other products have been traditionally produced in SPs, such as fruits in French *pre-vergers*, Dutch *boguards*, Spanish *pomaradas*, Centroeuropean *streuobstwiesen*, cork in Iberian dehesas, honey, mushrooms and medicinal plants. The production of high quality food (meat, milk, cheese) together with the recreational and cultural services could be important drivers of the economic revitalization of SPs. Iberian pig ham is a good example of high quality foods supported by SP practices. Previous research has demonstrated welfare benefits from agroforestry and in some countries producers have capitalized on this in product marketing i.e. the promotion of woodland eggs in the UK, and agroforestry-raised chicken in France and Italy. Good examples of the recreational value of SPs are the parklands in UK (Isted 2005), and Iberian dehesas (Surova and Pinto-Correia 2008; Surova *et al.,* 2013).

III – Ecosystem services

There is a general acknowledgment of the important contribution of agroforestry systems to multiple ecosystem services such as carbon sequestration, water quality, biodiversity conservation, control of desertification, soil preservation (Jose 2009). However, the true potential of silvopastoral systems in particular is not well known yet, and more examples are still needed. Here we demonstrate some examples well documented in the literature, mostly for European cases, and identify some gaps of knowledge.

1. Microclimate amelioration

The positive effect of trees on buffering the daily and seasonal variability of air and soil temperature is widely known (Moreno *et al.,* 2007). Although shade usually has detrimental effects for pasture production in high latitude (Silva-Pando *et al.,* 2002), under dry conditions the reduction of excess of radiation could become an advantage, and pasture production be higher under certain level of shade (ca. 50-75% of full sunlight; Quarro *et al.,* 1995; Kyriazopoulos *et al.,* 2006; Moreno 2008). Indirect effects of mitigated soil temperature variations under tree canopy on soil nutrient dynamic are not well known.

Climate change has been identified as one of the main threat to agriculture across Europe for the future (Brisson *et al.,* 2010). Recent findings indicate that agroforestry systems may be more resilient to climate change, as the tree cover may reduce some concerning events such as early heat and drought stresses on herbaceous understory (Schoeneberger *et al.,* 2012).

Animal welfare is becoming an important issue for the European Union and is included in the strategic guidelines for rural development. The shelter provided by trees in silvopastures is a key element (Rigueiro-Rodriguez *et al.,* 2009). For example, cows kept cool produce more milk under better animal welfare conditions (Oosterbaan and Kuiters 2009).

2. Soil fertilization

The turnover rate of nutrients on the soil surface of SPs is unusually high because the action of herbivores (e.g., litterfall decomposes up to 24 times faster in dehesa than in dense forest; Escudero *et al.,* 1985). Trees also play a prominent role in the process, because roots bring up nutrients from deep in the soil profile that is inaccessible to herbaceous vegetation (Young 1997) and net mineralization is higher beneath than beyond the canopy cover (Gallardo *et al.,* 2000). As result, soils beneath the tree canopy are richer in soil organic matter (SOM) and nutrients than soil beyond the canopy (Moreno *et al.,* 2013).

As a consequence, trees frequently have a positive effect on pasture production (Figure 1), especially in unfertilized oligotrophic soils (Moreno *et al.,* 2007). However, the effect of trees on pasture is a controversial issue. Many authors have reported a positive effect on pasture yield and nutritional quality, length of growing season, and stability against climatic variability, but other studies failed or found the contrary results (see Moreno *et al.,* 2013 for a review). As these authors state, the contradictory results are caused by the complex interactions that occur among trees and pastures, with a dominant role of water competition in dry areas and for light in high latitude regions. However, more studies are still needed to know under what ecological conditions and which species combinations produce the more favorable balance in term of pasture productivity.

3. Carbon sequestration and reduction of greenhouse gases emission

During the past 20 years, there has been an increasing appreciation of the extent of the negative externalities associated with livestock production, either as grazed ruminants or animals such a pigs and poultry (Burgess and Morris 2009). The key negative externalities include methane production by ruminants, ammonia and nitrous oxide production by all forms of livestock production and emissions related to feed production. Recently it was estimated that Europe's meat and dairy consumption was responsible for 14% of the total CO_2 emissions in the EU (Weidema *et al.,* 2008), and livestock production is seen as a key driver of global land use changes, with resulting impacts on climate change and biodiversity.

The integration of trees with livestock is seen as one method to mitigate ammonia emissions, and to store carbon as an offset for methane and nitrous oxide production (Hristov *et al.,* 2013). The contribution of trees to the build-up of the soil carbon pool has been repeatedly reported (Mosquera-Losada *et al.,* 2011) and comparison among pastures and silvopastures show that C pool is significantly higher in the latter ones (Nair 2012). Long-term effects of improved pasture establishment in Portuguese montados caused higher organic-C than those under unmanaged pasture, and the effects were stronger in the presence of oak trees (Gómez-Rey *et al.,* 2012). Howllet *et al.,* (2011a) and Howlett *et al.,* (2011b) reported good examples for Atlantic and Mediterranean oak SPs of Spain. In these studies, soil C was almost doubled beneath tree canopies compared to open pastures. The higher inputs of residues generated by trees in SPs than in tree-less systems may cause high soil C sequestration potential and C could be stored deeper and for longer, what need to be more explored.

4. Water quality

The move from mixed arable-livestock farming towards greater specialization, together with the general intensification of food production has had adverse effects on the environment. Livestock systems have largely become separated into pasture-based (cattle and sheep) and indoor systems (pigs and poultry).The increased losses of nutrients, farm effluents (e.g. livestock wastes), pesticides such as sheep-dipping chemicals, bacterial and protozoan contamination of soil and water are some of the main concerns regarding water quality degradation. There has been a general uncoupling of nutrient cycles, with frequent problems of unacceptable high nutrient deposition or uneven spatial distribution (Hooda *et al.,* 2000).

In this context of the Water Framework Directive, the need for reducing diffuse pollution from agriculture to water bodies imposes important costs to livestock farms (Fezzi *et al.,* 2008). Different studies have showed the capacity of deep rooting trees to capture nutrients from deep layer that are not anymore utilizable by herbaceous plants, and thus reduce nutrient leaching in SPs (e.g., Bambo *et al.,* 2009 and López-Díaz *et al.,* 2011 for N; Nair *et al.,* 2004 and Blazier *et al.,* 2008 for P). Recent research showed integrating pigs in a willow/miscanthus plantation results in a much smaller risk for N leaching than typically seen on grassland with the same stocking rate (Sørensen 2010) and that the pigs only caused limited damage to the trees (Horsted *et al.,* 2012). The optimal tree cover needed for an efficient control of nutrient leaching is however unknown.

5. Biodiversity

Diaz (2008) and Marañon *et al.,* (2009) compiles a huge number of studies that reported a noticeably high diversity of vascular plants, birds, mammals, lizards and butterflies for Iberian dehesas compared to other adjacent land uses. Bermeier *et al.,* (2010) reported similar results for vascular plants, birds, snails and beetles for other European SPs. An increase in invertebrate species and numbers has been reported when moving from open grassland to agroforestry conditions for carbid beetles in Northern Ireland (Cuthbertson and McAdam 1996) and for four arthropod groups in Scotland (Dennis *et al.,* 1996). Burgess (1999) also reports on the benefits of silvoarable systems, relative to traditional agriculture, in terms of the number of birds and mammals. Gillet *et al.,* (1999) determined a plant species richness optimum at 30% of tree cover for SPs of Swiss Jura Mountains.

Trees provide multiple tree-based gradients, in terms of light, soil nutrients and moisture, food availability, refuge, even certain low level of disturbance caused by uneven use of space by livestock (Moreno *et al.,* 2013). This fine-grained mosaic of microhabitats is a key factor for high species diversity of SPs (Bergmeier *et al.,* 2010). Besides, trees are essential sources of food and refuge. Indeed, they have a disproportionate value for different taxa, as reported by Fischer *et al.,* (2010) for birds and bats in an Australian livestock grazing landscape. Compared to treeless sites, bird richness doubled with the presence of the first tree; bat richness tripled with the presence of 3-5 trees (2-ha sites; n = 108 sites of 33 farms); and bat activity increased by a factor of 100 with the presence of 3-5 trees.

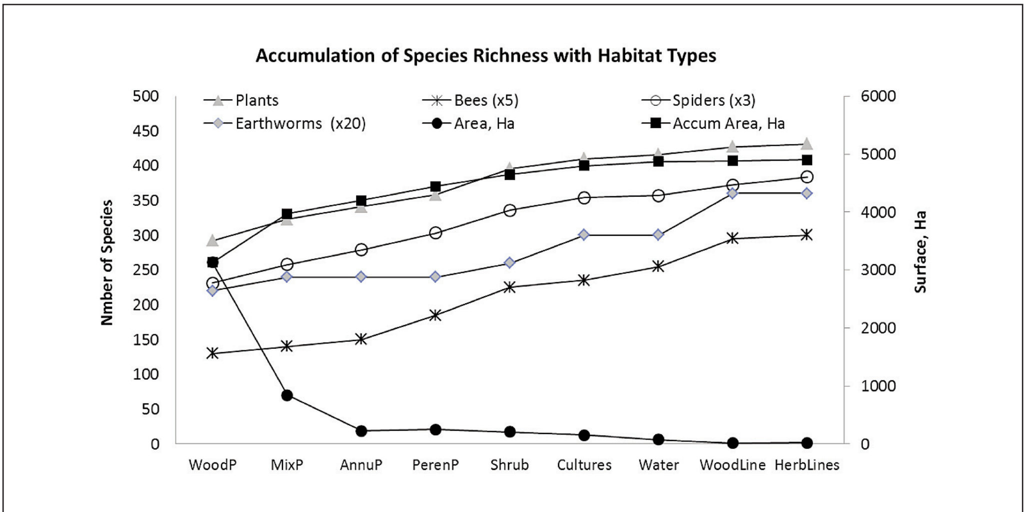

Fig. 3. Curves of accumulation of species with different habitats types of Iberian dehesas compared with the accumulation of surface occupied by those habitats. WoodP, MixP, AnnuP and PerenP refer to wood pastures, mix, annual and perennial pastures (Moreno *et al.,* 2014). Note that main fields (pastures that all together cover > 90% of farm surface) harbors only ca. 70% of species, and that marginal habitats contributed significantly to species richness of the dehesa farms.

In a recent study conducted in Iberian dehesas, Moreno *et al.,* (2014) reported higher species richness for vascular plants (primary producers), bees (pollinators), spiders (depredators) and earthworms (decomposers) in wood pastures than in adjacent monopastures. Moreover, there was very high β diversity (spatial heterogeneity) among different types of pasture within farms. While monopasture plots shared a high number of species among them, plots with wood pastures exhibited very different species assemblages. Finally, although wood pastures and monopastures displayed high number of species (alpha diversity), the fine mosaic of habitats within farms, including some marginal habitats and linear features (common in many silvopastures) played a very significant role in terms of species richness at farm-level and landscape-level (γ diversity; Fig. 3). Indeed, habitat heterogeneity at multiple spatial scales has been revealed as key for biodiversity conservation (Benton *et al.,* 2003; Concepción *et al.,* 2012).

6. Reduction of fire risk

Within Europe, Mediterranean rangelands and forests are prone to wild fire. Although less important, some continental and atlantic mountainous regions also suffer periodical wildfires. Important projects of silvopastoral management of fire-prone rangelands have been successfully implemented in Southern France (Etienne *et al.,* 1996), Italy (Pardini 2002; Franca *et al.,* 2012) and Spain (Rigueiro-Rodríguez *et al.,* 1999; Ruiz-Mirazo *et al.,* 2011; Casals *et al.,* 2009). Livestock feces, trampling and browsing can kill shrubs at a medium term, although anti-nutritional components of woody vegetation hinder the efficiency of livestock as fireguard (Rigueiro-Rodríguez *et al.,* 2009). Pasadolos-Tato *et al.,* (2009) evaluated the economics of silvopastoral systems established in Northern Spain on abandoned croplands afforested with *Pinus radiata* D. SPs were always more profitable than single timber production systems when fire risk was included in the analyses. Casals *et al.,* (2009) found that forest grazing is seen as the best cost-effective treatment (6-30 € ha^{-1} per year depending on animal type and management system adopted), in spite of the fact that it requires certain investments (water supplies, fences…) and must be combined with complementary shrub control. Using combination of manual and mechanical treatments alone costs 200-300 € ha^{-1} per year, with a return interval of 3-to-5 years. Fuel reduction by prescribed fires costs 600-1,000 € ha^{-1} and cannot be used repeatedly without jeopardizing the nitrogen fertility of the ecosystem (Casals *et al.,* 2004).

IV – Silvopastures dynamic: patterns and processes

Extensive SPs result from a simplification, in structure and species richness, of native forests, and are attained by tree clearance, eliminating of shrubs, and favoring grasses by means of grazing and occasionally forage sown. The landscape formed is maintained by a balance between divergent ecological processes such as grazing pressure and tree regeneration (Battler *et al.,* 2009). The coexistence of patches of pastures, woodlands and/or isolated trees is therefore a result of an unstable equilibrium, which can lead either to closed forests or to open pastures. Adequate grazing pressure for the maintenance of sufficient but not excessive tree/shrub regeneration is crucial for the persistence of SPs.

Low profitability is becoming a common characteristic of most of European SPs and owners are pushed either to the intensification of the farms (e.g., increasing stocking rate) or to their abandonment (Campos *et al.,* 2009; Pinto-Correia *et al.,* 2011). Intensification produces a loss of habitat and biological diversity. In Europe, many traditional SPs, especially those associated to fruit orchards or dense networks of hedgerows, were lost along the XXth century by farm consolidation programs (Eichhorn *et al.,* 2006). When intensification is made through the increment of stocking rate, leads to progressive soil degradation, lack of tree regeneration, overage of tree population, and thus to a gradual deforestation (Smit *et al.,* 2005; McEvoy *et al.,* 2006; Mayer 2009; Moreno and Pulido 2009; Plienninger *et al.,* 2010).

Overgrazing is one of the causes argued by many authors for the progressive loss of young trees in scattered-trees systems (Fisher *et al.,* 2009; Pinto-Correia and Godinho 2013; Fig. 4). Gibbons *et al.,* (2008) developed a simulation model to predict the rates at which these trees are declining in several landscapes, including some SPs. They predicted that mature trees would be lost from these landscapes in 90-180 years if current trends persist. The loss of scattered mature trees was most sensitive to tree mortality, stand age, number of recruits, and frequency of recruitment. Management need therefore be adapted to ensure the long persistence of extensive SPs that depends on soil fertility conservation and the natural regeneration of trees. A more rational grazing scheme, including periodical grazing exclusion, has been proposed for Iberian dehesas (Pulido *et al.,* 2010), what still deserves more research.

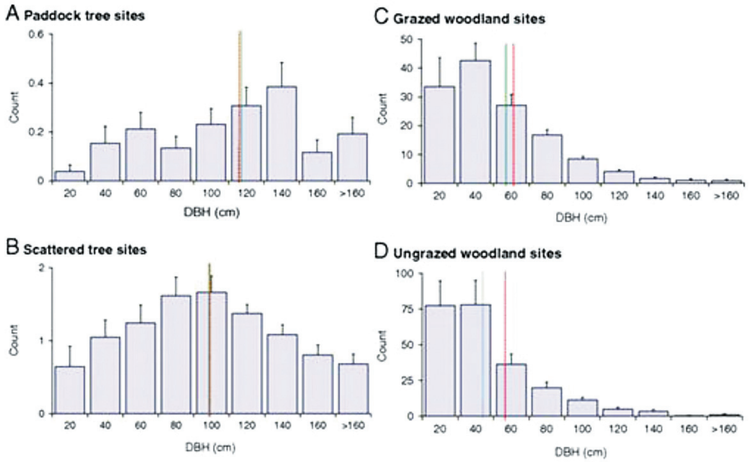

Fig. 4. Mean count of trees (and standard error) in different diameter classes across four agrarian systems that follow a decreasing gradient of grazing pressure: paddock (*A*), scattered (*B*), grazed (*C*), and ungrazed (*D*). Mean diameter is indicated by a dotted red line and median diameter is indicated by a solid green line (Fisher *et al.,* 2009).

Undergrazing results in the loss of the characteristic open two-layer structure of SPs to become dense forests or scrublands. Papanastasis *et al.,* (2009) described the rapid loss of SPs due to the progressive cessation of pastoral activities in Greek mountains, where the rural population exodus deprived these areas of the necessary labor to maintain SPs activities. Buttler *et al.,* (2009) reported a good example of patterns and processes occurring in mountain SPs based on experimental and observational studies carried out at various spatial scales across Swiss Jura Mountains. They revealed a high heterogeneity of large herbivore activities at both fine and large scales, with strong influence on the dynamics of plant species in the herb layer. Natural tree regeneration was closely affected by both herbivores activity and heterogeneous environment (e.g., presence of nurse plants). They also found out that with low grazing pressure a rich spatial mosaic is maintained, and it lost when grazing pressure is increased. Through a spatially explicit mosaic compartment model, Gillet (2008) modeled the dynamics of these silvopastoral ecosystems showing that the patterns of vegetation and cattle habitat use evolved very slowly toward a permanent state dominated by wood-pastures, strongly dependent on the spatial configuration of the environment. However, taking into account the effect of climate change, closed forests and densely wooded pastures tended to dominate and vegetation diversity to decrease (Fig. 5).

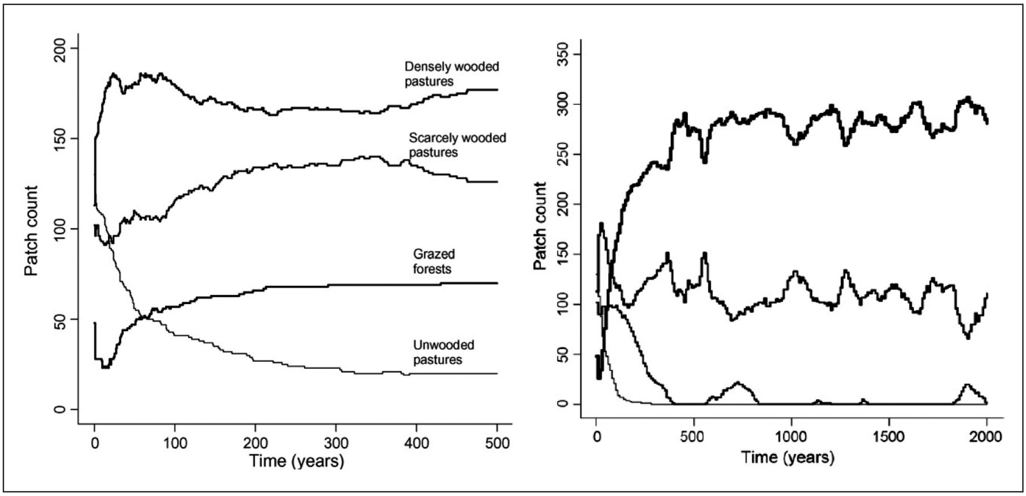

Fig. 5. Simulation of the dynamics of the landscape mosaic in a pasture-woodland in Swiss Jura mountains with environmental and management conditions fixed to their initial values (left) or including a linear temperature increase of 1.2 ºC per century (right). (Adapted from Gillet 2008).

V – Challenges and new opportunities

SPs, mostly based on traditional empirical knowledge, are increasingly threatened due to oversimplification of management techniques and rural depopulation. Currently they constitute only a minor part of the total livestock production. In these circumstances, and in order to be able to compete with conventional products, both the public perception and the management schemes must urgently be reoriented. For this reason, there is a strong demand for scientific knowledge and innovative management tools that may constitute an integrated system of support for decision making. Here we discuss some open fields of innovations.

1. Tree regeneration and nursery plants

One of the most determinant issue in the ecological sustainability of the system is strongly related with tree regeneration. The age structure of many systems is unbalanced (e.g. the Dehesa system in Spain and the parkland system in the UK). Methods to increase the cover of young trees include tree planting with protective fencing, but this can be very expensive. In recent years, important effort are being initiated to find out new management practices that reconcile land use (grazing) with tree regeneration, and promising results indicate the important role that nursery shrubs and periodical grazing exclusion could play (Gómez-Aparicio, 2009; Pulido *et al.,* 2010). Further analyses are needed to disentangle the effect of the different factors and nurse species involved in the regeneration process of trees (Rolo *et al.,* 2012).

2. Ecological intensification

Livestock breeders are interested in increasing the quality of the feed as well as to diversify forage offer (mitigating seasonal shortages). Some recent experiences in Portuguese *montado*, with the sowing of biodiverse permanent mixtures rich in legumes (Aguiar *et al.,* 2011) and in Sardinian oak woodlands, with the sowing of mixtures of autochthonous pasture grasses and legumes (Franca *et al.*, pers. comm.) evidence the need of a specific selection of seed mixtures suitable for silvopastoral purposes, where herbaceous plants have to cope with shade and competition imposed by trees. Intercrops with leguminous *shrubs forage* (*Medicago arborea*, *Atriplex* sp., *Acacia sp.*), but also with mulberry (*Morus* spp) and carob (Ceratonia siliquoa) is a promising way to overcome seasonal shortages of forage. Some studies have been conducted to identify shrubs species of nutritional value as part of the summer or winter diet of livestock (Robles and Passera 1995). Under current trend to aridification of Mediterranean region, shrubs species with high water-use efficient need to be explored as fodder source.

The genetic base of currently sown pastures is very narrow: more than three-quarters of the grass cultivars registered in the European Union are of just six species, and *Lolium perenne* and L. *multiflorum* account for more than 80 percent of the forage grass seed sold in the EU (Batello *et al.,* 2008). All them were selected under full sunlight conditions. Moreover, the availability in the seed market of pasture species suitable for dry environments (e.g. semiarid Mediterranean areas) is still scarce (Porqueddu and Gonzalez, 2006). There is need of widening the choice of available high-value grass and legume cultivars by exploring, evaluating and selecting from a wide range of species of several genera. More specifically there is still a need to improve our understanding of the positive (facilitative) and negative (competitive) effects of trees on different pasture species (or genotypes) to be used to improve pasture quality and productivity in SPs (Fig. 6).

3. High Nature Value farming

Agricultural intensification has led to a widespread decline in farmland biodiversity across many different taxa (Benton *et al.,* 2003), but farmland also hosts many species that depend on appropriate agricultural management (Kleijn *et al.,* 2003). One current proposal is that at least 7% of the utilized agricultural area of each farm should be allocated to ecological focus areas, which could include landscape features, buffer strips or afforested areas. It has been proposed that conserving what is left is more effective than getting back to what was lost, and consequently biodiversity conservation is more likely to be effective on farmlands that are already managed at low intensity and that retain a certain amount of seminatural vegetation (Kleijn *et al.,* 2011). At farm level, these criteria are mostly accomplished by extensive pasturelands that consist of grassland, scrub or woodland or a combination of different types, used for raising livestock (Parachinni *et al.,* 2008). Indeed, extensive pasturelands are dominant in the last European map of High Nature Value farming (Oppermann *et al.,* 2012).

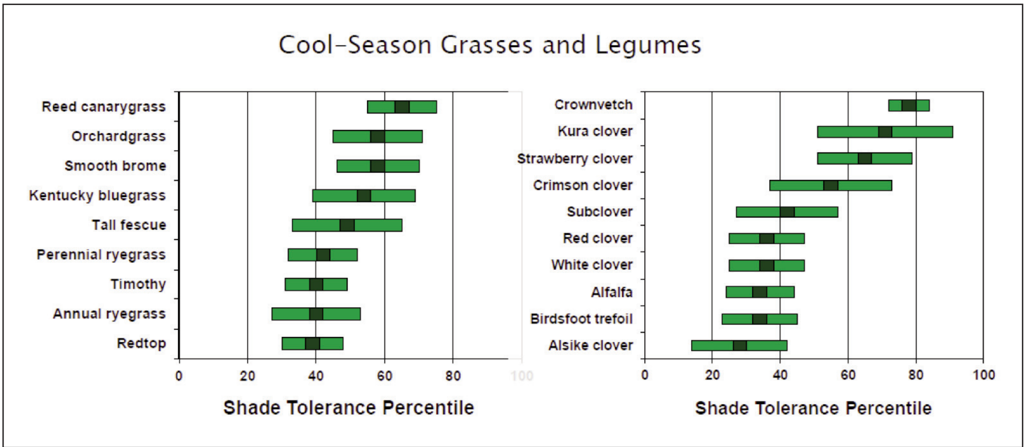

Fig. 6. Results of ten years of screening forage species for shade tolerance that clearly demonstrate that many cool-season forages benefit from 40% to 60% shade when grown in Missouri. Grazing trials have proven to be successful at least in the short-term (Adapted from Garret *et al.,* 2004).

4. Carbon sequestration and Life Cycle Assessments

The increasing intensification of many SPs, especially those in Mediterranean regions, has produced a worrying loss of soil quality (Coelho *et al.,* 2004), and new management practices that favor the increment of soil organic matter are now needed. Two kinds of materials could be useful for this purpose: ramial wood (Dodelin *et al.,* 2007) and biomass charcoal (Kimetu *et al.,* 2008). Both imply a "source" ecosystem (they can be produced in SPs) and a "sink" ecosystem (can be used to improve soil conditions and at the same time to store C for long time). In Europe there is an increased demand of biomass crops dedicated to bioenergy (Burgess *et al.,* 2012). The opportunity to produce (or use the excess of) wood biomass in SPs as local or in-farm source of energy has gained a recent interest. Incorporating life cycle assessments (LCA) that compute C cycle and overall C sequestration/emission for agrarian systems and products is also needed, and presumably would give a new momentum to SPs (Upson and Burgess 2012).

5. Branding high quality products of SPs

Advances in reliable assessments of the LCA, together with the identification (and quantification) of multiple ecosystems services provided by SPs should be associated with controlled certification processes. This would enable consumers to buy products with high environmental added-value. There is a focus on producing and marketing high value products from SPs. One of the most prominent examples is pig meat production in the Iberian dehesas with local Iberian pig. In other systems (e.g. Parkland systems in the UK), the systems are of particularly high cultural value. New needs for natural and high quality products derived from extensive SPs need also to be explored, as acorn-derived products (tannins for tan leather and for antioxidant uses, gluten-free flours, unsaturated fat …). However, the pace at which new market demands and environmental changes arise exceeds the capacity of individual managers to react accordingly. There is a need for decision-making support tools and more, for joint participatory actions supporting decision, which should be implemented (Pinto-Correia and Godinho 2013).

VI – Research agenda

There is an urgent need of promotion of SP practices across European pastoral areas that will advance sustainable rural development, i.e. innovative practices to assure the ecological persistence of SPs, improved competitiveness, and social and environmental enhancement.

To achieve this, we propose:

1. The elaboration of a comprehensive and categorized map, and the associated database of pastoral systems and grazing strategies within forest and woodland;
2. Selection and multiplication of species suitable for different silvopastoral conditions, with focus on site-specific mixtures, identified on the basis of pedo-climatic conditions and grazing characteristics;
3. Studies focusing on the conditions under which net balance of trees is positive (facilitation) or negative (competition) for pasture understory, what surprisingly is still lacking;
4. Improved knowledge on how silviculture and management practices can make forest more productive and better adapted to climate change adapted (e.g., determine the optimum tree density);
5. The analysis of consequences and opportunities of woody encroachment of extensive pastoral systems (as fodder and nursery plants) should also deserve more attention;

6. The scientific evaluation of environmental services, as reducing forest fires, C storage reinforcements, control of water loss and quality, and biodiversity preservation, under different environmental and management context;
7. Improved understanding of the trade-offs among those services;
8. Diversification and increment of forage offer (mitigating seasonal shortages) and other marketable products of SPs;
9. Economical evaluation of SPs including environmental goods and services (green accounting);
10. Finally, the popularization of the link among silvopastoral practices with the production of high-quality products and the provision of public environmental services.
11. And finally, there is a need for an increased understanding on landholders decision making process, and the drivers that mostly affect their choices, so that better targeted public interventions can be developed.

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Grazing management aimed at producing landscape mosaics to restore and enhance biodiversity in Mediterranean ecosystems

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Abstract. This article reviews some of the main effects of livestock grazing on landscape characteristics at different scales, from patch to landscape level. Examples are presented mostly from long-term research conducted in a 500 hectare Mediterranean nature park in Israel. The proposed approach views cattle and goat grazing as management tools targeted at creating a heterogeneous landscape mosaic to enhance biodiversity, restore wildlife habitats and maintain high amenity value for visitors. Managers, researchers, nature conservationists, goat and cattle breeders, and the local community collaborate to maximize the benefits from this relatively small area and create a multi-functional piece of land. Understanding the different factors that influence the way in which grazing affects the natural ecosystem, such as grazing history, grazing pressure, or livestock species, helps us to conduct the most suitable management regime for different areas in the park. Practical examples of grazing plan implementation are presented for cattle and goat herds, which apart from being an agricultural production enterprise, supply grazing as a high quality environmental service.

Keywords. Grazing service – Landscape structure – Multi-functionality – Habitat diversity – Heterogeneity.

Gestion du pâturage visant à produire une mosaïque de paysages pour restaurer et renforcer la biodiversité

Résumé. *Cet article recense certains des principaux effets du pâturage du bétail sur les caractéristiques du paysage à différents niveaux d'échelle, de la parcelle au paysage dans sa globalité. Des exemples sont présentés, issus principalement d'une recherche conduite à long terme dans un parc naturel de 500 hectares en Israël. L'approche proposée considère le pâturage des bovins et des chèvres comme un outil de gestion visant à créer une mosaïque hétérogène de paysages permettant de renforcer la biodiversité, de restaurer les habitats sauvages et de maintenir une haute valeur d'attrait pour les visiteurs. Gestionnaires, chercheurs, écologistes, éleveurs de bovins et de chèvres, ainsi que la communauté locale joignent leurs efforts de façon à maximiser les bénéfices dérivants d'une aire relativement petite et à en faire un espace multifonctionnel. La compréhension des différents facteurs qui influencent la façon dont le pâturage modifie l'écosystème naturel, comme l'historique du pâturage, l'intensité du pâturage ou les espèces animales utilisées, nous aide à mettre en pratique le régime de gestion approprié aux différentes régions du parc. Sont également présentés des exemples concrets de mise en pratique de plan de pâturage pour des troupeaux de bovins ou de chèvres qui combinent entreprise de production agricole et service environnemental de haute qualité.*

Mots-clés. *Service de pâturage – Structure du paysage – Multifonctionnalité – Diversité de l'habitat – Hétérogénéité.*

I – Introduction

Rangelands are of great importance for the quality of life on earth. They provide various goods and services, such as food and fiber, carbon sequestration, genetic diversity, recreational areas, and heritage values. Since the domestication of major livestock species some10,000 years ago, grazing has been the main practice for livestock feeding in most parts of the world. As opposed to modern intensive farming, where feed is presented to animals in pens or feedlots, grazing as a practice has an enormous effect on the spatial structure (Henkin *et al.,* 2007) and hence on ecosystem function, in terms of biodiversity, wildlife habitats (Lunt, 2005), and micro-climate (Yates *et al.,* 2000).

Livestock production is defined as the production of protein (milk and meat) and fiber for human consumption and use. In recent decades, livestock production based on grazing has decreased in many regions of the world (Bouwman *et al.,* 2005). This trend has strongly affected many of the rangeland ecosystems, causing profound changes, some of which, such as shrub encroachment, are considered undesirable (Barbaro *et al.,* 2001). Under these circumstances, the idea of using "grazing services" as a tool for rangeland ecological enhancement has arisen.

Naturally, the main effect of grazing on the landscape is expressed through changes in vegetation pattern and composition. The nature and extent of these changes depend on livestock species (Rook *et al.,* 2004), grazing history (Perevolotsky and Seligman, 1998), vegetation formation and grazing intensity (Coffin *et al.,* 1998), as well as on a-biotic variables such as soil type and precipitation. Global processes such as climate change also play a major role in determining successional trends (Mouillot *et al.,* 2002).

The aim of this article is to propose the use of livestock for the restoration and enhancement of biodiversity, through the creation of landscape mosaics at different scales.

II – Background

1. Spatial heterogeneity and functional heterogeneity

The relationships between landscape pattern and process, as well as the scale at which the landscape demonstrates patchiness, are of major interest in landscape ecology. The term 'spatial heterogeneity' has many different aspects. It can be viewed as a static state or as a dynamic process, as the result of deterministic factors only, or as subject to random or chaotic behaviors. Heterogeneity can be measured by various indices based on the different values of a selected parameter (such as vegetation cover) at different locations. The variable measured (e.g., Shannon's diversity index or the number of different patches) represents the observer's perspective and only a small aspect of the system heterogeneity. This approach, despite its convenience, may have low biological relevance. An alternative approach may be relating to the 'functional heterogeneity,' a more qualitative and multidimensional term, defined by the perspective of the ecological units of interest, e.g., the individual, species, or community (Kolasa & Rollo 1991). Functional heterogeneity is scale-dependent and is most relevant to ecological processes.

Spatial heterogeneity occurs either as a gradient, i.e., gradual variation over space, or as a mosaic composed of patches with distinct boundaries. The term 'spatial pattern' refers to the number, size, and juxtaposition of landscape elements or patches. It has important consequences regarding the effective dispersal of propagules and the spread of disturbance across a landscape (Dunn *et al*., 1990). Substrate heterogeneity, natural disturbance and human activity are three mechanisms that create the spatial pattern.

2. Scale dependency

Mediterranean landscapes are multi-scale mosaics of different vegetation types, associated with high ecological diversity. The recognition of the importance of conserving landscape mosaics has broadened the goals of rangeland management from relatively narrow targets, such as the conservation of a certain species, habitat or pattern, to a multi-scale and multi-purpose perception that identifies the importance of ecosystem structural and functional diversity (Stalmans *et al*., 2001).

Landscape mosaics, and hence grazing effects on them, must be viewed at different spatial scales. A small scale relatively homogenous structure that differs from its surroundings can be defined as a "patch" (Forman, 1997). A wider management unit comprised of many patches is considered a "plot". The largest scale of reference will be the "landscape", which may consist of one or more plots and habitats. These definitions are of course fluent, subjective and interact with each other in many ways. Today the importance of scale in ecological studies is well recognized (Wiens, 1989), and it seems impossible to understand ecological processes without scale determination.

3. Livestock grazing, heterogeneity and biodiversity

As opposed to disturbances, such as wildfire or clearing, which exhibit a pronounced and concentrated effect on the landscape, grazing is usually a continuous process and should be studied accordingly. It may shift vegetation structure in different directions depending on initial vegetation formation, animal species, grazing intensity and the way it is spatially distributed (Adler *et al*., 2001) Many studies demonstrate an increase in spatial heterogeneity under grazing conditions, mainly due to the dynamics between grazed and ungrazed patches, and to other effects of grazing, such as manuring and trampling (Hadar *et al*., 2000). These changes influence ecosystem function, for instance, through changes in the distribution of many species (Christensen,1997). In many cases, an increase in species richness is found under grazing, when many more species are able to maintain themselves in a variety of microhabitats (Whittaker 1977; Lavorel 1997).

In Mediterranean ecosystems, different patch types play different roles as "landscape modulators" (Shachak *et al*.,2008) that filter species composition within the patch. Different woody patches impose different sets of abiotic conditions thus inhabit different plant communities (Blank & Carmel, 2012). The size and shape of a patch also affect the composition, richness and diversity within it (Gabay, 2008). Consequently, many researchers see heterogeneity as the basis for conservation and ecosystem management (Christensen., 1997; Ostfeld *et al*., 1997; Wiens., 1997).

Grazing effects on biodiversity vary widely depending on conditions, such as invasion risk of certain plant species; grazing history; site productivity; plant palatability and plant regeneration requirements (Lunt, 2005). Nonetheless, it is possible to predict or evaluate the expected outcomes under similar conditions or ecosystems. Some examples can be found in species-rich Mediterranean ecosystems (Lavorel, 1999) where successional processes are well determined (Naveh, 1994). Many of these ecosystems have a long history of grazing (Blondel, 2006), and are characterized by a variety of mechanisms against herbivores, such as secondary compounds, high lignin concentration and thorniness, which lead to low palatability for livestock (Hartley & Jones, 1997).

Mediterranean landscapes are characterized by high woody vegetation cover, with patches of herbaceous vegetation and a heterogeneous structure. The introduction of livestock into these ecosystems is considered a disturbance (McIntyre *et al*., 2003), although for ecosystems that had developed under strong human impact, the cessation of grazing is, in fact, the un-natural situation. Natural processes with no interference will lead to dense scrublands and woodlands, with high fire risk, low landscape and habitat diversity, low amenity value (Carmel & Kadmon, 1999, Pausas & Vallejo, 1999), as well as low feed quality for livestock (Kababya *et al.,*1998).

In this paper we address the effects of grazing in which livestock directly affect landscape spatial structure and pattern and leads to changes in plant and animal communities, and we present the use of cattle and goat herds in order to achieve the desired conservation goals.

The cases presented here were studies conducted at Ramat Hanadiv, a 450 hectare privately owned Nature Park, located in the Mediterranean region of Israel (fig. 1). With over 25 years of intensive ecological research, and a long-term base of knowledge, the park serves as a "field lab" for testing conflicts between different parties of interest-managers, researchers, nature conservationists, goat and cattle breeders, and the local community.

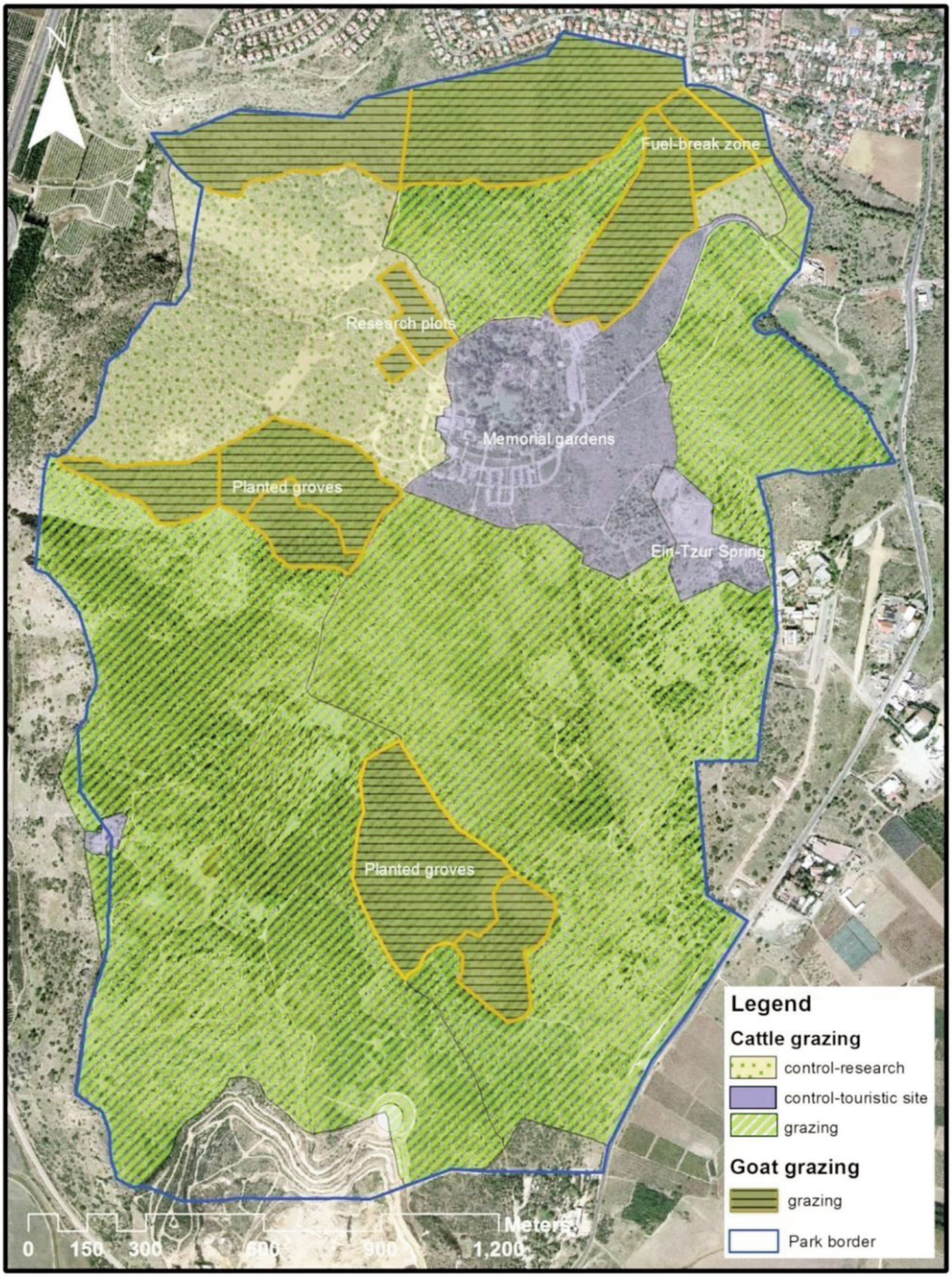

Fig. 1. Ramat Hanadiv Nature Park and the different sites subjected to goat or cattle grazing or not grazed.

III – Grazing effects on vegetation structure and ecosystem function

Spatial structure can be viewed in different dimensions, e.g. from the view of the human eye (horizontally) or the wider birds'-eye view (vertically). Spatial patterns are usually viewed and analyzed from the bird's-eye view by aerial photography analysis or other remote sensing techniques. The main advantages of these techniques are that they are easier to quantify, do not necessitate intensive field work, and enable landscape scale analyses. However, when dealing with shrublands or forests, structural changes occur under the canopy and will not be detected by most remote sensing techniques. Bar-Massada and his colleagues analyzed changes in small scale spatial patterns in a Mediterranean garrigue as a result of goat grazing and shrub clearing treatments (Bar-Massada *et al.,* 2008). They used several common landscape ecology indices for the investigation of the structural attributes of patches and landscape patterns. Among them are total woody vegetation cover, patch size, patch density and edge density. They found that the combination of grazing and clearing in small scale plots (0.1 ha) shifted landscape pattern towards higher patch densities, smaller patches with greater distances between them and with significantly longer edges (fig. 2). Similar trends were found in an open rangeland subjected to goat grazing (Glasser *et al.,* 2013). These structural changes have functional ramifications from the patch level to the plot and the landscape levels, as well as on the interaction between patches. Examples of interaction between closed (woody) patches and open (herbaceous) patches regarding plant community diversity following grazing and shrub clearing are changes in seed dispersal ability and patterns (Gabay, 2008), as well as changes in seed bank composition of the different species (Dutoit and Alard., 1995). These changes must be seen at different scales. Gabay (2008) found no significant effects of grazing on plant density or on species richness at the plot scale level (0.1 ha.) under goat grazing. Nonetheless, when analyzed at the patch level, significant differences in species richness and composition were found. Hence, grazing alters the spatial dispersal of species without changing their richness. Due to these results it was concluded that in landscapes exhibiting a mosaic of closed and open patches, separate analyses for the plot scale and for the patch scale is recommended due to the differential effects of grazing on different patch types (closed vs. open).

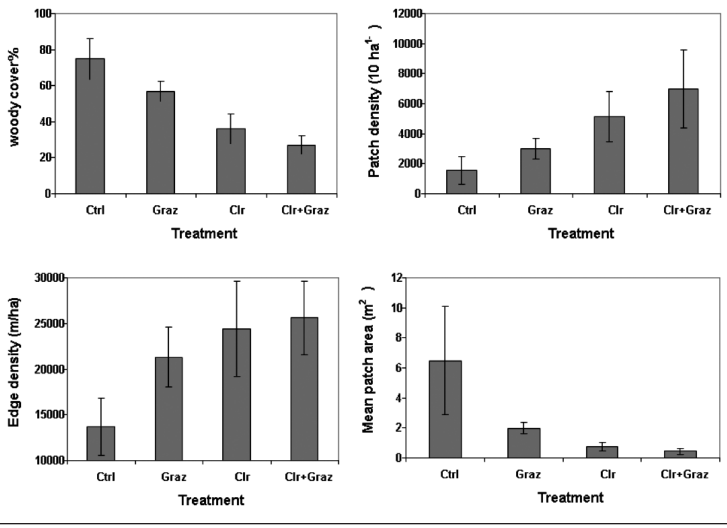

Fig. 2. Average values of landscape metrics for woody patches in the different treatments at the finest scale. The category axis lists the types of treatments: Ctrl–Control, Graz–Goat grazing, Clr–Shrub clearing, Clr+Graz–Clearing with grazing. (adapted from Bar-Massada *et al.*, 2008).

The approach that refers to Mediterranean landscape mosaics as a dichotomy of closed and open patches is argued by Blanc & Carmel (2012), who differentiate among different woody patch types. Woody patches play a major role in the modification of soil temperatures, soil organic matter concentrations, mineralized N, and microbial biomass (Belsky *et al.,* 1989). These changes are of unequal value for different woody patch types created by the different woody species. Different herbaceous species assemblies have affinity to specific woody patches. Species richness and community composition in less dense woody patches were found to be more similar to open patches than to other woody patches (Blank & Carmel, 2012).

Grazing can indirectly affect the expansion of invasive or colonizing species through changes in limiting resources and vegetation structure. An example can be taken from the colonization of *Pinus halepensis*, which is the most widespread pine species in the Mediterranean basin (Osem *et al.,* 2011). The expansion of this species from planted areas to natural shrublands may cause a major landscape change and affect the ecosystem at all levels. *Pinus halepensis* colonization in Ramat Hanadiv Nature Park has increased dramatically in grazed areas in relation to control plots (Osem *et al.,* 2011). Combination of cattle grazing and grazing by goats (which are browsers and can consume large amounts of secondary compounds, (Silanikov *et al.,* 1996) may assist in preventing the expansion of this species by the consumption of pine seedling. This approach has already been presented in controlling juniper encroachment in the southern United States (Ueckert, 1997). The use of livestock in modifying the structure at the landscape level is of great importance not only from a "pure" ecological perspective, but also from the human point of view (e.g. scenery, recreation). As mentioned, in many cases grazing affects landscape structure under the canopy height only. Different livestock species at different grazing regimes will profoundly change this aspect (Fernandez-Lugo *et al.,* 2013). Cattle and goats can exploit shrubs and trees to a height of 1.8-2.0 meters while sheep will utilize the grazing area up to about 1.0 meter. Of course there are differences among livestock species in other parameters, such as browsers vs. grazers, selective vs. more generalist, and other physiological attributes (Hofmann, 1989), These will further affect landscape structure and heterogeneity, important qualities from the human-scale viewpoint, relating to different activities and uses of the area, as well as its aesthetic value (Henkin *et al*., 2007). Cattle and modern goat grazing regimes have been shown to increase the diversity of plant shapes, as well as the landscape accessibility and transparency, by creating a wide diversity of gap shapes and dimensions (e.g. wide and open, narrow and closed) while traditional heavy goat grazing has created only wide and open gaps (Henkin *et al.,* 2007) (fig. 3).

A long-term study conducted at Ramat Hanadiv Nature Park has investigated the relationships between management practices and plant community composition and diversity (Hadar *et al*., 2013; Kent & Carmel, 2011). Data was collected at different sites (garrigue, dense shrubland, cypress grove, pine grove and a fuel-break zone) and treatments (grazed by cattle vs. ungrazed) every second year between 2003-2012. The results of these two studies have shown that cattle grazing alone did not affect plant richness or diversity (Shannon-Weiner and Simpson indices) and caused only a minor change in community composition. Nonetheless, when the cattle grazing was combined with shrub clearing or goat grazing, higher richness and diversity values were found along with a significant change in community composition (Hadar *et al*., 2013) (fig 4).

Another study (Kent & Carmel, 2011) reported that 29%-43% of all species had a significant affinity to a certain treatment (grazing or protection). Among these species, the majority had affinity to the grazing treatment (fig. 5).

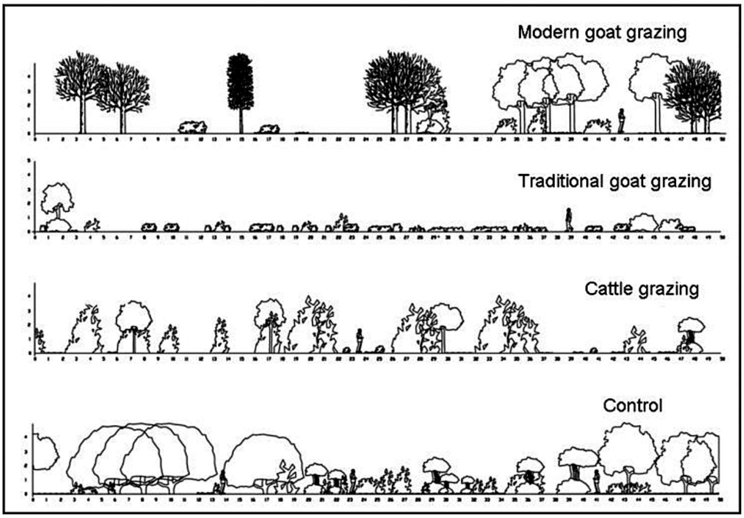

Fig. 3. Drawings that illustrate the structural profiles of the woody vegetation in all four treatments (adapted from Henkin *et al.,* 2007).

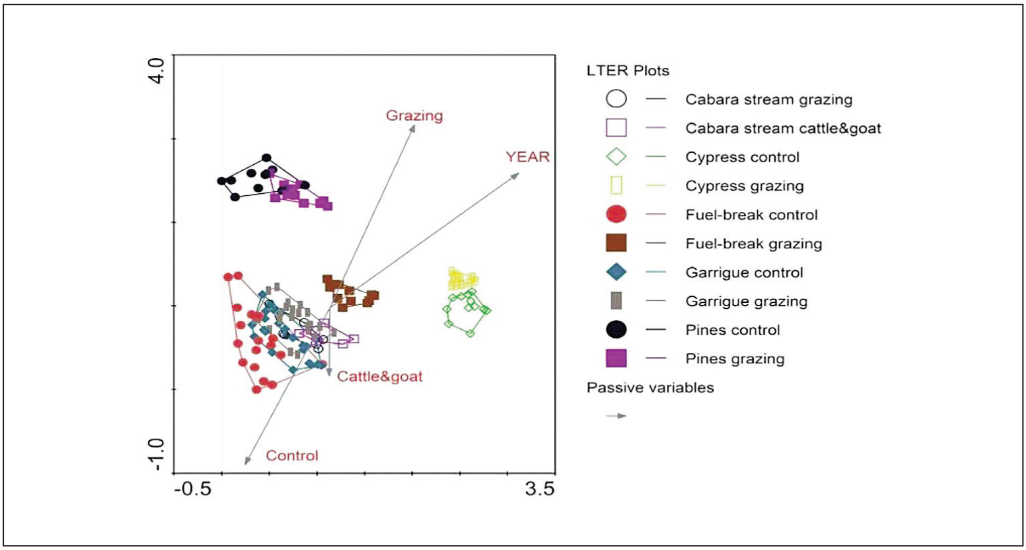

Fig. 4. Site and management effect on species composition. DCA (Detrended Canonical Analysis) on the whole dataset 2003-2008. The passive variables are year, control, grazing (cattle) and cattle & goat grazing. Symbols represent different transects (Adapted from Hadar *et al.,* 2013).

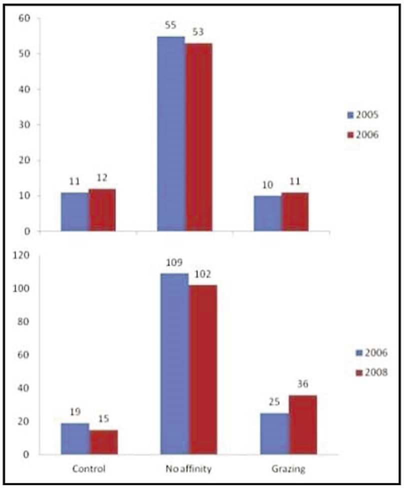

Fig. 5. Number of species found in affinity to a certain treatment compared at different years (2005-2006 top; 2006-2008 bottom). Adapted from Kent and Carmel (2011).

1. Wildlife habitats and diversity

Changes in landscape structure directly affect wildlife habitats at all scales. Arthropod species that need humidity were not found in medium-to-open patches where radiation vaporizes soil moisture (Shure and Phillips, 1991) or where there is increased tree structural diversity that may widen the niches for arboreal arthropods (Lubin *et al*., 2010).

Research conducted at Ramat-Hanadiv has found that shrub clearing reduced the number of spider families, while goat grazing did not have a significant effect on the number of families or on the ground spider community composition. The ground spider community of cut woody patches differed significantly from that of uncut woody patches and was more similar to that of open patches (Lubin *et al*., 2010).

Moderate grazing has been found to positively affect butterfly communities in various habitats around the world (Kirkland, 2002; Krauss *et al*., 2004; Ellis, 2003). In Ramat Hanadiv, research regarding the use of butterflies as bio-indicators has shown that on one hand grazing has positively affected host plants‘ richness, while on the other hand the consumption and trampling of herbaceous vegetation by the cattle has presented a negative trend in their affect on their abundance. This negative trend may have deteriorated the nutritional foundation for butterflies (Schwartz-Tzachor, 2007). One of the management conclusions of this research was that goat grazing, which also contributes to the reduction in woody cover, may assist in retaining butterfly fauna due to minimized trampling effect while expanding the cover of open herbaceous patches (Schwartz-Tzachor, 2007).

Grazing also affects small mammal (i.e., rodent) abundance and diversity (Torre *et al.,* 2007; Jones and Longland, 1999), mainly through a reduction of herbaceous volume, which increases their exposure to predation. (Schmidt & Olsen, 2003; Rosenfeld, 2004) or a reduction of their habitat quality by trampling (Keesing, 1998). Nevertheless, small mammals that depend on rocky refuges would be less susceptible to population changes due to grazing (Rosenfeld, 2004). Interestingly, under moderate cattle grazing small mammal populations have managed to recover by the existing resources, immediately after the cattle has left the area or by the next vegetative growth season (Rosenfeld, 2004).

With regard to ground-nesting birds, cattle grazing, which was assumed to be destructive for this group, was found to positively affect chukars (*Alectoris chukar*) and stone curlew (*Burhinus oedicnemus*) populations, due to a general opening of the dense shrubland. thus providing more sites for nesting (Perelberg 2011; Adar, 2013;). A similar result was found regarding gazelle (*Gazella gazella*) population (Perelberg 2011).

After focusing on the structural and functional effects of grazing from the ecological aspect, we would like to present a practical approach that has been applied at our nature park, which takes into consideration the different aspects, viewpoints and interests.

IV – Implementation of a multi-functional grazing plan

The perception of livestock grazing as a feed source only is limited, and seems irrelevant nowadays. Livestock grazing is increasingly perceived as a tool for landscape and ecosystem management. The vast changes in a range of ecological qualities, such as vegetation structure and biodiversity are only part of the picture. Additional landscape functions and services, such as fuel-breaks or recreation, must be taken into account when introducing livestock to a rangeland. For these reasons we believe that in order to build a good grazing management plan, which maximizes the benefit from this natural resource, all parties of interest (livestock breeders, ecologists, landscape managers and the local community representatives) should work in close collaboration.

When defining a goal for the grazing plan, a multi-functional approach should be implemented that refers to the correct spatial and temporal grazing regime, e.g., in order to avoid flammable dry herbaceous biomass, a fuel-break zone should preferably be grazed by grazers such as cattle or sheep, during a season that will still provide the best nutritional quality. Can this fuel-break zone be simultaneously used for recreational purposes? Should livestock be introduced after flower blooming or even after seed dispersal? Finding this delicate balance is a great challenge for landscape and grazing managers.

In the eyes of a livestock breeder, rangelands provide forage of varying quality. Among his considerations we can identify the importance of feed quality, type of terrain, distance from water resources, management practice (milk or meat production), and location from the farm center or stables. All of these considerations have practical and economic ramifications. Facing the livestock breeder we can find land managers who must take into account ecosystem and natural resources conservation in the rangeland and the wise exploitation of the herd on the premises. Furthermore, many parks, forests and nature reserves under grazing also serve as recreational areas open to the public, and in some cases there are conflicts with certain aspects of the grazing regime (fences, gates, sheds, water troughs, etc.).

1. Management of beef cattle grazing – A test case

Since 1991, a herd of beef cattle has been introduced into the nature park every year to consume most herbaceous biomass, mainly to diminish fire risk and maintain a mosaic of different vegetation structural types. About 30% of the park's area is left as a control without grazing, as wildlife habitats, tourist sites, research plots and for the future. A yearly grazing plan is prepared and takes into account parameters such as rainfall amount and distribution, herbaceous biomass accumulation, and developmental stage. Location of water troughs and feed supplementation points are considered as well. Since the park serves as a recreational area, interaction and potential conflicts with the public (in time and space) must also be considered, particularly the location of electric fences, gates and sheds. Due to fluctuations in precipitation (quantity and timing), a yearly "tentative grazing plan" is prepared in full collaboration with the park manager, other departments staff (visitors, education, research), and the livestock breeder. One of the main factors influencing primary production is precipitation. The amount and distribution of rain is never known beforehand. Research conducted at a climatic gradient in Israel has shown a relation between the amount of rainfall and herbaceous production at different grazing sites, however, in arid areas these relations were stronger (Golodiatz *et al*., 2013). As part of the adaptive management approach, data regarding precipitation as well as the grazing regime in the park are collected constantly. This data is analyzed on yearly basis in order to learn and improve future management practices. Data collected since 1990 has shown that the minimum precipitation that will provide enough forage for cattle grazing is 300mm. Nonetheless, trying to predict when is the right time for introducing the cattle herd into the park is more difficult due to variation in rain distribution. The average rainfall from October to January is 252 mm. Analyzing past data presents a correlation coefficient of 0.4 for the prediction of date of entry by rainfall amount until January 1st (Fig. 6). In order to get more accurate data regarding the amount of vegetation, direct monitoring of available herbaceous biomass along three fixed 1500meter trails located in different areas of the park is conducted. In each trail, ten 25 x 25 cm samples are measured for vegetation cover and height, harvested, dried at 60ºC for 48 hours and vegetation dry biomass is weighed and recorded. For each harvested sample, nine other estimations are recorded without harvesting. This method produces 300 estimations before introducing the cattle herd, 300 estimation during the grazing season and 300 at the end of the grazing season.

This method enables the estimation of the amount of forage available for the cattle and of the biomass remaining after the herd has left the area. It is important to note that in order to achieve goals such as ecological values, fire prevention, and nature conservation with minimal conflict with other parties of interest, much effort should be invested in every grazing season, both in monitoring and in finding creative solutions that might not be ideal for everyone, but can work for the park as a whole.

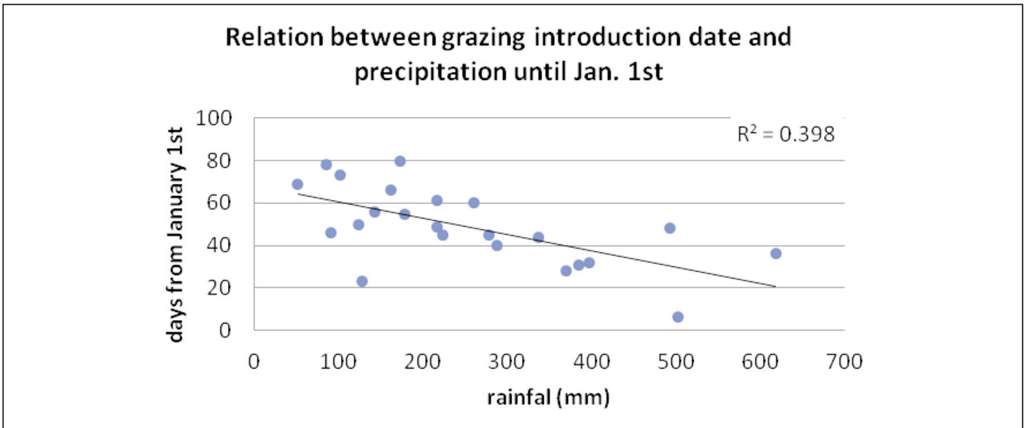

Fig. 6. Relation between amount of rainfall until January 1st and date of grazing introduction into the Ramat-Hanadiv Nature Park. Based on data from 1990-2012.

The main points of conflict are:

Date of entry into the park: Park managers would like the cattle herd to enter the park at a later date, to allow as many species as possible to disperse their seeds, and to minimize conflicts with nature conservationists and hikers, who wish to see the blooming of ornamental plants, especially geophytes. From the livestock breeders' point of view, an early entry of the herd into the area (in most cases before blooming, but only after a minimal biomass value is achieved) will provide vegetation of a higher nutritional quality and allow a longer time of exploitation of this rangeland (on account of other grazing areas).

Date of exit from the park or entry into the firebreak zone: Different targets are set for different areas of the park. When the main goal is fire prevention, park managers would be interested in grazing the area at extremely high pressure to reduce herbaceous biomass to minimum. In this case the farmer must supply the cattle with concentrated food of higher quality (mainly nitrogen). On the other hand, this leads to excessive exertion of nitrogen by the cattle which leads to changes in soil nutrient flows and encourages the development of nitrophyllic plant species, an undesired process from ecological perspective. In other areas, less prone to fire risk, park managers may not insist on having high grazing pressure hence creating a variety of vegetation structural types and habitats. Reducing grazing pressure needs of course to be negotiated with the livestock breeder.

2. Management of goat browsing – a test case

A herd of goats owned by the park authorities has been browsing the park since 2004. The herd consists of 200 goats of local breeds (Damascus, Mamber) and local breeds crossed with Alpine bucks, which exploit the park all year round. The management of the goat herd is aimed at the inhibition of shrub encroachment and the conservation of landscape diversity. The main purpose of the goat herd is to supply grazing services as one of the parks management tools. In addition, the herd is milked daily and produces about 60,000 liters of milk and sells about 200 kids a year. This herd is also routinely monitored and supports the conduction of various research projects related to agricultural and ecological issues. As opposed to the cattle herd, which grazes on large and fenced areas of the park, the goats graze in unfenced polygons with a very focused target (termed “targeted grazing”) with a herder on site at all times. The goat grazing plan is built for the long term and is accompanied by a monitoring plan, mainly aimed at detecting desired or undesired changes at the landscape level. Since goats rely mainly on woody plant foliage, which is mostly evergreen, the plan is based on seasonal preferences and availability of the different woody species and the different goals at each site. This plan is not limited by yearly variance in precipitation and is re-opened for discussion every 3-4 years according to monitoring results or when new areas need specific treatment that goats can assist in achieving. A classic example of this kind of treatment is when new areas are cleared of trees and shrubs (e.g., creating a fuel-break, restoration of ancient olive orchards). The browsing of goats is a useful tool for the maintenance of these areas by the suppression of new regrowth of shoots. Goats’ diet selection is also affected by season, due to differences in abundance, phenology and palatability of the different species (Glasser *et al*., 2008). They also increase dry-mater intake rate when planning the grazing rout considering these issues (Meuret, 1997). Goats must be directed to the different areas taking into account these issues in the grazing plan. Goats can also be very useful for the eradication of specific unwanted plant species (Goehring *et al.,* 2010). There are several very useful methods for increasing specific plant consumption by grazing goats, such as pre-conditioning (Richman, 1993), feed supplementation (Campbel *et al.,* 2007,) or supplementation of Poly-ethylen Glycol (PEG) (Silanikov *et al.,* 1996). A monitoring protocol accompanies the grazing plan. The main objective of the monitoring protocol is to estimate spatial and temporal effects of goat browsing on vegetation and landscape properties. Several methods are used, each being conducted at different intervals. These methods include daily monitoring of the herd‘s route by GPS, ground surveys and aerial photo analysis. A GPS collar is put on one goat in the herd and supplies data regarding the time and location of the herd at all times (1 min’ intervals). Data from this device are downloaded into a GIS map and database and enables calculation of the accurate grazing pressure at every location in the rangeland. Figure 7 demonstrates a processed grazing pressure matrix which is composed of a 10x10 meter grid (Segal *et al.,* 2014). The outcome of this processing procedure enables the coupling and exploration of various interactions and relations such as biomass removal at each pixel, temporal and spatial grazing patterns at the polygon or landscape level, interactions between grazing intensity and landscape appearance as

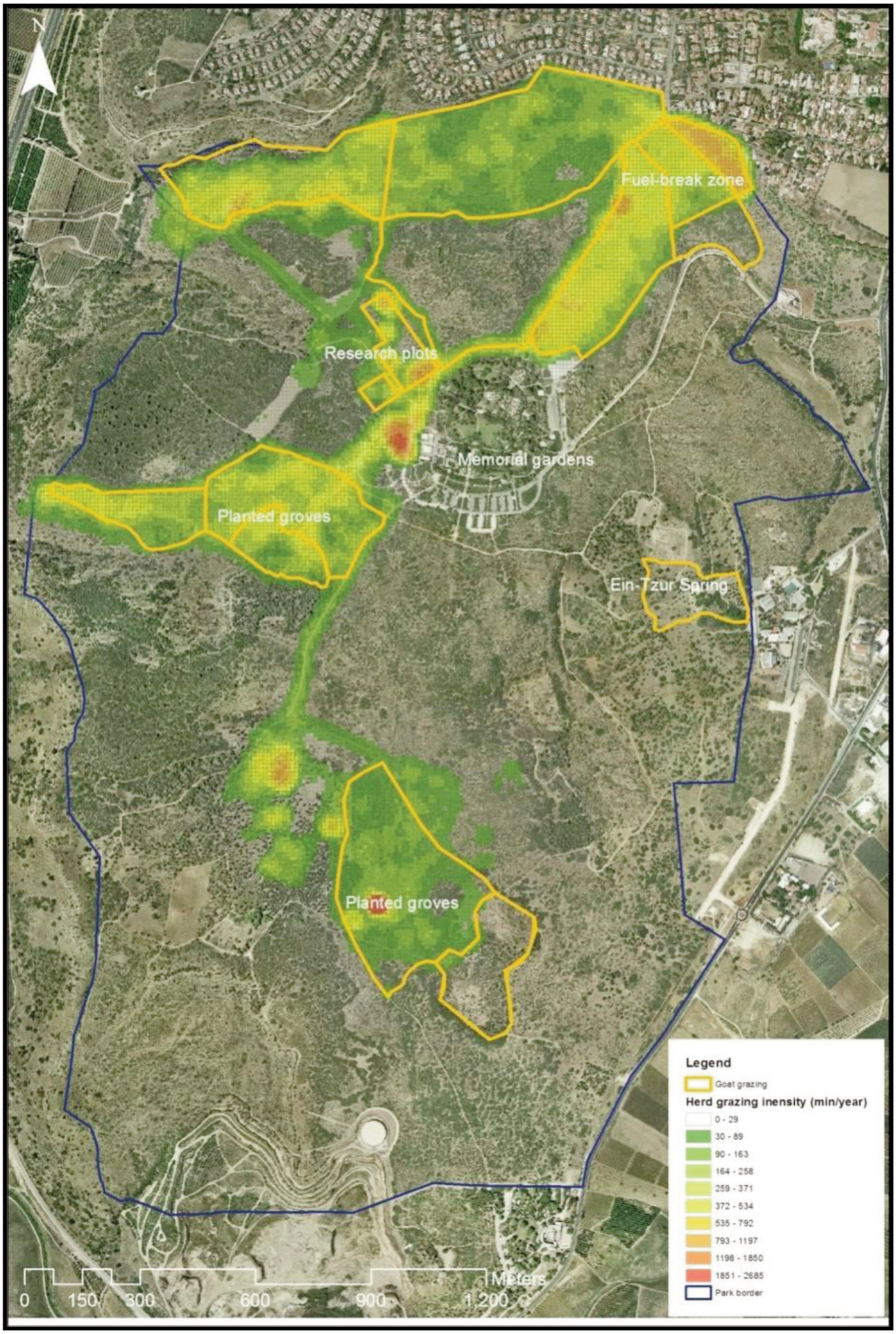

Fig. 7. Goat grazing intensity (min/year) in a 10x10 grid after GPS data analysis.

well as interactions between grazing location, intensity and livestock production. Ground surveys are conducted as well and include field transects where parameters such as defoliation, browsing line intensity and debarking are indexed (BLD index; Glasser *et al.,* 2013). Along these transects vegetation structure and dimension of gaps between shrubs are documented by graphic means (Henkin *et al.,* 2007). Aerial photos are classified and parameters such as woody cover, woody patch area, woody patch density and edge density are measured and analyzed.

V – Conclusions

We believe that grazing must be perceived from the broad perspective of its effects on and benefits to the natural ecosystem, and not only from its agricultural aspect as feed for livestock. Good collaboration between all stakeholders and profound understanding of the effects of different grazing regimes on the ecosystem is an important key for success. Understanding and taking into account the livestock breeders' interests will help promote the use of livestock for production of healthy food for human consumption while at the same time managing grazing for a healthy ecosystem with high diversity of habitats, species and landscapes. Knowledge-based management practice is crucial in this case. Good acquaintance with the different habitats, ecological processes, wildlife species, as well as the needs of livestock and livestock breeders, will not only reduce potential damage but rather enable the utilization of the cattle herd to enhance ecosystem function.

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Session 2

Ecosystem services, prevention of risks

Oral presentations articles

Biodiversity provides ecosystem services: scientific results *vs* stakeholders' knowledge

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Abstract. Maximizing the ecosystem services (ES) provided by biodiversity is presented as a solution to increase food production and decrease environmental problems. Science has produced significant results supporting this strategy. But what do stakeholders know about the ES provided by plant biodiversity? And does this knowledge agree with scientific results? We address these questions by combining a literature review and interviews with farmers and farm advisors in France. Scientific results and stakeholders' knowledge both indicate that plant biodiversity has a positive effect on the provision of ES. However our work revealed two gaps in our scientific knowledge. Only 3 scientific articles connected ES with plant biodiversity at the farm scale or between fields while stakeholders did so for 43% of the ES they mentioned. Similarly, management services concerned about one third of the services mentioned by stakeholders but were addressed in only 3 scientific articles.

Keywords. Biodiversity – Agroecology – Farming systems– Expertise – Innovation systems.

Biodiversité et services écosystémiques : résultats scientifiques* vs *connaissances d'acteurs

Résumé. *Maximiser les services écosystémiques (SE) fournis par la biodiversité est présenté comme une solution pour augmenter la production alimentaire et diminuer les problèmes environnementaux. La science a produit des résultats significatifs en ce sens. Mais que connaissent les acteurs des SE fournis par la biodiversité végétale ? Et leurs connaissances concordent-elles avec les résultats scientifiques ? Nous abordons ces questions en combinant une revue de la littérature et des entretiens avec des éleveurs et des conseillers agricoles en France. Les résultats scientifiques et les connaissances des acteurs indiquent que la biodiversité végétale a un effet positif sur la fourniture de SE. Cependant, notre travail révèle également des lacunes dans les connaissances scientifiques. Seuls 3 articles scientifiques associent SE et biodiversité végétale à l'échelle de la ferme ou entre parcelle alors que les acteurs le font pour 43% des SE qu'ils mentionnent. De même, les SE de gestion représentent 1/3 des SE mentionnés par les acteurs mais ne sont abordés que dans 3 articles scientifiques.*

Mots-clés. *Biodiversité – Agroécologie – Systèmes agricoles – Expertise – Systèmes d'innovation.*

I – Introduction

The challenge to increase and secure food production while decreasing environmental problems is increasingly associated with a new agricultural production often called agroecology (Wezel *et al*., 2009). Crop, livestock and landscape diversification is one pillar of agroecology. Diversification is expected to enhance the likelihood of biological complementarities and synergisms enabling reduced reliance on external input use. Such management policies and practices may enable the ecosystem services (ES), i.e. the benefits human obtain from ecosystems, provided by biodiversity to be maximised at the expense of the disservices. In recent years science has produced a number of significant results confirming that efficient use of biodiversity may maximize ESs (e.g. Hector and Bagchi, 2007). Yet application of these results in the field is dependent on stakeholders' knowledge and especially farmers' and farm advisors' knowledge. This article therefore addresses the following questions: 1) What do stakeholders know about the services and disservices provided by biodiversity? 2) Does stakeholders' knowledge agree with scientific results? We address these questions by combining a literature review and interviews with farmers and farm advisors in a French region characterized by a diversity of livestock production systems. This article is focused on the plant component of livestock production systems. Indeed, livestock production systems are known to contain a diversity of interacting plant components. The article is also focused on planned biodiversity (Altieri, 1999) at the field and farm scales, as this type of biodiversity and these scales correspond to what farmers manage in their daily activity.

II – Materials and methods

1. Literature review

The literature in the fields of ecology, agronomy and agricultural science was analysed to establish the state of the art about the services and disservices provided by plant biodiversity in livestock production systems. Search requests were used on ISI Web of KnowledgeSM with topics such as "biodiversity AND agricultural system AND service" and "biodiversity AND grassland AND production". Selected articles had to satisfy three criteria regarding the validity domain of the results, the type of research setup and the research protocol. In the end, the analysis was not exhaustive but considered 41 articles (see Lugnot and Martin, 2013 for an extended list).

2. Stakeholder interviews

Stakeholder selection was comparable to the case-study research approach (Eisenhardt, 1989). With this approach, qualitative surveys do not rely on statistically significant samples but rather on samples corresponding to the diversity of studied objects in order to grasp the diversity of situations and representations. Following this approach, 8 farmers and 3 farm advisors located in the French region of Aveyron were selected based on several factors describing their situations, e.g. land use, support receive (Table 1). They were interviewed for the survey and this sample was not extended as no new fact or information emerged in the last interviews we conducted. The interview guide was designed to provide latitude to the interviewee in constructing an answer reflecting his ideas and opinions. A list of themes and open-ended questions was established and dealt with the provision of definitions by the interviewee, the main characteristics of her/his livestock production systems, the ESs and disservices she/he associated with plant biodiversity, her/his social networks.

Table 1. Main characteristics of the studied farmers

	Farmer	FM	LM	JYB	AS	IC	BV	XP	JMA
Climate	Moderate oceanic				x	x	x	x	x
	Semi-montane	x	x	x					
Animal production	Beef				x				
	Dairy	x	x	x	x	x		x	x
Forage production (% of the farm area)	Forage crop	0	0	15	21	30	31	37	46
	incl. maize	0	0	0	10	20	9	14	30
	Sown grassland	35	27	17	49	26	51	22	22
	Permanent grassland	65	73	68	30	44	18	41	32
Support received	Advisor chambre of agr.	x		x	x	x	x	x	x
	Advisor dairy coop.		x	x					
	Group of conv. farmers				x	x	x	x	x
	Group of organic farmers				x				

3. Data analysis

A deductive content analysis (Elo and Kyngäs, 2008) of interview recordings was made. A deductive content analysis is a combination of two approaches, content analysis and deduction. Content analysis consists in organizing words and discourses into a few content-related categories. Deduction is based on previous knowledge such as literature reviews. Then, in a deductive content analysis, the analysis moves from previous knowledge condensed into a few content-related categories to the specific material being studied and distributed in these categories. Starting with the classification of ESs and disservices proposed by Zhang *et al*. (2007) and refined by Lamarque *et al*. (2011), analysis of the literature enabled us to further subdivide the suggested classification. After this categorization matrix had been developed, stakeholders' discourses were reviewed and coded for correspondence with or exemplification of the identified content-related categories.

III – Results

1. Literature-based classification

In many reviewed articles, plant biodiversity has often been used as a synonym for species richness (SR). In the remaining cases, plant biodiversity referred to functional diversity (FD), i.e. the diversity of functional traits or functional groups within or between plant communities. Grassland ecosystems are overrepresented in this literature. These grasslands are either permanent or sown. In the latter case, studies deal with a limited number of species (typically 2-3). Hence, the reviewed biodiversity levels match any farming context. Indeed, in addition to permanent grasslands, farmers may manage low diverse plant communities such as pure stands, possibly included in a crop rotation. Because different species and functional groups favour different functions (Hector and Bagchi, 2007), there is an overall positive effect of within- and between-field plant biodiversity on the provision of ESs. Still, the reviewed articles seldom discussed the site-dependence of the results.

We distinguish five types of input services and disservices corresponding to supporting and regulating services (Zhang *et al*., 2007). These are: (i) biological control, e.g. resistance to weeds and pest control; (ii) soil structure, e.g. soil organic matter content improvement and erosion control; (iii) soil water status, e.g. soil water retention; (iv) soil fertility, e.g. conversion of inorganic into organic nitrogen; (v) pollination. Our production services are similar to Zhang *et al*. (2007) provisioning services and Lamarque *et al*. (2011) marketed services. We distinguish three types of such services and disservices: (i) crop and forage production, e.g. increase of biomass production; (ii) crop and forage nutritive value, e.g. higher forage crude protein content; (iii) stability of crop and forage production and nutritive value in response to external disturbances. We identified a third type of ESs and disservices that had never been reported in previous classifications, i.e. management (dis)service. They refer to services and disservices enabling farmers to improve or worsen their management and working conditions. We distinguish two such services and disservices: (i) management flexibility, e.g. timing flexibility in grassland use, i.e. the extent to which the use of a given grassland may be brought forward or deferred at various times of year depending on biomass availability, digestibility and herd feeding objectives; (ii) work, e.g. improvement in labour productivity.

2. Stakeholders' knowledge

Farmers and farm advisors cited input services 16 and 6 times respectively in the interviews. No disservices were mentioned by either. In 8 cases, services were connected to within-field plant biodiversity. Fourteen other references to services referred to plant biodiversity at the farm scale or between fields due to crop rotations. The most cited input service was soil fertility (10 times). Both farmers and farm advisors mentioned the benefits provided by the integration of legumes, lucerne in particular, in the crop rotation. Soil structure was the second most cited input service (6 times). Plant biodiversity was also seen as a means of biological control by farmers and farm advisors (4 mentions). For instance, the organic farmer (AS) practices undersowing. He sows each new grass/legume ley under oats. In this way, the weeds are restricted by the emerging grass and legume species and by the shading by the oats. The last input service mentioned was pollination (2 mentions).

Production services were the ones most cited by farmers and farm advisors, i.e. 75 and 18 times respectively. Farmers also mentioned disservices 6 times. In 61 cases, services were related to plant biodiversity at the field scale. Another 32 references to services related to plant biodiversity at the farm scale or between-fields through crop rotations. The most cited production service was crop and forage nutritive value (39 times). For instance, one farmer (AS) combined legume species by adding 10% trefoil to lucerne seed mixes in order to improve forage palatability. Increased yields of crops and forage (mentioned 22 times) and their stability (32 times) due to plant biodiversity were also frequently mentioned and often interconnected. For instance, farmers AS and FM incorporated a small proportion of Italian ryegrass in their perennial ryegrass seed mix in order to compensate for the lower yield of the perennial ryegrass in the year following sowing. One farmer (IC) explained that she included maize and lucerne in addition to grasslands in her crop rotations to ensure forage stocks despite year-to-year weather variability.

Farmers and farm advisors mentioned management services 24 and 8 times respectively in the interviews. They also referred to management disservices 12 and 4 times respectively. Fifteen references to services related to plant biodiversity at the field scale against 17 at the farm scale or between fields through crop rotations. Disservices were related to plant biodiversity at the field scale and at the farm scale or between fields through crop rotations in 6 and 10 farm cases respectively. The most cited management service provided by plant biodiversity was management flexibility (16 times). Several farmers and one farm advisor (BD) explained that within a field, it is possible to benefit from the differences in timing of production between species as it enlarges the time window for grassland use. Plant biodiversity was also considered to provide labour services (8 times). Multi-species sown grasslands last longer than pure stands or two-species mixtures traditionally used in the region thereby requiring less frequent resowing. However, one farmer considered managing within- and between-fields plant biodiversity may be a hard task (BD). A third type of management service was mentioned by farmers and farm advisors, namely risk reduction. Indeed, one farm advisor (CM) explained that mixing species is a kind of insurance against weather variation.

IV – Discussion and conclusion

According to scientific results, there is scope for implementation of a new agricultural production paradigm often called agroecology. Stakeholders' knowledge confirms opportunities for implementation of this new paradigm. Indeed, stakeholders consider that plant biodiversity has an overall positive effect on the provision of ESs yielding among other things input reductions, higher and more stable plant production and even improvement of farmers' management conditions. Still, our work revealed two scientific gaps susceptible to slow down this implementation process. Compared with stakeholders' knowledge, science insufficiently addresses (i) ESs provided by plant biodiversity at the farm scale or between fields; (ii) management services and diservices provided by plant biodiversity. Stakeholders' expertise can thus help us to prioritize research options in order to simultaneously fill scientific gaps and produce knowledge relevant for practice.

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Effect of long term defoliation by cattle grazing with and without trampling on soil compaction and plant species composition in temperate grassland

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Abstract. Here we report the results for soil compaction and plant species changes in mesotrophic temperate Central European grassland after 12-years of grazing management with and without cattle trampling. Five grazing treatments (including intensive and extensive grazing, cutting and grazing with no trampling under permanent fencing), with two replicate blocks, have been applied since 1998. In 2010 species richness, the cover of vascular plant species and bryophytes, sward height and soil penetration resistance were recorded. Long term grazing by large herbivores had a significant effect on soil compaction with the lowest values in the "not trampled" treatment. Legumes and short forbs were supported by intensively defoliated and trampled treatments, whereas tall forbs prevailed under the extensive ones. The cover of tall and short graminoids was not dependent on applied treatments. The "not trampled" treatment had the highest prevalence of bryophytes (with more than 95% domination of *Rhytidiadelphus squarosus*) and was also the richest in a number of vascular plant species, on the other hand had the least Hill's evenness index. Long-term defoliation by grazing animals without trampling does not lead to the creation of a typical pasture community. Species forming pasture communities are essentially dependent on both types of disturbances: (i) regular defoliation by grazing and (ii) regular trampling by hooves, which causes a high degree of soil compaction as well as sward disruption.

Keywords. Grazing – Trampling – Soil compaction.

Effet à long terme de la défoliation par le pâturage du bétail (avec et sans piétinement) sur le compactage et sur la composition des espèces végétales dans les prairies tempérées

Résumé. *Nous présentons les résultats du compactage des sols et des changements d´espèces végétales dans les prairies mésotrophes tempérées d'Europe centrale après 12 ans de gestion du pâturage avec et sans piétinement. Cinq types de pâturages (pâturage intensif et extensif, coupe et pâturage sans piétinement sous clôture permanente) ont été appliqués depuis 1998 et répétés sur deux blocs. En 2010, la diversité des espèces, la couverture des espèces de plantes vasculaires et de bryophytes ainsi que la résistance à la pénétration du sol ont été mesurées. Le pâturage à long terme par les grands herbivores a eu un impact significatif sur le compactage du sol. Le compactage du sol le plus faible a été enregistré dans le traitement « non piétiné ». Les légumineuses et les herbacées dominaient dans les traitements intensifs défoliés et piétinés, alors que c'était les hautes plantes herbacées dans les traitements extensifs. Le couvert des hautes et courtes graminées ne dépend pas du type de traitement appliqué. Le traitement « non piétiné » présente la plus forte prévalence de bryophytes (avec de 95% de* Rhytidiadelphus squarosus*) et était également le plus riche en quantité d'espèces de plantes vasculaires, mais avait le plus faible indice de régularité de Hill. La défoliation à long terme par les animaux pâturant sans piétinement ne conduit pas à la naissance d'une communauté de pâturage typique. Les espèces composant les communautés de pâturage dépendent essentiellement des deux types de perturbations: (i) la défoliation régulière par pâturage et (ii) le piétinement régulier par les sabots; ce qui conduit à un degré élevé de compactage du sol ainsi qu´à la perturbation du couvert végétal.*

Mots-clés. *Pâturage – Piétinement – Compactage du sol.*

I – Introduction

The sward under grazing management is mainly affected by (i) defoliation, (ii) manipulation of nutrient availability by removal of biomass or by defecation, and (iii) trampling (Wallis De Vries, 1998). Studied effects of grazing management are often interpreted as results of only defoliation and manipulation of nutrient availability, and trampling effects are frequently underestimated or ignored. Only a few studies have underlined the impact of trampling (e.g. Curll and Wilkins, 1983) on vegetation, and these have shown the marked impact of these disturbances on plant species patterns.

To date, the majority of studies dealing with the effects of cattle trampling have been short-term, and so the results can only show the typical temporary changes that mostly follow after introduction of a new management treatment, or they reflect an inter-seasonal dynamic (Kohler *et al*., 2004). Through the following questions we analysed how the absence of cattle trampling affects soil and vegetation in species-rich temperate grassland with a 12-year history of grazing: (i) how does the absence of trampling affect vegetation height, plant species richness and composition; and (ii) can the long term effects of no trampling be detected by differences in soil compaction?

II – Materials and methods

The study was performed in the long-term Oldřichov grazing experiment (OGE) in 2010. The OGE is situated in the Jizera Mountains, 10 km north of the city Liberec (the Czech Republic). The trampling study was established and conducted in 2010 after 12 years of different management under OGE (yearly continuously grazed with heifers from May to October). Five following treatments with two replicate blocks have been applied since 1998: intensive (IG) and extensive (EG) grazing; cut for hay in June followed by intensive (ICG) or extensive (ECG) grazing, and intensive grazing with no trampling under permanent electric fencing (GNT). The stocking density in the different treatments was adapted to the target sward height. See Pavlů *et al.* (2007) for details about the study site.

The penetrometer was used to measure soil penetration resistance (MPa) among studied treatments. Prior to grazing in May samples were collected in the study data set plots using a grid of 0.33 m x 0.33 m subplots in 5 distant triplet plots along the permanent fence. The percentage canopy cover for all vascular species and bryophytes was visually estimated. The compressed sward height of each subplot was measured. To show the effect of the absence of trampling on the species richness of the community the Hill's N_1 diversity index and evenness index expressed as Hill's ratio (Hill, 1973) were calculated for each treatment. One-way ANOVA followed by *post-hoc* Tukey comparison was performed to identify significant differences in soil penetration resistance, sward height, Hill's diversity and evenness indices. To reveal the effects of grazing intensity and trampling on plant species composition a redundancy analysis (RDA) followed by a Monte Carlo permutation test in the CANOCO program (ter Braak and Šmilauer, 2002) was used.

III – Results and discussion

Soil compaction expressed as penetration resistance showed significant differences among investigated treatments. The subsurface layer of the soil under trampled treatments had significantly higher penetration resistance up to c. 30 cm in comparison with the GNT treatment. Significantly lower soil compaction was also observed under the EG and ECG treatments in comparison with IG and ICG treatments, especially in upper soil layers. This is in accordance with the study by Novák (2009), where the penetration resistance was higher under higher stocking rates even in a short term experiment. Measurements of the actual mean sward heights showed significant differences among the treatments (GNT < IG < ICG, EG < ECG).

The Hill's N_1 diversity index and Hill's ratio N_1/N_0 (in brackets) for plant species richness were 7.02 (28.63), 7.48 (43.32), 8.08 (44.50), 8.26 (53.62) and 8.96 (48.13) for GNT, IG, ICG, EG and ECG treatments, respectively. The differences among the treatments were not significant for N_1 (F = 2.23, P = 0.078) but were significant for N_1/N_0 (F = 17.01, P < 0.001). The GNT treatment was found to be the least equitable. The percentage cover of bryophytes in the treatments shows Fig. 1a. The lowest coverage of vascular plant species and significantly highest cover of bryophytes occurred in the GNT treatment, where more than 95% of bryophytes were represented by *Rhytidiadelphus squarrosus*. The RDA showed significant differences in plant species composition among treatments (explained variability by axis 1 and all axes = 16.8 % and 30.4 % resp.). Species became associated with three groups according to defoliation by grazing and trampling intensities: EG with ECG, IG with ICG and intensive defoliation by grazing and no trampling (GNT) (Fig. 1b). Bryophytes as a major component of the vegetation in the GNT treatment were observed to form 'a carpet' with a sparse density of vascular plants. Similarly, Chappell *et al.* (1971) found that *R. squarrosus* was reduced with increasing trampling pressure on chalk grassland. Although bryophytes are considered to be poor competitors with vascular plants (van Tooren *et al*., 1988), they can prevent seed germination or seedling survival (Kotorová and Lepš, 1999). In particular, if there is an absence of any bare ground disturbance, which would create germination, then bryophytes can prevail over vascular plants. However, during grazing in the GNT treatment cattle could pull up bryophytes with their mouths together with vascular plants. This factor probably causes small disturbances, which can lead to the formation of germination gaps. The prevalence of bryophytes in the 'not trampled' treatment resulted in the lowest compressed sward height in this treatment. A previous study (Kobayashi *et al*., 1997) found that trampling itself significantly suppresses vegetation height, but the trampling in this study was not separated from grazing. Therefore these results are consistent only with our IG treatment, where vegetation was defoliated by grazing and trampled.

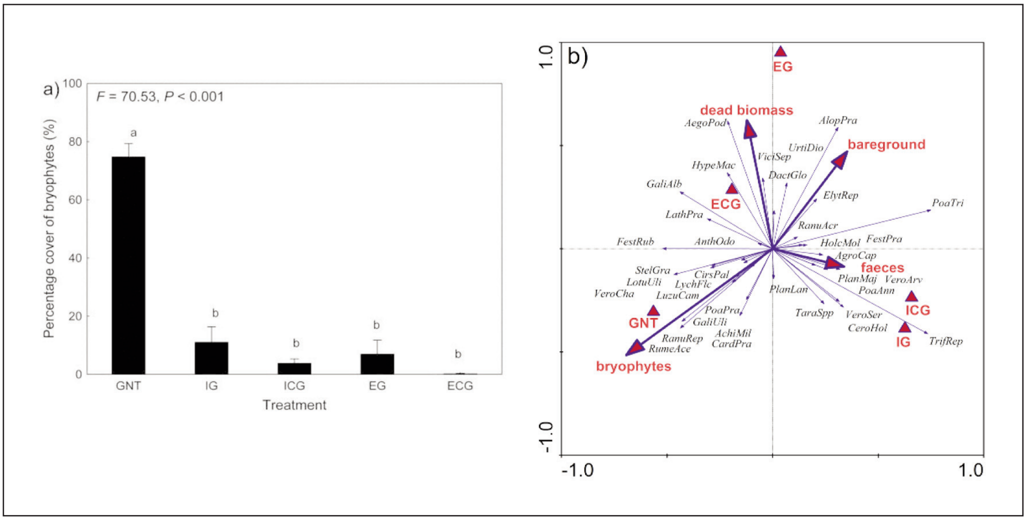

Fig. 1. (a) The mean percentage cover of bryophytes, (b) Ordination diagram showing the results of RDA of plant species composition data.

F = F statistics in one-way ANOVA, and P = probability value. Significant differences (P < 0.05) according to Tukey's post hoc test are indicated by different letters. Error bars represent standard errors of the mean. Abbreviations: for treatment abbreviations see Chapter II. Species names are abbreviated with the 4+3 letters.

The species that benefited from the absence of trampling (GNT treatment) were mostly bryophytes and e.g. *Ranunculus repens* or *Lychnis flos-cuculi*. In the EG and ECG treatments the species with the highest abundance were *Aegopodium podagraria* or *Hypericum maculatum.* In the IG and ICG treatments the species with the highest abundance was *Trifolium repens* (Fig. 1b). From previous studies performed in comparable conditions it can be concluded that *T. repens* is restricted to intensively grazed swards with good light conditions (e.g. Hejcman *et al*., 2010). From our study it appears that not only an intensive defoliation is important for the prevalence of *T. repens*, but also the disturbances associated with trampling. Kohler *et al.* (2004) and Kobayashi *et al.* (1997) also acknowledged that the abundance of legumes was related to trampling. Furthermore, short graminoids (including *Agrostis capillaris*) were negatively correlated with the GNT treatment. In general *A. capillari*s is described as a species promoted by regular defoliation in low-production temperate grasslands (Louault *et al*., 2005). However, the present study demonstrates that only the interaction of defoliation with trampling promotes the abundance of such species.

IV – Conclusions

In conclusion, long-term defoliation by grazing animals without trampling does not lead to the creation of typical pasture communities. We demonstrated that the species present in pastures do not profit only from regular defoliation but they also need bare ground disturbances and sward compaction which favour them in strong intraspecific competition. This means that not only defoliation by itself, but also the disturbance associated with trampling is one of the key factors responsible for supporting typical pasture species.

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A methodological approach to model the grass-tree relationship in *Quercus suber* Mediterranean forest ecosystems

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Abstract. Livestock is an important social and economic component for the livelihoods of resource-poor farmers in North Africa. A portion of livestock feed resources is forest rangeland. Overgrazing and a failure to use rotational grazing systems prevent the proper functioning of forest ecosystems. To protect vegetation and to guarantee human activities, natural resources manager need tools for supporting decision-making. The North African forest ecosystems are composed mainly of *Quercus suber* trees. The aim of this work is to develop models relating fodder production as the dependent variable to the independent variables: *Quercus suber* canopy cover, ecological factors, and human pressure. This paper presents the methodological approach used in the Kroumiry-Mogody mountains (Tunisia). Initially, a forest inventory based on stratified sampling was conducted looking at density, height, and canopy cover. A comparative study was later established. In parallel, a survey was conducted in the surrounding agglomerations to assess the impact of human activities. The buffer technique was used to establish the relationship between fodder production and distribution, canopy cover, and human pressure. The methodology involved the creation of a specific zone around each agglomeration, which was mainly a function of the distance to the forest, the topographical features, and the number of domestic animals. The proposed approach will provide forestry managers with the ability to determinate different levels of anthropogenic pressure and to respond with contingency measures for each of these levels.

Keywords. Silvo-pastoral management – Anthropogenic pressure – Vegetation mapping.

Approche méthodologique pour la modélisation de la relation herbe-arbre dans un écosystème forestier Méditerranéen de chêne liège (**Quercus suber*****)***

Résumé. *En Afrique du Nord, l'élevage constitue une activité économique et sociale importante pour les ménages à faible revenus. Les parcours forestiers contribuent à la satisfaction des besoins fourragers du cheptel. La durabilité de ces écosystèmes est, donc, mise en cause par la pression anthropozoïque. Nous avons étudié, en premier lieu, les relations qui existent dans un écosystème de chêne liège (*Quercus suber*) en Afrique du Nord. Notre objectif étant de développer des modèles d'estimation de la production fourragère herbacée sous le chêne liège en fonction du couvert arboré, des facteurs écologiques et de la pression anthropique. Un inventaire des paramètres dendrométriques et une appréciation de l'impact de l'activité humaine ont été réalisés. Des zones tampons ont été créées autours des agglomérations pour définir les différents niveaux de dégradation.*

Mots-clés. *Aménagement Sylvo-pastoral – Pression Anthropique – Cartographie de la végétation.*

I – Introduction

Cork oak is an evergreen species native to the Western Mediterranean Basin. Cork oak forests are mainly located in the coastal and precoastal areas from the Iberian and Italian Peninsula, South France and North Africa (López de Heredia *et al*., 2007; Staudt *et al*., 2008). In North Africa, cork oak forests extend from the Atlantic Coast in Morocco through the Algerian Coast to the North Western of Tunisia with a scattered distribution over the two mountain ranges of Kroumiry and Mogody. Excessive human pressure is usually pointed out as the main cause of the reduction in cork oak forest ecosystems (Ben Mansoura *et al*., 2001).

Cork oak provides many products and services such as livestock grazing, fuel-wood, and acorns (Daly and Ben Mansoura, 2009). A study recently conducted evaluating the economic valuation of goods and services of Tunisian forests showed that the forage production is the main direct benefit (38%) of cork oak forest (Daly *et al*., 2012). For local populations, the income generated from animal production represents a major source of the household total income, primarily from sheep and goat enterprises. Overgrazing and a failure to use rotational grazing systems prevent the regeneration of cork oak and the associated herbaceous species (Daly and Ben Mansoura, 2009).

An element for supporting decision-making for reciprocal protection of vegetation and human activities (Sedda *et al*., 2011) is the promotion of sustainable management of cork oak forests (Daly *et al*., 2012) which links livestock and forest. Analysing changing landscape patterns is one approach to better understand the ecological dynamics and the influence of natural and human disturbances in the cork oak forests (Turner, 1990). Such approach offers a useful tool for natural resource managers to better manage woodland resources. This paper presents the methodological approach to develop models for predicting forage yield under cork oak forests across different regions of North Africa.

II – Methods

1. Study area

The study was conducted in Tunisia in Kroumiry-Mogody, located between 8°34' and 9°44' longitude E and 36°27' and 37°20' latitude N. The major soil groups are forest soils (leached brunified soils, mull soils) settled on the flysch oligocene zone of numidia and Mediterranean red soils, (Mtimet, 2001). The climate varies from a semi-arid with moderate cool winters and dry summers in the southern of Kroumiry-Mogody to humid with cool winters and modest warm summers in the centre of the Mountain ranges, to a sub-humid climate with mild winters and moderate summers (Staudt *et al*., 2008).

2. Methodology

Forest inventory. The forest inventory is conducted on large circular plots, 1256 m^2 in area with 20 m radius (Gilliam 2007). A total of 90 plots were assessed. The parameters measured were density, height, 1.3 m diameter and canopy cover.

Understory assessment. To study the understory, vegetation cover was measured using two methods: the quadrat point frame and digital vegetation charting technique (DVCT). The quadrat point frame used two perpendicular transects of 20 m, each with 100 observations. The DVCT images were taken with a digital charting apparatus composed of digital camera, a handled GPS, a bubble level mounted on a wooden platform attached to a Bogen-Manfrotto 3025 3D Junior Tripod Head (Louhaichi *et al*., 2010, 2012) in six subplots of 1 m² each, delimited on the ground with a PVC square (3 under the crown cover projection on the ground and 3 out in open sky). Captured images were analysed using a computerised vegetation measurement image processing software "VegMeasure"®.

Gilliam *et al.* (1995), in West Virginia hardwood, also used 1 m² subplots nested within circular 400 m² plots to combine assessment of the tree and herbaceous strata in the same sample area.

Plant height was measured at five points (the four corners plus the middle) and the fresh weight after harvesting with shears was recorded. Herbage cover and height were used to develop a formula to predict above ground herbaceous biomass.

III – Results

To explain variation in fodder production in the cork oak forest resulting from human activities, we established several buffer zones with 500 m radius around the agglomerations using analyst module in geographical information systems (GIS) environment. This technique has been used for various purposes to study cork oak forests in Morocco and Tunisia (Torres *et al*., 2009; Cherki and Gmira, 2012). Mathematical relationship will be tested in each buffer zone.

The mathematical expressions between the cork oak trees and the herbaceous understory do not explain the basic causes of the relationship; nevertheless, they have many useful applications (Jameson, 1967). Generally, those expressions included measurement of trees as the independent variable (x) and measurement of herbage as dependent variable (y).

Jameson (1967) reported several models such as $\log y = a + bx$, $y = a + bx + cx^2$ and for some cases $y = a + bx + cx^2 + dx^3$ which would generate acceptable results. He also used a sigmoid expression given by Grosenbaugh (1965)

$Y = H + A [1-e -B(X-G)] M + 1$

Where “A and H are the upper and lower asymptotes, respectively. B provides the necessary curvature, M adjusts the inflection point and G adjusts the value of X so that X-G = 0 when Y = H” (Jameson 1967).

North African forests are quite populated. In recent years, the Tunisian forest population was estimated to about one million habitants, which represents 10% of the Tunisian population (Saadani *et al*., 2012). In fact population density in forest areas doubles the national Tunisian average which is about 61 inhabitants per km² (Daly and Ben Mansoura, 2009). Thus population could be considered a composed independent variable (X), grouping the population size, the livestock population size and the agglomerations distance to the forest.

$X = [x_1 + x_2 + x_3 + x_n]$

where X: independent variable expressing the human factor, x_1: population size, x_2: livestock size and x_3 is the distance separating agglomerations to forest. xn could be considered for human activities other than grazing such as cork, wood and non-wood products harvesting.

Cherki and Gmira (2012) used the agglomerations proximity and activities as independent variables ($y = a + bx$) to explain the number of forest fires in Mamora, Morocco. They demonstrated that if livestock grazing is implemented in a well-balanced manner, it could play a key role in reducing fire hazards.

Ecological models, such developed by Scanlan (1992), could be useful in ecosystems with minor disturbance and need to be valid in ungrazed or lightly grazed sites. North African forests are characterized by overgrazing and its impact on environmental degradation (Ben Mansoura *et al*., 2001) and ecological relations in such cases could not be properly identified.

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Assessing ecosystem services provided by livestock farms in upland areas in the French Massif Central

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Abstract. The emergence of challenges linked to global change combined with new societal expectations has forced a reconsideration of the role of livestock farming systems in the provisioning of goods and services. The multifunctional approach makes it possible to find trade-offs between environmental benefits and production services, but it requires tools that are able to evaluate the farming system's potential to take up the challenge. DIAM is an innovative prospective diagnostic tool designed for dairy systems and co-developed through collaboration between extension services, research and cheese organizations in the Massif Central. Outputs allow a multi-criteria diagnosis that focuses on forage self-sufficiency, system coherence, and the services provided by grasslands: forage and environmental services, and those related to the nutritional and sensorial characteristics of cheeses. This paper details and analyzes the results obtained on a panel of 36 organic or conventional farms located in highland and upland areas of the Massif Central (France) raising cows, ewes or goats. The tool's assets are discussed.

Keywords. Grasslands – Typology – Forage systems – Animal products – Environment – Ecosystem services.

Evaluation des services écosystémiques rendus par les exploitations d'élevage : le diagnostic DIAM appliqué à des exploitations de montagne dans le Massif central

Resumé. *Les nouveaux défis liés au changement global associés aux attentes de la société conduisent à un réexamen du rôle des systèmes d'élevage et notamment à essayer de quantifier leurs contributions à la fourniture des services écosystémiques. DIAM est un outil de diagnostic prospectif et innovant qui répond à ce défi. Il a été conçu pour les systèmes laitiers et est issu d'un travail de co-construction entre le Développement, la Recherche et les filières fromagères AOP du Massif central. Il permet de réaliser un diagnostic multicritère qui porte sur l'autonomie fourragère, la cohérence du système fourrager et sur les services rendus par les surfaces herbagères de l'exploitation : services fourragers, environnementaux et ceux liés à la qualité nutritionnelle et sensorielle des fromages. Cet article détaille et analyse les résultats obtenus sur 36 exploitations de montagne du Massif Central (France) appartenant à une large gamme de systèmes d'élevage. L'intérêt de cet outil est discuté.*

Mots-clés. *Prairies – Typologie – Système fourrager – Produits animaux – Environnement – Services écosystémiques.*

I – Introduction

DIAM has been developed at farm-scale as a tool for running multifunctional diagnosis on forage-system livestock farms. It is the outcome of a co-development effort led by Research, extension services and PDO (Protected Designation of Origin) cheese organizations (Hulin *et al.*, 2012). As an agricultural analysis tool, it gives a diagnosis on forage system management and self-sufficiency that highlights the importance of the grass resource and the grassland diversity. As an agricultural extension tool, it educates livestock farmers and farm-sector advisors on the ecosystem services that the farm's grassland provides (Farruggia *et al.*, 2012). Originally designed for farms producing cow's milk AOP cheeses, DIAM has since been tested on a broad gradient of Massif Central-based farms encompassing cattle, sheep and goats farmed for meat and dairy. This paper shows the results obtained by using DIAM on a panel of farms and summarizes the lessons learned for the Auvergne-region livestock sector.

II – Materials and methods

Five agricultural advisors belonging to Auvergne agricultural development services performed a total of 36 diagnostics in 2012 and 2013 with farmers ready and motivated to test the tool. DIAM was thus implemented in farms equally split between the highland (altitude > 900 m asl) and upland (altitude < 900 m) located in granitic or volcanic areas. Two thirds of the surveyed farms are specialized dairy cattle farms, with the remainder oriented towards sheep, goats or cattle. A quarter of the farms are organic and half is engaged in local food supply chains, with farm-gate sales direct-to-consumer. A prerequisite to running DIAM on-farm is to collect global and easily-accessible data on the farm's forage system and animal performances. The brunt of the effort involves working with the farmer to establish a 'plot-by-plot profile' of his farm that maps each grassland plot to its management and grassland type, as defined in the Massif Central grassland typology (Carrère *et al.*, 2012). This typology counts 60 types of permanent and temporary grassland. The 23 most common types found in the DPO area are described in detail in a typology document (www.prairies-aop.net). To determine the type match for each plot, the advisor has a series of 4 ID keys rank-ordered based on altitude, management, fertilization and soil hydromorphism criteria. Plots may be visited with or without the farmer to verify that they have been assigned to the right type. Types 1 to 23 come with a factsheet listing their characteristic plant species, species rarity index, vegetation productivity and early maturity and potential annual productivity. Agricultural services are evaluated by indexes scored on a scale of 1 (low) to 5 (high) and captured through a set of 5 indicators: production, productive seasonality, forage nutritive value, management flexibility, and potential dairy production (Carrère *et al.*, 2012). Environmental services are also described through indicators on the soil carbon storage, botanical patrimonial asset, diversity of flower colors, and capacity as a habitat for pollinators and for fauna. Services linked to cheese quality are captured through indicators on carotenoids content, sensorial characteristic, potential antioxidant content and potential nutritionally valuable fatty acids content. Once this baseline data has been collected, the DIAM package algorithms calculate and give the results as four modules. The forage module gives the range of grassland types found on-farm and the functional distribution of the grassland area: proportion of area offering high productive potential and proportion allowing late-season management. It also estimates potential mean annual production of the all-farm grassland area, calculates effective and potential (deduced via potential productivity) stocking rates, and provides a forage budget and forage system management indicators, and finally the annual animal intake expressed in tons of concentrate intake and of quantities available as stored or grazed forage per LU. The environmental module and the cheese module are split into 6 and 4 indicators, respectively, that give a score at system scale of the environmental services. Lastly, the on-farm resources valorization module aggregates three indicators: proportion of milk produced during the grazing season, forage autonomy, and proportion of milk produced by on-farm resources.

III – Results

3600 ha spread across 1600 plots were analyzed counting 41 different grassland types. Two-third of farms required at least two ID keys to be used, which underline that plots are stretched between highland and upland zones within farms. Only 9% of total grasslands are temporary grassland. The remaining 91% permanent grassland is distributed over a wide fertility gradient: 9% are poor grasslands, 49% are moderately fertile and 33% are fertile-to-highly fertile. Only 11% of total grasslands are qualified as wet meadows. Grasslands in the all-farm population are dominated by 11 types, with a good symmetry of the types found in the two altitude zones: moderately fertile to fertile hayfield types and moderately fertile to highly fertile pasture types found in both zones and, temporary grassland type in the uplands coped with highly fertile pasture type associated to poor pasture type in the highland zones. Some types are relatively common on the farms but amount to little area, such as pasture on poor and dry soil type. Herbage area on the farms varies in the range 15-250 ha, with a mean of 94 ha, spread across an average 45 plots, with a mean plot size of 2 ha. Three farms produce corn and 11 grow cereal crops as self-feed. Eleven farms –9 organic and two conventional– do not use any mineral fertilizer inputs. The other farms make only modest use of mineral nitrogen fertilizer, with a mean 29 U mineral N/ha on the forage area. Grasslands diversity well-characterizes the grass systems independently of animal stocking rate, livestock systems and altitude since the average farm counts 10 different grassland types, 8 of which belong to the 23 most common types. The all-farm mean potential grass production is 5.4 t DM/ha which among other factors, varies according to mineral nitrogen input per ha ($r^2 = 0.50$). In all the farms, herbage area that offers assets in terms of productivity coexists alongside herbage area that offers greater management flexibility within the forage system. Calculated potential stocking rates are higher on average (0.97 LU/ha) than effective stocking rates and suggests that the farms have opted for a strategy based on securing their forage budget. Herbage, whether grazed or stored, constitutes the essential of the annual feed intake of livestock. Available herbage grazed averages 52% of intake profile and its part tends to increase with the decrease of the animal stocking rate ($r^2 = 0.52$). This finding suggests that in the less intensive systems, a fraction of the biomass produced on pasture is not used by the animals. In the more intensive farms, grazed resource balances out with stored fodder. Where fodder is bought, it accounts for only a minor fraction of the food intake profile (0.3 t DM/LU). Amount of cereal crops consumed on-farm and bought concentrate account for a mean 900 kg/LU, but varies strongly in a range from 100-2000 kg/LU.

A principal component analysis (PCA) was carried out to study the relationships between the different services provided by the farms (Fig. 1). The principal component axis (45% of variance) shows close relations between biodiversity indicators, aromatic density, antioxidant content of the dairy products and the management flexibility factor which are opposed to grassland productivity, stocking rate, and carotenoids content. This principal axis allows discriminating the farms according to the altitude.

Farms in highland zones are characterized by provisioning significant environmental services, more aroma-dense and antioxidant-rich animal products, and a greater proportion of farm area offering management flexibility without a significant loss in performances. Farms in upland zones are characterized by provisioning services linked to production and by products that present a yellower color due to the carotenoid-rich grass offered to the animal. In this spread, organic farms do not stand out from conventional farms. The second component axis (14% of variance) is negatively correlated to farm size, plot size and number, and high stocking rate on spring pasture. Interestingly, soil carbon storage, capacity as a habitat for pollinators, number of grassland types on the farm, nutritionally valuable fatty acids content, and the indicator on forage system coherency are not discriminant variables for farms (Fig. 1).

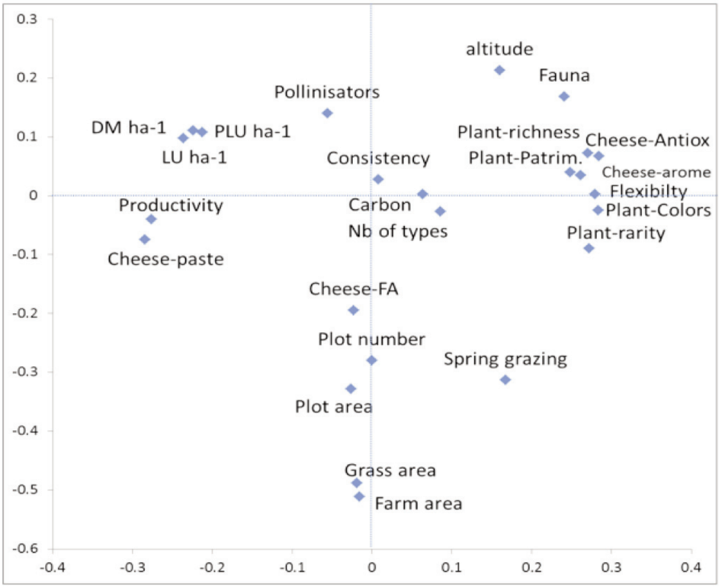

Fig. 1. Principal Component Analysis on environmental, provisioning, and animal products quality services, and characteristics of the forage systems.

IV – Discussion and conclusion

These results show that DIAM gives a broad global vision of the farm tying together agronomy, animal performances, environmental impacts and animal products qualities. It gives to the farmer a new vision on the environment previously experienced mostly by him as a source of constraints. DIAM reframes environmental impacts as positive services provisioned by grasslands –services that offer the livestock farmer a source of pride. Furthermore, this work creates starting references on the news issues of the ecosystem services provided by a wide range of livestock farming systems. These references have to be shared and extend further, with the overriding priority being to work with farmers groups, as many of the indicators given by DIAM are still too abstract for individual farmer. Results feedback sessions show that the livestock farmers are still relatively unreceptive to ecosystem services, despite farmers are engaged in PDO schemes with farm-gate sales direct-to-consumer. Advisors are also still uncomfortable with the process of reporting the DIAM results feedback and analyzing it to highlight hidden value. Nevertheless, through DIAM, advisors and farmers appropriate together the novelty of the concept of grasslands diversity. DIAM brings a new awareness that the crux of the issue is that there is not just one ‘grassland’ but a mosaic of many different grasslands, and that it is through this diversity that forage systems can be sustainable in herbage mountain areas. The DIAM diagnosis also prompts the protagonist to share and to begin understanding the finer-grained perception of grasslands held by botanists.

Nevertheless, the tool does involve a learning curve to gain the expertise needed to correctly allocate types to plots. Diagnosis accuracy relies on both the mastery of the tool and the accuracy of the typology use: a plot with several plants communities may be assigned to a single type or split into different-typed subplots. Finally, this study demonstrates that DIAM can be applied to livestock farms other than the dairy cattle targeted in its initial project brief, although the tool still needs work to re-adapt it to small ruminant and suckler-based systems. Although the overall result remains coherent, there is still room for improvement through various adjustments, particularly via more accurate descriptions of grasslands types commonly found in these systems and yet not featuring among the main 23 types of the typology document.

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Session 2

Ecosystem services, prevention of risks

Posters articles

Wildfire effects on species composition and nutritive value in different thermo-Mediterranean vegetation types

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Abstract. Wildfires have an important impact on species composition and moreover on forage production and its nutritive value in the arid Mediterranean rangelands. The present study was conducted in the East Aegean island of Oinoussa, in which a wildfire occurred in summer of 2012. Three different phryganic communities were identified in the field in burned and adjacent unburned areas at the middle of May 2013 (one year after the fire): *Sarcopoterium spinosum* phrygana, *Cistus creticus* vegetation type covering inclined slopes and *Cistus creticus* vegetation type covering abandoned terraces. Species composition and its chemical composition (herbaceous and woody species separately) were determined in each one of the three plant communities. Species composition was differentiated between burned and unburned areas as wildfire resulted in an increase of herbaceous species and in a decrease of woody ones. *C. creticus* only in terraces had similar recovery with *S. spinosum* after fire only. The nutritive value of herbaceous vegetation in terms of fiber and CP content was slightly higher in the burned areas of *C. creticus* and lower the ones of *S. spinosum*, while among the tested woody species *Cistus creticus* had the higher nutritive value.

Keywords. Revegetation – Burning – *Cistus creticus* formation – *Sarcopoterium spinosum* formation.

Effets d'un incendie sur la composition en espèces végétales et sur la valeur nutritive dans les différents types de végétation thermo-méditerranéens

Résumé. *Les feux de forêt ont un impact important sur la composition en espèces et aussi sur la production de fourrage et la valeur nutritive des parcours méditerranéens arides. La présente étude a été menée dans l'île de l'Egée d'Oinoussa, dans lequel un incendie survenu à l'été 2012. Trois communautés phryganiques différentes ont été identifiées dans les zones brûlées et non brûlées adjacentes à la mi-mai 2013 (un an après l'incendie) :* Sarcopoterium spinosum *de la* phrygana*, des communautés de* Cistus creticus *couvrant les pentes inclinées et des communautés de* Cistus creticus *couvrant les terrasses abandonnées. La composition en espèces végétales et la composition chimique des espèces herbacées et ligneuses séparément ont été déterminées dans chacune des trois communautés végétales. La composition en espèces est différente entre les superficies brûlées et non brûlées, l'incendie ayant entraîné une augmentation des espèces herbacées et une diminution des espèces ligneuses. Seul* C. creticus *sur les terrasses a eu une récupération similaire à celle de* S. spinosum *après l'incendie. La valeur nutritive de la végétation herbacée sur la base des teneurs en fibres et en protéines était légèrement plus élevée dans les zones brûlées de type* C. creticus *et plus faible dans les zones de type de* S. spinosum*, tandis que pour les espèces ligneuses* Cistus creticus *avait valeur nutritive la plus élevée.*

Mots-clés. *Végétalisation – Combustion – Formations de* Cistus creticus *– Formations de* Sarcopoterium spinosum*.*

I – Introduction

Sclerophyllous shrublands are common components of the Mediterranean vegetation and an important forage resource for the grazing animals in the Mediterranean basin (Perevolotsky *et al.*, 1998). Additionally, they are among the major fire-prone biomes of the world (Bond *et al.,* 2005). The recovery of these ecosystems after fire is differentiated among shrub species. As consequent, the vegetation structure and dynamics of sclerophyllous shrublands are controlled by both wildfires and grazing (Naveh and Dan 1973).

The reduced livestock grazing results in an increase of fire risk in these ecosystems. On the other hand, the decline of shrub cover by grazing reduces fire risk and serves hydrological purposes as well as aesthetic values (Moreira *et al.,* 2009). Moreover, the reduction of shrub cover in favor of herbaceous vegetation improves the foraging conditions (Perevolotsky *et al.,* 2002). Although illegal in Greece, fire is a traditional method, used by shepherds in order to increase the available herbage production in shrublands and to improve its feed quality (Nastis and Tsiouvaras, 2009). Thus, the aim of the present study was the comparative evaluation of species composition and their nutritive value in burned and unburned areas of different thermo-Mediterranean vegetation types one year after the fire.

II – Materials and methods

The study was conducted in Oinoussa Island, northeastern of Chios Island in East Aegean, one year after a wildfire that occurred in the northwest part of the island in 2012. The bioclimate of the area is classified as sub-humid with mild winters (Panitsa *et al.,* 1994). The mean air temperature is 16°C and the mean annual rainfall 600 mm. The vegetation types that were indentified in the study area were: (1) *Sarcopoterium spinosum* phrygana in the north-west part of the Island, (2) *Cistus creticus* vegetation type covering inclined slopes and (3) *Cistus creticus* (Ter) vegetation type covering abandoned terraces in the north-east part of the island.

Five transects of 20 m long were used in each vegetation type in burned and adjacent unburned areas along the contour lines. The plant cover was measured by using the line-point method (Cook and Stubbendieck, 1986) in May 2013, and the floristic composition was calculated. Contacts were obtained every 20 cm. The sampling of above ground biomass was carried out in two 0.5 X0.5 m quadrats in the 1st, 3rd and 5th transect in each time. The samples from the unburned areas were separated in shrubs and herbaceous vegetation. All samples were oven dried at 50ºC for 48 h and weighed. Nitrogen content was measured by the Kjeldahl method (AOAC, 1990) and crude protein (CP) was calculated by multiplying N by 6.25. Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), Acid Detergent Lignin (ADL) were measured using the procedure described by Van Soest *et al.* (1991).

The obtained data were tested for normality using the Kolmogorov-Smirnov test and Log data transformations were performed for the non-normally distributed data. One-way ANOVA was used to analyse the effect of fire on coverage of plant functional groups and nutritive value among the vegetation types with IBM SPSS 21 for Windows. The LSD at the 0.05 probability level was used to detect the differences among means.

III – Results and discussion

Wildfire resulted in a significant decrease of the coverage of woody species in all vegetation types, but the relatively lowest reestablishment of them one year after fire was observed in *C. creticus* formations in inclined slopes (Table 1). This could be attributed to the combined resprouting and seeding regenerative strategy of *S. spinosum* that promotes its recovery and competitive ability (Seligman and Henkin, 2003). On the other hand, the recovery of the obligate seeder *C.*

creticus depends on seed bank and on the degree of germination stimulation (Roy and Sonie, 1992). The more favorable germination conditions in abandoned terraces probably contributed to the better recovery of *C. creticus* there. The coverage of grasses in burned areas was significantly reduced in *C. creticus* (Ter), increased in *S. spinosum* and not affected in *C. creticus* formations in inclined slopes. The coverage of legumes was increased only in burned areas of *C. creticus* (Ter) while the forbs were not affected in all cases (Table 1).

Table 1. Coverage percentage (%) of the plant functional groups in unburned and burned areas of the three vegetation types

Vegetation types	Woody (%)		Grasses (%)		Legumes (%)		Forbs (%)	
	No-Fire	Fire	No-Fire	Fire	No-Fire	Fire	No-Fire	Fire
C. creticus	63 ± 5a	12 ± 2b	15 ± 2a	18 ± 2a	3 ± 0.8a	4 ± 1a	7 ± 3a	13 ± 2a
C. creticus (Ter)	53 ± 8a	32 ± 3b	21 ± 5a	6 ± 1b	3 ± 0.4b	7 ± 2a	12 ± 3a	2 ± 1a
S. spinosum	77 ± 3a	34 ± 4b	9 ± 2b	24 ± 5a	3 ± 1a	3 ± 2a	6 ± 2a	12 ± 3a

Means followed by the same letter in the same row for the same functional group are not significant different (P≥0.05).

S. spinosum had significantly higher NDF concentration compared to *C. creticus* in the unburned areas, while *C. creticus* had the highest CP concentration in unburned areas of abandoned terraces (Table 2). Similarly, Parlak *et al.* (2011) have reported for the same period of the year higher fiber content for *S. spinosum* compared to *C. creticus* in Turkey.

Table 2. Chemical composition ($g.kg^{-1}$) (Means±S.E.) of the dominant shrubs, *C. creticus* and *S. spinosum* in unburned areas of the three vegetation types

Vegetation types	NDF($g.kg^{-1}$)	ADF($g.kg^{-1}$)	ADL($g.kg^{-1}$)	CP($g.kg^{-1}$)
C. creticus	356 ± 16a*	362 ± 24a	135 ± 11a	80 ± 12b
C. creticus (Ter)	339 ± 11a	351 ± 19a	122 ± 4a	116 ± 7a
S. spinosum	540 ± 10b	370 ± 12a	110 ± 7a	74 ± 8b

Means in the same column followed by the same letter are not significantly different (P≥0.05).

The NDF and ADF concentration of the herbaceous vegetation was significantly reduced in *C. creticus* formation, while it was increased in *S. spinosum* (Table 3). The ADL concentration was increased in all cases. The CP concentration was reduced in *S. spinosum* formation and was not affected in *C. creticus* (Table 3). The nutritive value of herbaceous vegetation in terms of fiber and CP content was slightly increased and decreased after fire in *C. creticus* and *S. spinosum* respectively. This divergent result could be attributed to differences in species composition and in stages of maturity among plant species (Huyghe *et al.*, 2008) among the vegetation types.

Table 3. Chemical composition ($g.kg^{-1}$) (means ± S.E.) of the herbaceous vegetation in unburned and burned areas of the three vegetation types

	NDF($g.kg^{-1}$)		ADF($g.kg^{-1}$)		ADL($g.kg^{-1}$)		CP($g.kg^{-1}$)	
	No-Fire	Fire	No-Fire	Fire	No-Fire	Fire	No-Fire	Fire
C. cr.	648 ± 16a†	473 ± 43b	385 ± 11a	340 ± 18b	60 ± 5b	98 ± 1a	110 ± 2a	103 ± 5a
C. cr (Ter)	620 ± 12a	414 ± 24b	403 ± 11a	310 ± 5b	71 ± 1b	91 ± 6a	83 ± 7a	93 ± 5a
S. sp.	541 ± 12b	600 ± 9a	347 ± 6b	399 ± 10a	70 ± 4b	96 ± 5a	91 ± 3a	76 ± 1b

† Means followed by the same letter in the same row for the same functional group are not significant different (P≥0.05) (C.cr: *Cistus creticus*, S.sp: *Sarcopoterium spinosum*).

IV – Conclusions

Species composition was differentiated between burned and unburned areas as wildfire resulted in an increase of herbaceous species mainly grasses and in a decrease of woody ones. The post-fire recovery of obligate seeder *C. creticus* was similar with that of the resprouter *S. spinosum* only in abandoned terraces. The nutritive value in terms of fiber and CP content was positively affected by fire in *C. creticus* vegetation type but negatively in *S. spinosum.*

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Analysis of ecosystem services provided by grassland-based livestock systems

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Abstract. Characterizing ecosystem services (ES) and their underlying drivers remains a challenge. Issues are related to scale, knowledge and outcomes that are stakeholder-dependent. We characterise plant functional diversity at different scales (field, farm). Then, we analyse its response to environmental and management factors, and its effects on ES. Based on five previously established grass functional types (GFTs), three indicators were defined; among them the percentage of GFT having a fast ($Fast_{GFT}$) growth strategy. The approach was applied on eight farms having three grassland uses (LMU: cutting, grazing by cows and heifers), but differing in their orientation and management. $Fast_{GFT}$ responded positively to N fertiliser application and negatively to field elevation (n=169). Herbage production at field (n=60) and LMU (n=24) levels was positively correlated to $Fast_{GFT}$, while it is negatively correlated with soil C content and species richness. Within farm grassland diversity for $Fast_{GFT}$ allows matching animal feed requirement to available quality of resources, and contributes to create a landscape mosaic. A framework is proposed for evaluating trade-offs between services.

Key words. Landscape – Management – Provision services – Supporting services – Trade-offs.

Une méthode pour caractériser les services écosystémiques fournis par les élevages herbagers

Résumé. *La caractérisation des services écosystémiques (ES) est difficile (échelles, connaissances, porteurs d'enjeux). Nous caractérisons la diversité fonctionnelle des plantes prairiales aux échelles parcelle et ferme, puis nous analysons sa réponses aux facteurs environnementaux et de gestion, et ses effets sur les ES. Basé sur cinq types fonctionnels de graminées (TFG), trois indicateurs ont été calculés parmi lesquels la proportion de TFG ayant une stratégie de croissance rapide ($Fast_{GFT}$). L'approche a été appliquée à 8 fermes où les prairies ont trois usages identiques (fauche, pâturage : vaches et génisses), mais diffèrent de par leur orientation de production et leur chargement moyen. $Fast_{GFT}$ a répondu positivement à l'azote apporté et négativement à l'altitude. La production de biomasse estimée à l'échelle de la parcelle (n=60) et de la sole (n=24) est positivement corrélée à $Fast_{GFT}$, tandis que la teneur du sol en C et la richesse en espèces le sont négativement. La diversité entre prairies au sein d'une ferme permet une cohérence entre le type de prairie et les besoins alimentaires des animaux et crée une mosaïque paysagère. Un cadre d'analyse est proposé pour évaluer les compromis entre ES.*

Mots-clés. *Paysage – Gestion – Type fonctionnel de plante – Compromis.*

I – Introduction

Policy makers are keen to encourage more sustainable livestock systems for maximizing the provision of ecosystem services (ES). We consider production services (e.g. forage), non-marketed services (e.g. C storage, cultural value) and "input services" (e.g. soil fertility) provided by biodiversity. Trade-offs among ES are essential to know for management and policy decisions. Studying ES provided by grasslands for determining trade-offs arise several issues. ES are scale-dependant (field, landscape), and the farm scale is understudied (Lugnot and Martin, 2013). So, within-farm grassland diversity can provide opportunity to lower production costs through fitting grassland types to animal feed requirements. Second, most research on grassland produce outputs suitable for understanding effect of drivers upon ES, but struggle to produce research outcomes easy to handle by stakeholders. Thus particular attention should be paid for building relevant indicators, in addition to their scientific credibility. In this study, we propose an approach whereby stakeholders can characterize the provision of a set of ES in grassland-based livestock systems: forage production services, input services, management services, environmental services (species richness and soil C storage) and cultural services (within and between grassland field diversity). The approach applies on three scales: field, land management unit (LMU: those parts of farms allocated to single groups of animals corresponding to single management units for production, feeding, health care, etc), and set of fields at farm or landscape scales. The LMU scale is needed because averaging data at farm levels loses possible within-farm differences due to differences in the management of animal groups (e.g. cows and heifers). Set of fields at farm or landscape scales are needed for evaluating ES related to within and between grassland field diversity. We discuss strength and weaknesses of the approach for characterizing trade-offs and synergies between ES.

II – Materials and methods

Method. Based on leaf and phenological plant traits, five elementary grass functional types (GFT) were previously defined according to their plant growth strategy (Duru *et al*., 2013). Among these, three groups ($Fast_{GFT}$) correspond to plants with a fast growth strategy. Two additional indicators of grassland functional composition are considered: Sum_{GFT}, the proportion of grass species in the herbage mass, and functional divergence (Div_{GFT}), an indicator of GFT diversity. Forage production and herbage quality at leafy stage are correlated to $Fast_{GFT}$ (Duru *et al*. 2013). By construction, there is a parabolic relationship between Div_{GFT} and the percentage of $Fast_{GFT}$, the maximum functional diversity being expected for mean values of $Fast_{GFT}$. In this paper, we examine whether such indicators can be used for predicting other ES at field level (input services; species richness and C sequestration) and management services at LMU-farm levels. We assume that an effective management is related to the degree to which forage quality (assessed by $Fast_{GFT}$) match animal feed requirements (dairy cow> beef cow; cow> heifers). Farmers combine fields displaying different vegetation types into several assemblages, each single assemblage being used to feed a particular herd batch. To assess such assemblages, we first compared plant functional composition per farm between LMUs. Then we examined whether there was a between-farm effect of production orientation and stocking density to determine whether or not there is a specialization of plant types at LMU level. Examining vegetation diversity at different space scales for phenology, height and colour can provide the raw data for assessing cultural services. Thus, we use the Div_{GFT} x$Fast_{GFT}$ framework for characterizing the within- and between diversity for a field or a set of fields. For each studied ES, the scale according to the beneficiaries (farmers or society), and indicators of grassland functions and of ES provided are indicated (Table 1).

Table 1. Mapping of grassland properties to grassland services

Types	Scale (beneficiaries)	Grassland functions	Services provided
Forage provision	LMU, field (farmer)	Fast $_{GFT}$ (LMU level)	Stocking rate
Management	LMU (farmer)	Within and among farm GFT distribution	Degree at which forage match animal requirements
Input (fertility)	Field (farmer)	Div_{GFT} N uptake permitted by within field diversity	Biomass/ N supplied
C sequestration	Landscape	$Fast_{GFT}$	Soil C content
Species richness	Field/landscape (society)	$Fast_{GFT}$; Sum $_{GFT}$	number of species
Cultural (field mosaic)	Field-> landscape (society)	$Fast_{GFT}$ x Div_{GFT} mapped at different scales	Visual within and between fields diversity

***Case study*.** The work was done in the Aubrac region (southern part of the French Central Massif (800 – 1400 m a.s.l), on 8 specialized dairy or beef farms having different stocking densities. On their 169 fields, we recorded grassland plant composition and land use practices: fertilizer applications, type of first use [grazing or cutting only, early grazing that removes the apexes (topping)], date of first use, and type of grazing animals. On 60 grassland fields, detailed soil and plant data were recorded for calculating N uptake, soil C content and plant richness. The stocking rate (SR) was considered as a proxy for forage production).

III – Results: ecosystem services provision

At field level, herbage mass was significantly correlated to the percentage of $Fast_{GFT}$. For the less fertilized grazed grasslands (24.4 ± 26 kg N per ha), N uptake was significantly and positively correlated with Div_{GFT} (r = 0.4, n = 38). Soil C content and species richness were significantly and negatively correlated to $Fast_{GFT}$. For species richness correlation was improved when taking into account Sum_{GFT} which was significantly and negatively correlated.

At LMU and landscape levels, there was a significant positive correlation between SR and the percentage of $Fast_{GFT}$ (P<0.001). For pastures alone, the values of SR and $Fast_{GFT}$ were on average higher for dairy cows and lower for heifers. However, there was evidence of variation in SR and of $Fast_{GFT}$ percentages of at least 50% for the same land use type and farm production orientation. Conversely similar grassland functional composition was found for all three types of animal groups (beef and dairy cows, heifers). A minimum SR of 0.5 animal units/ha was observed in the absence of $Fast_{GFT}$. For cut areas alone, there was no relationship between the SR and the percentage of $Fast_{GFT}$. The SR depended mainly on the proportion of the cut area which was topped in early spring (r = 0.9; P = 0.08). However, SR was positively correlated with N fertilizer rate and timing of the first cut (r= 0.82; p<0.05).

For management services, there were significant differences in $Fast_{GFT}$ between the three land management units (cut, grazed by cows and by heifers) for 6 of the 8 farms. Except one dairy farm, the cut LMU had the highest percentage of $Fast_{GFT}$. This means that the forage production and the forage quality at leafy stage ($Fast_{GFT}$) were usually the highest for cut areas (except one dairy and one beef farms), and the same was observed for cow grazing areas in comparison with heifer grazing areas (except for one dairy and two beef farms). These data show consistent rankings of animal feed requirements and type of vegetation allocated, except for one dairy farm. Consistently, there was an effect of farm production orientation on the percentage of $Fast_{GFT}$ (P<0.01) for all LMU. $Fast_{GFT}$ were significantly lower for beef farms. Among dairy farms and grazing areas, there was a significant difference between $Fast_{GFT}$, as was the case between farms for heifers.

Within-(Div_{GFT} values) and between-(differences in $Fast_{GFT}$ values) field diversity, proxies of cultural services were examined for a set of fields among farms or landscapes. The more the within-field or between-field diversity, the more heterogeneous were the grasslands in terms of height and phenology. At the farm scale, the analysis of the three LMU showed that for cow grazing and cutting areas, there was a trend to observe higher values of $Fast_{GFT}$ for dairy farms than for beef farms. Within the range of 40-60% for $Fast_{GFT}$, the three LMU types were observed for both types of farm enterprise. In dairy farms, the heifer LMU enlarged the between-LMU differences due to their low values of $Fast_{GFT}$, while for beef farms, it was the cut LMU type which enlarged the differences between LMUs due to their high values of $Fast_{GFT}$. For the whole data set, we considered three components of plant diversity Div_{GFT}, $Fast_{GFT}$. and Sum_{GFT}. Same patterns between Div_{GFT} and $Fast_{GFT}$ were observed whatever the percentage of grass species (Sum_{GFT}), excepted for very low $Fast_{GFT}$ values. Comparison of analysis at field and LMU scales show that this is the LMU level that mostly structures grassland diversity: grassland diversity is greater between than within LMUs. It means that differences in farm orientation and stocking density are required to maintain a grassland mosaic at landscape level.

IV – An integrated framework for linking management and services

$Fast_{GFT}$ increased with nutrient availability and decreased with temperature which is negatively related to field elevation. Stress factors for nutrient availability and average temperature (resulting from field elevation) act in the same direction, favouring species having fast growth strategy when the stress level is low. The effects of defoliation management add to those of stresses. Disturbances modify the effect of stress, either by reducing or by amplifying it. For given climatic and soil conditions, mowing promotes acquisitive types, while grazing promotes conservative types. Functional diversity being characterized here by Div_{GFT}, the direction of effect for stress factors (fertilisation rate and field altitude) depended on the dominant plant strategy. Previous research on the intermediate stress hypothesis supports the idea that maximum diversity was only observed when considering stress and disturbance factors simultaneously. In our framework, both are roughly mediated by the proportion of $Fast_{GFT}$. A high level of Div_{GFT} results from the coexistence of species with both types of growth strategy.

Based on the farm sample studied, we found that even a single farm could contain a wide range of within- and between-field functional plant diversity, and that contrasting land use within a farm can create as large diversity on a small spatial scale as observed at the landscape scale. As observed in a very different context, GFT assemblages are the result of deliberate management choices resulting from farm production orientation and from assets and constraints such as available facilities and field topography (Martin *et al.* 2009). Differences in GFT diversity at LMU scale are the result of land use and farm enterprise types. Usually cut grasslands have the highest proportion of fast growing species, firstly because they receive more fertilizer and secondly due to the direct effect of management regime. Dairy farms have a higher proportion of $Fast_{GFT}$ for both cut and grazed areas, consistently with the highest digestibility of these plant types. Between-farm comparisons can show whether there is scope for reducing the cost of feedstuffs. For example, the fourth dairy farms have similar milk production per cow (around 5000 kg / year) while the percentage of $Fast_{GFT}$ varied greatly: it was highest for one dairy farm and lowest for another dairy farm. Since a high percentage of $Fast_{GFT}$ requires high fertilizer input, this means that production costs could be reduced if enough land is available. The method also allows discrepancies to be detected, for example for dairy heifers in farm one dairy farm that used high-quality herbage. It allows a large number of ES to be evaluated at different spatial scales, and the main trade-offs between ES to be analysed. $Fast_{GFT}$ was a good proxy for forage production at field and LMU levels. For low N rates, we verified that the coexistence of GFT having different strategies for resource acquisition leads to higher input efficiency for herbage production as suggested by Fornara and Tilman (2009). For management services, we found that between-farm differences are related to consistent allocation of vegetation types or forage resources to different animal groups in order to save labour or feedstuffs costs. Furthermore, our framework provides a basis for comparing within- and between-field plant functional diversity; this could simplify the gathering of stakeholders' perceptions about cultural services. It allows the main trade-offs between ES to be examined. Using the approach at LMU scale, we have shown that such trade-offs were not usually a problem for managers because the targeted ES mainly depended on the group of animal (cow vs heifer) or the land management (grazing vs cutting) considered. Thus, the diversity of animal groups on a farm, and the diversity in farm enterprises in a region lead to a diversity of vegetation types in a landscape which is enhanced by environmental factors such as field aspect and elevation. This explains why such diversity in agriculture creates a mosaic of vegetation types and a great landscape heterogeneity that contribute to cultural services, and more broadly to multiple ES.

The approach based on GFT is easy to understand by stakeholders. Farmers give positive feedback when their land was depicted as GFT through a graph bar or a map. It should help advisors to understand the implications of different management choices on grassland diversity. It also provides lessons to examine the impacts of policies to support biodiversity with subsidies based on stocking rate thresholds calculated for a set of fields or the whole farmland. The field scale may be sufficient for assessing their impact on plant diversity, while the farm scale is still needed to understand the drivers of management practices.

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Effects of extreme drought on grasslands
Evaluation of the buffering effect of plant diversity using an experimental approach

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Abstract. The frequency and magnitude of extreme drought events are expected to increase with climate change. Consequently, it is important to assess the ability of temperate grassland to resist and recover from more frequent and intense drought stress. To study this topic, we established a mesocosm experiment in autumn 2012: large pots (100 L) containing combinations of grassland species (1, 2 or 5 species) were placed on weighing scales to continuously measure the actual evapotranspiration of the plant canopy. Species selected (four grasses and one legume) were representative of temperate upland grasslands on fertile soils. An extreme summer drought was applied to half the pots and plant recovery following rewetting was monitored. Total biomass and evapotranspiration were analyzed to test the effects of species diversity on the resistance and recovery of grasslands to extreme drought. As expected, drought dramatically reduced by 79% biomass of all mixtures. The 5 species mixtures showed higher drought avoidance by maintaining integrated water-use efficiency and took up water at deeper soil layers than the less diverse mixtures during drought. These findings indicated that buffering effect of diversity during drought occurs for the 5-species mixtures, possibly due to below-ground niche differentiation. This study emphasizes the high capacity of grass species mixtures to recover after an extreme drought.

Keywords. Drought – Resistance – Resilience – Plant diversity – Functional complementarity.

Effet d'une sécheresse extrême sur l'écosystème prairial : évaluation du rôle tampon de la diversité végétale par approche expérimentale

Résumé. *Avec le changement climatique la fréquence et l'ampleur des phénomènes extrêmes de type sécheresse devraient augmenter. Dans ces conditions, il est important d'évaluer la capacité des prairies de moyenne montagne à résister et à récupérer de stress plus fréquents et plus intenses. Une expérience en mésocosmes a donc été mise en place à l'automne 2012 : de grands pots (100 L) contenant des cultures d'espèces prairiales (1, 2 ou 5 espèces) ont été placés sur des balances permettant de mesurer en continu l'évapotranspiration réelle du couvert végétal. Les espèces sélectionnées (quatre graminées et une légumineuse) sont représentatives des prairies permanentes fertiles de moyenne montagne. Une sécheresse extrême estivale a été simulée sur la moitié des pots, puis les cultures ont été réhydratées pour suivre leur capacité de récupération. La biomasse totale et l'évapotranspiration ont été analysées pour tester les effets de la diversité en espèces sur la résistance et la récupération des prairies à une sécheresse extrême. Comme attendu, la sécheresse a considérablement affecté tous les mélanges avec une réduction de biomasse de 79%. Pendant la période de sécheresse les mélanges à 5 espèces montrent un évitement plus marqué que les mélanges moins diversifiés notamment avec un maintien de leur efficience d'utilisation de l'eau et un prélèvement de l'eau dans des couches plus profondes du sol. Ces résultats indiquent que l'effet tampon de la diversité lors de la sécheresse apparaît pour les mélanges 5 espèces, probablement en raison de la différenciation de niches au niveau souterrain. Cette étude souligne la grande capacité de récupération des mélanges d'espèces prairiales après un évènement de sécheresse extrême.*

Mots-clés. *Sécheresse – Résistance – Résilience – Diversité – Complémentarité fonctionnelle.*

I – Introduction

The frequency and magnitude of extreme drought events are expected to increase with climate change. Beyond a certain threshold, these extreme events can alter the resistance and resilience of grasslands, modifying grassland productivity and/or forage quality. However, the ability of grassland communities to resist and recover from more frequent and intense drought stress events remains unclear. According to the insurance hypothesis (Yachi and Loreau, 1999), diversity promotes resistance and resilience to stress, and this effect should be maintained under climate change (Vogel *et al*., 2012). In the present experiment, we assess the buffering effects of species diversity on the resistance and recovery of grasslands to extreme drought, and examine the mechanisms involved (between-plant facilitation or complementarity).

II – Materials and methods

The mesocosm experiment was established in autumn 2012. Large cylindrical pots (100 L, 93 cm deep and 37.5 cm diameter) were filled with grassland soil and equipped with soil water content sensors (ECHO-5, Decagon, USA) at three depths (15, 30, 50 cm). Monocultures, binary and five-species mixtures were established by planting mature plants in autumn. Species selected were representative of temperate fertile upland grasslands: *Dactylis glomerata*, *Festuca arundinacea*, *Poa pratensis*, *Trisetum flavescens* and *Trifolium repens*. Five types of monocultures, ten types of binary and one mixture of five species were established, each pot initially containing 30 individuals with an equal proportion between species in mixtures. In spring of the following year, the pots were placed on weighing scales to continuously measure the evapotranspiration of the plant canopy. In total, 96 pots were set up: two treatments (control and drought) and six replicates by type of mixture. Following mesocosm establishment, all pots were maintained at 80% of the field capacity by watering or rainfall for eight months. In June 2013, an extreme summer drought lasting two months was applied to half of the pots (3 pots by type of mixture). This extreme event was simulated by a total rainfall interception from mid-June to mid-August (Fig. 1). The remaining pots (control treatment) were irrigated to maintain soil water content at 80% of field capacity for the duration of the experiment. Mesocosms were managed by cutting to 5 cm at five dates from April to October (Fig. 1). During the drought (July cutting date), only the control pots were cut. All biomass samples were oven-dried (48 h, 60°C) and weighed.

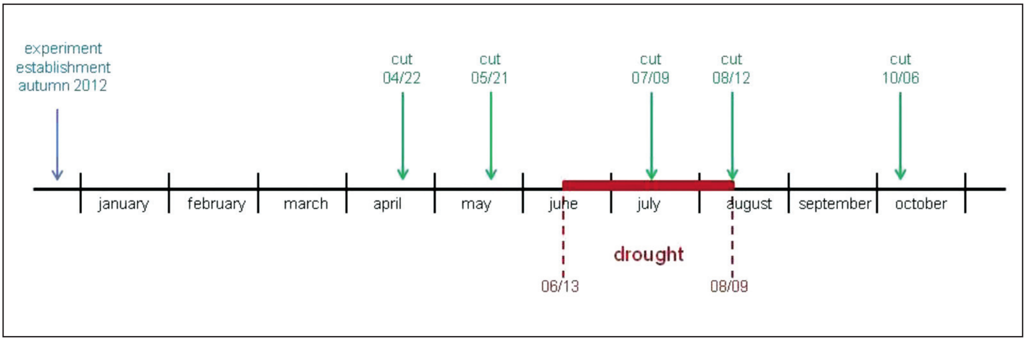

Fig. 1. Time course of the experiment. Red bar corresponds to period of drought.

Cutting dates were used to define three major periods of vegetation biomass production (g m^{-2}) during the experiment: before the drought (between 04/22 and 05/21), during the drought (between 05/21 and 08/12) and after the drought (between 08/12 and 10/06). Integrated water-use efficiency (WUE, g kg^{-1}) was calculated as the ratio of biomass to cumulative evapotranspiration for each period. Data on biomass production, evapotranspiration, WUE and soil moisture were used to assess the resistance and recovery of the different mixtures to a severe drought, and to study the potential buffer role of plant diversity. Statistical analyses were performed using mixed effect models with the software R (R Development Core Team, 2009).

III – Results and discussion

Before drought, biomass and WUE were similar for 1, 2 and 5 species mixtures (Fig. 2a). As expected, biomass produced during the drought was significantly lower in the drought treatment compared with the control (average -79%). Diversity treatments had no significant effect on biomass production during drought (Fig. 2b).

Unlike biomass, WUE showed a significant drought x diversity interaction, with smaller drought-induced decreases in WUE in the 5-species mixture (Fig. 2f). This result could indicate a greater resistance to drought for 5-species mixtures in terms of WUE, and is consistent with the idea of a buffering effect at high species diversity.

In the control treatment, 5-species mixtures had lower soil moisture values at 15 cm (P1) soil depth throughout the experiment compared with the 1 and 2 diversity levels (Fig. 3). But during the drought, the largest decrease of soil moisture was observed at 30 cm (P2) and 50 cm (P3) for the 5 species mixture (Fig. 3.c). In case of less diverse mixtures, this decrease was more important at P1 and P2 (Fig. 3.a, 3.b). These findings indicate that the more diverse mixture took up water deeper, suggesting the presence of deeper active roots in diverse mixtures. Higher competition for water in the shallow soil in diverse mixtures could have promoted a differentiation in root depth between species. Mechanisms of complementarity by niche differentiation could involve better resource partitioning and increased water use efficiency, resulting in higher drought resistance for high diversity mixtures (Cardinale *et al*., 2007; Verheyen *et al*., 2008).

During the recovery period after drought, biomass and WUE of droughted-mixtures reached the same levels as the control (Fig. 2c, 2g), which highlights a strong and fast capacity of recovery in terms of biomass production and WUE. However, diversity treatments had no significant effect on biomass production or WUE during the recovery period.

The belowground species complementarity seems to appear for high levels of diversity (5 species) and could involve a better resistance to stress. However for the 5 species mixtures we observed a decrease of species richness to 3 or 4 species during the recovery period due to species mortality (low or absence of recovery for *Festuca arundinacea* and *Trifolium repens*). The observation of a positive diversity effect at the community level for the 5 species mixtures should be mitigated by this mortality observed at the species level.

IV – Conclusions

Our experiment shows that a buffering effect of species diversity during drought occurs for WUE of the 5-species mixtures, possibly due to below-ground niche differentiation. However this effect was transitory as it disappeared during the recovery period. Finally our results highlighted the high capacity of grass mixtures to recover after an extreme drought, although some species like *Festuca arundinacea* or *Trifolium repens* did not. Further analyses will explore differential specific response of the mixtures to drought and after rehydration.

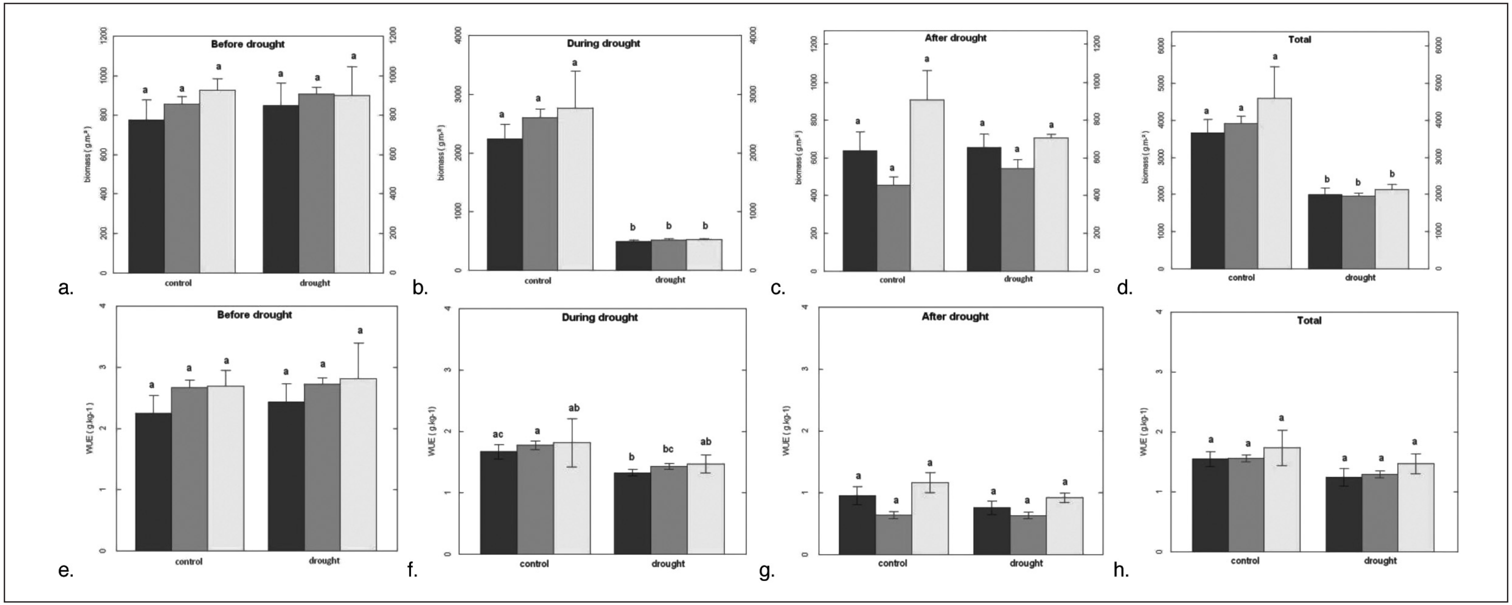

Fig. 2. Biomass (a),(b),(c),(d) and WUE (e),(f),(g),(h) of the three diversity levels: monocultures in black, binary in dark grey, and mixtures of 5 species in light grey. Means ± standard errors are shown. Letters represent the post-hoc Tukey tests performed after ANOVA.

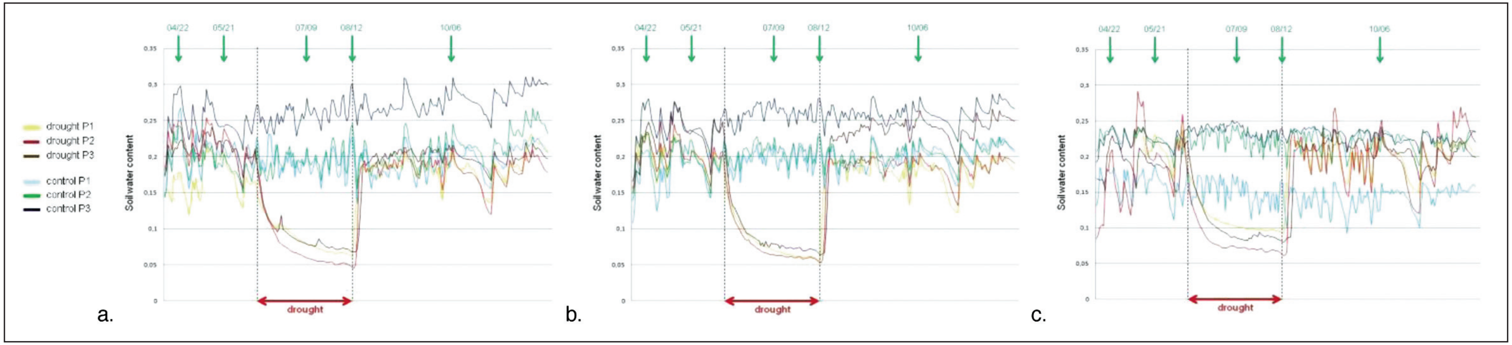

Fig. 3. Time course of soil water content for monocultures (a), binary (b) and 5 species mixtures (c), measured at three depths (P1: 15 cm; P2: 30 cm; P3: 50 cm). Green arrows correspond to cut dates.

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Quantifying grazing intensity and ecosystem services in subalpine pastures

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Abstract. Centuries of summer grazing on subalpine pastures have created unique ecosystems providing society with food of special quality, recreation and cultural heritage. Structural change in mountain agriculture has led to rationalisation of labour and modifications of traditional grazing regimes in many regions. Both processes affect the ecosystem and the services provided. Policy makers and herdsmen are confronted with the question of how livestock management needs to be adjusted in order to maintain and improve the provision of ecosystem services. In order to understand the connections between grazing intensity and ecosystem services, both elements have to be quantified independently of environmental characteristics (soil and vegetation). We demonstrate these connections based on investigations in six summer farms in the Swiss Alps. Three ecosystem services (forage production, biodiversity conservation and carbon sequestration) were assessed on eleven plots per farm. Grazing intensity was quantified using high-frequency GPS tracking. Our results show that environmental variables explained an important part of all three ecosystem services. Nevertheless, there is independent influence of grazing intensity on plant species richness and fodder production, demonstrating the importance of appropriate management for these services. Since the effects of grazing intensity on these two services are opposite, an adjustment of grazing intensity requires consideration of the specific aims on a grazed site.

Keywords. Mountain pastures – GPS – Animal behaviour – Vegetation.

Quantifier l'intensité de pâturage et les services écosystémiques dans les pâturages subalpins

Résumé. *Des siècles de pâturage estivaux dans les alpages ont créé des écosystèmes uniques qui fournissent à la société des produits du terroir de qualité spéciale, de l'espace récréatif et un patrimoine culturel. Les changements structurels dans l'agriculture de montagne ont donné lieu à une rationalisation du travail et à des modifications des régimes de pâturage traditionnels dans de nombreuses régions. Ces deux processus ont modifié l'écosystème et les services fournis. Les décideurs et les éleveurs sont confrontés à la question de savoir comment la gestion du bétail doit être ajustée afin de maintenir et d'améliorer la provision des services écosystémiques. Afin de comprendre les liens entre l'intensité de pâture et les services écosystémiques, ces deux éléments doivent être quantifiés indépendamment de l'environnement (sol et végétation). Nous avons étudié ces relations à partir d'enquêtes réalisées dans six alpages suisses. Trois services écosystémiques (production de fourrage, conservation de la biodiversité et séquestration du carbone) ont été évalués sur onze parcelles par alpage. L'intensité de pâture a été quantifiée par un suivi GPS à haute fréquence. Nos résultats ont montré que les variables environnementales expliquent une partie importante des trois services écosystémiques. Néanmoins, l'intensité de pâture influence de manière indépendante la richesse spécifique végétale et la production de fourrage. Les décisions dans la gestion de pâture auront donc une forte influence sur ces services écosystémiques. Etant donné que les effets de l'intensité de pâture sur ces deux services sont opposés, il est nécessaire d'examiner les objectifs spécifiques sur un site pâturé afin d'y adapter l'intensité de pâture.*

Mots-clés. *Alpages – GPS – Comportement animal – Végétation.*

I – Importance of subalpine pastures

Subalpine pastures provide crucial services to society: they are habitat to specialised plant and animal species, represent areas for recreation and cultural heritage, deliver forage for grazing animals, prevent soil erosion and sequester carbon. While biodiversity is an important determinant of ecosystem functions (e.g. Diaz *et al.*, 2007), forage production has a direct economic value to farmers. Soil organic carbon (SOC) plays a role in regulating climate and soil fertility (McSherry and Ritchie, 2013). Since pasture ecosystems have been shaped by centuries of animal grazing, the provision of ecosystem services is strongly related to the intensity of grazing (Homburger *et al.*, 2013; Kampmann *et al.*, 2008). Grazing animals respond to environmental properties such as topography and vegetation (Schneider *et al.*, 2013) and, hence, there are strong interactions between such abiotic and biotic drivers of ecosystem services. At the same time, herders decide on amount, timing and duration of stocking as well as on the type of grazing animal. Grazing intensity is therefore one of the most important system variables influenced by land managers.

In order to manage grazing intensity for the provision of ecosystem services, we need to understand the connections between the two and with the environment. For this purpose, grazing intensity has to be quantified independently of environmental characteristics (soil and vegetation). In what follows, we give a brief overview on (1) techniques available for the quantification of grazing intensity in rough terrain, (2) measurements of ecosystem services in subalpine pastures and (3) the connection between the two and their interactions with the environment.

II – Quantifying grazing impact in heterogeneous terrain

In the highly heterogeneous subalpine environment, the assessment of grazing intensity remains a challenge. Since most paddocks are large, approximating grazing intensity by average stocking rate within the paddock, for example, does not account for small-scale patterns of grazing on large subalpine pastures (Homburger *et al.*, 2012). In heterogeneous environment, livestock select favoured fodder patches and avoid unsuitable areas (Adler *et al.*, 2001). Therefore, average stocking rate overestimates true intensity on a large portion of extensively grazed sites and underestimates grazing of those locations preferred by the animals. Approximating grazing intensity by average stocking rate can introduce substantial bias into estimates of its impact on ecosystem services.

Most approaches to improve estimates of local grazing intensity involve the recording of positions and activity of grazing animals. In its simplest form, this can be done by counting animals from an overview point (e.g. Jewell *et al.*, 2005). However, the technique is time-consuming and imprecise. The miniaturization of GPS receivers has greatly simplified animal tracking and allows recording positions continuously at a high temporal resolution (Fig. 1). Homburger *et al.* (2012) tracked animals at a frequency of 20 seconds, which allowed reliably attributing positions to the behavioural states of grazing, walking and resting based on behavioural observations in the field. The density of observed positions classified as grazing can subsequently be analysed for effects of environmental variables on grazing intensity (Schneider *et al.*, 2013).

III – Measuring ecosystem services

Quantifying ecosystem services in subalpine pastures requires dealing (1) with the large heterogeneity in environmental conditions and (2) the scales, at which services can be measured and at which quantification is of interest. The latter need not be similar. For example, soil C stocks are quantified based on core samples with very small volumes compared to the gigatons cycling globally. Random sampling with stratification and subsequent interpolation using statistical modelling is a prominent technique to deal with heterogeneity and can also be used to extrapolate results to larger areas (Müller, 2007).

Homburger *et al.* (2013) measured three prominent ecosystem services of subalpine pastures - plant species richness, fodder production and SOC content – on six summer farms in the Swiss Alps. The detailed measurements were carried out on eleven sites per farm. Nine of them were selected in crossed strata of terrain slope and distance from the central shed of the farm. These two environmental variables were readily available before the investigation and known to be important for the distribution of ecosystem services in subalpine pastures (Kampmann *et al.*, 2008; Peter *et al.*, 2009). In addition, two sites were selected based on information from farmers on herd management. A suitably homogenous sampling area of 25 m^2 was used to determine plant species richness (Fig. 2). Fodder production was measured as biomass dry matter production using 1 m^2 grazing exclusion cages. SOC content was quantified from 16 pooled soil cores per plot.

Fig. 1. Cow carrying a white box containing the GPS device on a subalpine pasture.

Fig. 2. Assessment plot for the measurement of the ecosystem services plant species richness, forage production and soil C storage. Arrow indicates the location of another plot on a steeper site at equal distance from buildings.

IV – Connecting the two

Homburger *et al.* (2013) used generalized linear mixed-effects models to analyze effects of grazing intensity and environmental variables on ecosystem services. They found that terrain slope had a positive effect ($P<0.001$) on plant species richness, in line with various other studies, e.g. Kampmann *et al.* (2008) or Peter *et al.* (2009). These studies attributed most of the slope effect to a reduced grazing intensity in steep terrain but did not really quantify it. The preliminary results of Homburger *et al.* (2013) indicate that there is an additional significantly negative effect of grazing intensity ($P<0.01$) on plant species richness, independent of terrain slope. This effect may be due to naturally drier and shallower soils on slopes than in flat areas.

Similar but inverse relationships were found for forage production, which was negatively related to terrain slope ($P<0.01$) and distance to the farm building ($P<0.05$) as well as positively to grazing intensity ($P<0.001$). The contrasting response of these two ecosystem services was also indicated by a relatively close hump-shaped relationship as demonstrated by Schneider *et al.* (2011).

Homburger *et al.* (2013) showed that only a complex model was able to partially predict SOC content. The only explanatory variable with a significant effect was soil phosphorus content, which was positively related to SOC content ($P<0.001$). Terrain slope, altitude and grazing intensity had effects only in interaction with one another. Homburger *et al.* (2013) concluded that grazing intensity slightly altered environmental effects on SOC storage but had no effect alone. In their recent meta-analysis, McSherry and Ritchie (2013) also found no univariate effect of grazing on SOC and highlighted the importance of the environmental and biotic context in SOC sequestration.

V – Conclusions

An independent quantification of grazing intensity and ecosystem services offers new insights into the provision of these services in subalpine pastures. Evidence suggests that different ecosystem services are not controlled by grazing intensity in the same way. Grazing intensity was most strongly connected to fodder production, to a lesser extent to plant species richness and did not explain variance in SOC content alone. Since the relationships of grazing intensity with fodder production and plant species richness are opposite, the provision of both services at a given site is difficult and an adjustment of grazing intensity requires consideration of the specific aims on a grazed site. This means that land managers need a clear view on ecosystem services provided by their pastures and the consequences of management action for these services. Since relationships are complex, as shown above, management planning on subalpine pastures should take into account multiple ecosystem services in order to guide land managers in their daily decisions.

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The impact of transhumant livestock system on the diversity of two mountainous grasslands in Northern Greece

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Abstract. The transhumant livestock system, which involves sheep and goats, is common in many countries of the Mediterranean basin. In Greece, transhumance uses the semi-natural vegetation of intermediate and high elevation grasslands for 5-6 months imposing variable pressures on the native vegetation. This paper investigated the impact of long term grazing of transhumant sheep and goats flocks on the diversity and land reclamation of two mountainous grasslands of Northern Greece. The experiment involved two high elevation Mediterranean grasslands of Northern Greece (Smolikas and Vermion mountains) located approximately 120 km apart. Measurements were carried out in the above areas in the middle of June 2012 including vegetation cover, while composition and the richness of the species were calculated. Thereafter, the index of similarity and plant species diversity and evenness were estimated. The results revealed no differences between the two grasslands regarding the (a) composition of species, (b) diversity of plant species, and (c) species richness. The percentage of vegetation cover was similar in the two grasslands, while the similarity index was small.

Keywords. Species composition – Richness – Sheep – Goats – Similarity index.

L'impact du système d'élevage transhumant sur la diversité de deux prairies montagneuses dans le nord de la Grèce

Résumé. *Le système d'élevage transhumant, qui associe des moutons et des chèvres, est courant dans de nombreux pays du bassin méditerranéen. En Grèce, la transhumance utilise la végétation semi-naturelle des prairies d'altitudes intermédiaires et élevées pendant 5-6 mois, imposant des pressions de pâturage variables sur la végétation indigène. Nous avons étudié l'impact à long terme du pâturage de troupeaux de moutons et de chèvres transhumants, sur la diversité et la remise en état des terres de deux prairies montagneuses du Nord de la Grèce. L'expérience comportait deux prairies méditerranéennes de haute altitude de la Grèce du Nord (montagnes de Smolikas et Vermion) situées à environ 120 km de distance. Les mesures ont été réalisées dans ces domaines au milieu de Juin. La couverture de la végétation a été mesurée, tandis que la composition et la richesse en espèces ont été calculées. Par la suite, l'indice de similarité et la diversité des espèces végétales et la régularité ont été estimées. Les résultats n'ont révélé aucune différence entre les deux prairies quant à (a) la composition des espèces, (b) la diversité des espèces végétales, et (c) la richesse en espèces. Le pourcentage de couverture de la végétation était similaire dans les deux prairies, tandis que l'indice de similarité était faible.*

Mots-clés. *Composition des espèces – Richesse – Moutons-Chèvres – Indice de similarité.*

I – Introduction

The transhumant livestock system is common in many countries of the Mediterranean basin. Transhumance developed by the livestock farmers in order to cope with the grazing seasonality of Mediterranean (Galanopoulos *et al*., 2011). In Greece, transhumance uses the semi-natural vegetation of intermediate and high elevation grasslands during late spring to autumn (5-6 months) (Zervas, 1998). In these mountainous areas plant species are still actively grow due to later stages of maturity and wetter climatic conditions ensuring abundant and nutritious forages to fill up the feeding gap of the animals (Ispikoudis *et al*., 2004). The transhumant sheep and goats livestock system has a dynamic character, which is manifested through its social, economic and environmental impact in the areas involved. It also constitutes a particularly suitable activity for the development of less-favoured areas (Laga *et al.,* 2012) and it helps to keep cultural linkages among winter and summer residences. However, in Greece as well as in many Mediterranean countries (Oteros-Rozas *et al*., 2013), the transhumant livestock system presented a decreasing trend during the last 30 years.

This decrease affects the grassland landscape ecology as the characteristics of grassland communities (composition, production) are strongly oscillating in space and time according to plant species composition, succession stages, herbivore pressure, human activities as well as climatic conditions (Gatti et *al.,* 2005; Karatassiou and Koukoura, 2009). Moreover, grazing animals represent a key factor to avoid the activation of the successional processes, which causes the replacement of herbaceous communities with shrub communities (Rook *et al.,* 2004; Gatti *et al*., 2005). Shrub encroachments are generally assumed to have negative effects on floristic diversity (Dalle *et al.,* 2006; Kyriazopoulos *et al*., 2012) and to animals' diet as many of these are often unpalatable even to browsers (Knapp *et al*., 2008).

The two mountainous rangelands Smolikas and Vermion for many years have received high grazing pressure during late spring and summer from the transhumant sheep and goats especially from Thessaly (central Greece), but over the last year's this pressure seems to relaxed. The aim of this study was to investigate the impact of long term grazing of transhumant sheep and goats flocks on the diversity and land reclamation of two mountainous grasslands of Northern Greece.

II – Materials and methods

The study was conducted in grazed rangelands located near the village Ano Grammatiko (Vermion mountain) and Samarina (Smolika mountain) about 125 km and 225 km west of Thessaloniki, Greece respectively. Four experimental sites were selected in both areas in an altitude range from 1400 m to 1500 m. The areas are grazed mainly by sheep and goats from May to October. According to the bioclimatic map of Greece (Mavromatis, 1978) the climate of the two regions is characterized by a sub-Mediterranean and belong to humid bioclimatic floor with severe winter.

In both areas, ground cover was measured, at the middle of June 2012, according to the line and point method (Cook and Stubbendieck, 1986). Thereafter, species composition was estimated in four plant groups: (1) grasses, 2) legumes, (3) other forbs, and (4) shrubs. Three transect lines of 20 m long were used in each experimental site. In order to calculate the species richness (S), and evenness (E), two sampling quadrats of 0.35 x 0.35 m were used in every transect line. Species diversity was calculated by the Shannon Index (H'). Also, the similarity coefficient Sj (Jaccard) was calculated using the formula: $Sj = a/(a+b+c)$ where a = number of species common in both areas, b = number of species in the first area only, c = number of species in the second area only (Magurran, 1991; Gurevich *et al*., 2006).The data were analyzed by ANOVA (Steel and Torrie, 1980) using the SPSS statistical software v. 20.0 (SPSS Inc. Chicago, IL, USA).

III – Results and discussion

The ground cover was 87.5% and 84.3% in Smolikas and Vermion respectively and, therefore, no significant differences were detected ($P \geq 0.05$). In addition, there were no significant differences ($P \geq 0.05$) in the contribution of the various plant groups in vegetation composition of the two grasslands. Significant differences ($P<0.05$) were found only among the different plant groups within each grassland.

Table 1. Plant groups composition (%) in the two experimental mountain areas

Plant groups	Vermion	Number of species	Smolikas	Number of species
Grasses	60.51Aa	10	47.31Aa	9
Legumes	5.63Bb	2	23.17Ba	6
Other forbs	31.32Ca	13	27.08Ba	11
Shrubs	2.54Ba	1	2.44Ca	1

Means with different lower case letter in the same row differ significantly ($P<0.05$).
Means with different capital letter in the same column differ significantly ($P<0.05$).

In both experimental areas, the grass species contribute with the highest percentage compared to other plant groups. In Smolikas grasslands, participation of legumes species was significantly higher compared to Vermion ones. The differences in the vegetation composition between the two areas could be attributed to the biotic and/or abiotic factors such as climatic fluctuations, grazing pressure and/or to soil conditions (Gatti *et al.,* 2005; Salis, 2010).

Table 2. Species richness (S), Shannon diversity index (H') and evenness (E) in the two experimental areas. Values present means ± SE

Experimental area	(S)	H'	E
Vermion	26	1.84 ± 0.102	0.42 ± 0.023
Smolikas	27	1.70 ± 0.112	0.37 ± 0.028

During the experimental period, in the area of Vermion 26 plant species had been recorded while in the Smolikas one 27. There were no significant differences between grasses and other forbs, which were the dominant species in both areas. The species richness is in agreement with the species composition (Table 1), and it seems that the group species with the higher abundance contributed with higher percentage in vegetation composition of the two areas. The Shannon index and evenness presented the higher values in the Vermion grasslands but without significant differences from the Smolikas ones. These results confirm that vegetation of these areas has been formed by long term grazing for many years from the transhumant sheep and goats though both ecological and evolutionary process (Noy-Meir, 1998). Although, high similarity between the two areas was expected the similarity index between them was very low (17%). Low similarity coefficient under grazing has been earlier demonstrated (see Osem *et al*., 2004). The low similarity index between the two areas could be explained by the different grazing pressure (in recent years Vermion had low grazing pressure) as well as to different soil and climatic conditions (Migo, 2006; Ali-Shtayeh and Salahat, 2010). It is known, that the continuous grazing system with moderate grazing pressure allows the establishment and development of a more species-rich community compared to seasonal grazing (Sternberg *et al.,* 2000).

IV – Conclusions

Although the two mountainous grasslands present comparable species richness, diversity and evenness their similarity index is very low. It seems that the low grazing pressure (Vermion) negatively affected the number of legumes, and positively the number of grasses and forbs. In order to draw safer conclusion further and more research needs to be done.

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Predicting annual grassland productivity from community-level mean traits: how does a rapid method based on botanical survey perform?

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Abstract. Because methodology used to assess functional structure of the community has to be adapted to the objectives of the study and the processes of interest, two simpler methods for measuring cumulated weighted mean values of three traits are compared, and the ability of the functional descriptors to predict the annual aboveground production tested on a set of 28 grassland plots. The non-destructive method, applied once a year and based on botanical survey to assess the species abundances, provides cumulated weighted mean (CWM) values that are highly correlated to values resulting from the reference method, that is from species hand sorting of biomass sampled all along the year to assess annual productivity. Statistical models predicting annual production using the CWM of leaf traits and plant height showed good to very good fits, are highly significant, with r² of 72.4 for the reference method and 63.7 for the simplest one. This latter is thus considered highly valuable for studying links between functional structure and processes.

Keywords. Temperate permanent grassland – Functional diversity.

Prédire la production annuelle de biomasse à partir des traits moyens de la communauté : intérêt d'une méthode simplifiée d'observation botanique

Résumé. *Dans un contexte d'analyse des relations entre structure fonctionnelle des communautés et fonctionnement de l'écosystème, les méthodes utilisées pour estimer les descripteurs fonctionnels doivent être adaptées aux processus d'intérêt étudiés. Deux méthodes simplifiées d'estimation de la valeur moyenne des traits de communauté ont été testées ainsi que la capacité de ces variables à prédire la production annuelle de biomasse de 28 parcelles de prairie permanente. La méthode simplifiée non destructive par observation visuelle de points quadrats avec une mesure annuelle pour évaluer les abondances spécifiques a conduit à des valeurs de traits moyens très fortement corrélées aux valeurs de la méthode de référence basée sur le tri pondéral des espèces dans les repousses successives de biomasse tout au long du cycle annuel. Pour ces deux méthodes, les valeurs moyennes de traits foliaire et de hauteur des plantes apparaissent comme des variables explicatives de la production annuelle de biomasse dans des modèles très significatifs et à forts R², validant l'emploi de la méthode simplifiée.*

Mots-clés. *Prairie permanente – Diversité fonctionnelle.*

I – Introduction

Herbage production of semi-natural multispecies grasslands is a key process that still need to be explained in more details and predicted. Previous works have provided evidence of the usefulness of plant functional traits and their diversity at the community level to predict grassland properties and services, including production (Diaz *et al.,* 2007). Reliable implementation of this approach requires first selecting appropriate descriptors of the functional structure of plant communities among the variety of indices that have been proposed so far. Moreover, the methodology used to estimate these indices has to be adapted to the question and the scale at which processes are studied (Lavorel *et al.,* 2008). Among the available indices, community weighted mean (CWM) of a trait is defined as the mean of the values recorded in a community weighted by the relative abundance of the species bearing those values. It is considered as an informative index because it relies on the hypothesis that the most abundant species drive the processes. In the calculation of CWM, standardized methods have been defined for traits measurement. For species relative abundances, the reference method is based on their contribution to the total biomass. However, direct estimation of such contribution is destructive and time consuming, particularly when measurement have to be realized all along the year as it is required for properly estimating such annual production. Here, we aim at testing the performance of simpler methods, using measurements realised once a year at the moment of active growth. One is based on botanical survey where the relative abundance of species is visually estimated, the other on hand sorting of species biomass. Questions are: (i) do estimates of CWM differ between the methods?; and (ii) is there any effect of the method on the relationship between the community-level functional descriptors and annual aboveground production? These questions are treated using a set of 28 grassland plots differing for functional structure and productivity.

II – Materials and methods

1. Study site and measurements

This study was based on a long-term experiment located on upland (850 m asl) on a semi-natural grassland in Auvergne, Theix, France (45°43'43'' N, 03°1'21'' E), belonging to the SOERE Acbb[1]. Measurements were carried out in 2011 on 28 plots, i.e.7 management treatments applied since 2005, with four plots per treatment. Treatments include cattle grazing at high or low stocking rate, sheep grazing at low stocking, control not used (abandon), and three treatments under cutting differing by the level of fertilizer. The community is dominated by tall grasses such as *Festuca arundinacea* Scherb., *Alopecurus pratense* L., with other species including smaller grasses (*Poa pratense* L., *Lolium perenne* L.), forbs (*Taraxacum officicalis, Achillea millefolium* L.) and legumes (*Trifolium repens* L.). These species are characterized by high Ellenberg indicator values for N, which indicates a high level of soil fertility at this site.

We implemented the simple non-destructive method of species contribution to the partial or total biomass and the time-consuming destructive methods as follows:

Non-destructive method based on quadrat points (QP): in May, the plant species composition was estimated within each of the 28 plots by a QP method (Daget and Poissonet, 1971). At 40 points located along transects, a pin was moved downward the vegetation and all the species that hit this pin were listed and scored. For each species, its relative abundance, expressed in percentage, was calculated as sum of scores of that species divided by the sum of scores attributed to all species.

Destructive method based on biomass measurements: the aboveground production has been estimated in 2011, using 4 sampling areas per plot, 0.6*0.6 m^2 each, clipped (5.5 cm heigth) all along the year before each grazing or cutting events. In mowed and abandoned treatments the aboveground biomass has been cut in May, July and October, whereas it was cut in April, May, June, September, November in grazed treatments. Initial standing biomass at the beginning of the regrowth period in February was removed; sampling areas were moved within the plot at each clipping date, and, in grazed plots, sampling areas were protected from animal by enclosure (0.6*0.6m).

[1] SOERE ACBB : Système d'Observation et d'Expérimentation sur le long terme pour la Recherche en Environnement : Agro-écosystèmes, Cycles biogéochimiques et Biodiversité.

In the laboratory, a representative sub-sample of the clipped biomass (by mean, 19.5% of the total) was selected for species hand sorting. Each species material sorted from the sub-sample and the rest of the sample were oven-dried (60 °C, 48 h) and weighed. Doing so we obtained for each plot at each sampling date, the best assessments of the aboveground production between two successive dates, and the associated contribution of each species. The annual herbage production (g DM m^{-2} y^{-1}) was then calculated as the sum of all sampling dates. The species relative abundances at the community level were calculated at the annual scale, taking into account the species contribution in biomass at each sampling date.

Plant traits: a plant-traits database of the dominant species of the experimental site has been built since 2006 (data not shown). Three main traits, ie, leaf dry matter content (LDMC), specific leaf area (SLA) and reproductive height (RepHt) have been measured according to Cornelissen *et al*., (2001) in each plot. A mean trait value has been calculated for each species at the treatment level, using values measured at the plot level.

Plant trait values at the community-level: community weighted mean (CWM) was calculated for each of the three traits in each of the 28 plots, following Lavorel *et al.* (2008):

$$\text{CWM} = \left(\frac{1}{\sum p_i}\right) * \left(\sum p_i * trait_i\right),$$

where p_i is the relative abundance of species i to the community and $trait_i$ is the trait value of species i.

Three sets of CWM were derived. One based on species relative abundance provided by the quadrat point method (QP hereafter), one based on biomass measurements at annual scale (An_Biom hereafter), and one based on biomass measurements in May (May_Biom hereafter).

2. Statistical analyses

We first assessed the differences in CWM estimates between the different methods of measurement of species abundance. To do so, Pearson's correlations were used. In addition, three Anova (one for each trait) were performed in order to test for the effect of treatment, method, and treatment x methods interaction on CWM values. Data were Log transformed when necessary and the Shapiro-Wilks test was used to check for the normality of the residuals. Second, we compared statistical models relating the annual above ground biomass and the CWM values estimated from the different sampling methods. We used a step-wise forward and backward regression procedure to emphasise the best predictors (among CMW of LDMC, SLA, RepHt) of the annual aboveground production. The procedure was used successively with CWM calculated by QP, An_Biom and May_Biom methods.

III – Results

CWM values resulting from the different methods (Table 1) are significantly correlated (Table 2). For the three traits, correlation appears much higher between quadrat point (QP) and Annual biomass methods, than between quadrat point (QP) and May_biomass methods.

CWM values are significantly affected by management treatment and also by method of assessment for two traits out of three. There is no significant effect of the interaction between treatment and methods (Table 3). However for LDMC the interaction is almost marginally significant. Annual biomass production in 2011, by mean at 566g/m², ranged from 236 to 986 g/m² across the whole data set. It was successfully predicted by linear models based on CWM as explicative variables (Table 4). The best fit was found for An_Biom with the CWM of the three traits selected (r^2 = 72.4, p<0.0001). The model for the QP method showed weaker but still good fit (r^2 = 63.7, p<0.0001), with the same three traits. Parameter estimates of these two models showed comparable values. The model using the May_biom method showed much weaker fit.

Table 1. Community weighted mean for three traits, LDMC (mg/g), SLA (cm²/g) and RepHt (cm) in the 28 plots in 2011 for the different methods. Mean, minimum and maximum for CWM-QP method, CWM-An_Biom method, CWM-May_Biom method

Method	Quadrat Points			An_Biomass			May_Biomass		
Trait	LDMC	SLA	RepHt	LDMC	SLA	RepHt	LDMC	SLA	RepHt
Mean	239	230	74	242	242	82	245	247	81
Min/Max	207/294	179/287	55/99	203/281	197/330	49/107	200/281	186/337	51/113

Table 2. Correlation across methods used to calculate CWM for three traits: LDMC, SLA, RepHt

	LDMC		SLA		RepHt	
Methods (x-y)	r	*p* value	r	*p* value	R	*p* value
An_Biom-May_Biom	0.925	<0.0001	0.941	<0.0001	0.921	<0.0001
An_Biom-QP	0.831	<0.0001	0.863	<0.0001	0.871	<0.0001
May_Biom-QP	0.719	<0.0001	0.844	<0.0001	0.768	<0.0001

Table 3. Three separated ANOVA for testing the effect of Management Treatments and Methods on estimates of CWM for LDMC, SLA and RepHt

	LDMC			SLA			RepHt		
	df	F ratio	*p* value	df	F ratio	*p* value	df	F ratio	*p* value
Treatment (T)	6	41.07	<0.0001	6	20.76	<0.0001	6	26.73	<0.0001
Method (M)	2	1.43	0.248	2	4.5	0.015	2	8.76	0.0004
T x M	12	1.59	0.116	12	0.44	0.939	12	0.55	0.87

Table 4. Stepwise multiple regression models of annual above ground production (dependent variable) performed with CWM traits (explicative variables) values assessed with three different methods. For each fitted model, intercept, coefficient estimates (and standard error in bracket) of the selected variables, r-square and p value are reported

Method	Intercept	CWM-LDMC	CWM-SLA	CWM-RepHt	R²	P value
An_Biom	382 *(421)*	-4.01 *(1.16)*	3.25 *(0.77)*	4.50 *(1.82)*	72.4	<0.0001
QP	-187 *(471)*	-3.24 *(1.25)*	4.39 *(1.08)*	7.01 *(2.35)*	63.7	<0.0001
May_Biom	736 *(449)*	-3.10 *(1.27)*	2.38 *(0.83)*	–	52.5	0.0001

IV – Discussion and conclusion

CWM of traits estimated from the different methods are tightly correlated. Correlation involving CWM_QP is higher with CWM_An_Biom than with CWM_May_biom. Difference could be link to the better ability of QP method to assess species contribution by covering larger area compared to biomass method, which, at each measurement time, explore a limited sampled area.

CWM estimations were affected by the method for two traits, and by treatment for all of them. No interaction between the methods and the treatments indicates that the methods produce unbiased estimate of CWM for SLA and RepHt traits (caution has to be taken for one trait LDMC as interaction is not far from significance) and this, whatever the grassland type (among those covered by the experimental set). Moreover, our result indicates that the three methods could be used for testing the effect of management treatments on functional descriptor (i.e. the functional response of communities).

Statistical models set with the annual aboveground production as response to the CWM of leaf traits and plant height showed good to very good fits. Most importantly, our results highlight that the QP method showed very similar performance to the An_biom method, which is expected to be the best method. We conclude that the much simpler, rapid and non-destructive method based on plant trait data and relative species abundances retrieved from botanical survey is highly valuable.

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Effects of drought and cutting frequency on agronomic value and functional traits of two pastures of the Jura mountains

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Abstract. In order to determine the impacts of summer drought on the agronomic value and functional characteristics of two semi-natural grasslands, a trial was carried out in 2013 in the Jura mountains. The first grassland (540 m, lowland site) was dominated by *Lolium perenne* and *Poa pratensis*; the second one (1320 m, mountain site) by *Festuca rubra* and *Agrostis capillaris*. Two factors: moisture (drought *vs* control) and intensity of use (high *vs* medium cutting frequency), were tested in a split plot design at each site. The drought was simulated by means of rain shelters. The botanical composition of the meadow and the functional traits of the most abundant species were assessed in spring (initial stage), in summer (after drought treatment) and in autumn (recovery). The drought treatment lowered the yield only during the period of stress (= one growth cycle) and interacted with the cutting frequency. After stress, at the plant community level, important changes were observed in mean trait values (CWMs), whereas the abundance of the main species remained more or less constant. Our results suggest that the ecophysiological plasticity (intraspecific variability) plays a key-role in the response of the meadows in case of a short-time drought.

Keywords. Drought – Functional traits – Permanent meadows – Jura mountains.

Effets de la sécheresse et de l'intensité d'utilisation sur deux pâturages permanents du Jura

Résumé. *Un essai a été mis en place en 2013, dans le but d'évaluer l'effet d'une sécheresse estivale sur les services agronomiques et les caractéristiques fonctionnelles de deux prairies permanentes. La première (540 m) était dominée par des espèces comme* Lolium perenne *et* Poa pratensis*; la seconde (1320 m) était majoritairement composée de graminées comme* Festuca rubra *et* Agrostis capillaris*. Deux facteurs, approvisionnement hydrique (sécheresse* vs *témoin) et intensité d'utilisation (élevée* vs *moyenne), ont été combinés dans un dispositif split-plot. La période de sécheresse a été simulée à l'aide de tunnels maraîchers. La composition botanique ainsi que les valeurs de traits des principales espèces ont été déterminées au printemps (état initial), en été (juste après le stress) et en automne (récupération). La sécheresse n'a impacté que le rendement du cycle ayant subi la sécheresse (interaction « sécheresse × intensité d'utilisation »). Au niveau de la communauté végétale, d'importants changements ont été observés au niveau des valeurs de traits moyens (traits agrégés). La composition botanique est en revanche restée plutôt stable. Ces résultats suggèrent que la plasticité écophysiologique des plantes (variations intra-spécifiques) joue un rôle-clé dans l'adaptation de la végétation lors d'un stress hydrique de courte durée.*

Mots-clés. *Stress hydrique – Traits fonctionnels – Prairies permanentes – Jura.*

I – Introduction

With climate changes, the frequency and the severity of extraordinary events are expected to increase, in an unknown extent. In central and south part of Europe, reduced water availability has become a major concern. For western part of Switzerland, models predict for 2060 a mean decrease up to 40% of the rainfall during the summer period; in addition, periods of hot and dry weather will become more frequent (CH2011). Detailed information about responses of temperate permanent grasslands to summer drought remain incomplete (Gilgen and Buchmann, 2009). In this context, Agroscope has started in 2012 trials which aim at improving grasslands management under water stress (Deléglise *et al.*, 2013). The functional traits approach is an interesting tool that allows a better understanding of plant community responses to changing environmental conditions (Díaz *et al*., 2004). We applied these tools to assess the effect of drought in interaction with cutting frequency on two permanent grasslands situated in the Jura mountains. We made the hypothesis that the short-term responses to drought would mainly be observed on the traits values, rather than on shifts in the botanical composition.

II – Materials and methods

The trial was carried out in 2013 on two permanent meadows of the Jura mountains. The first site (lowland), located at 540 m, was dominated by *Lolium perenne* and *Poa pratensis*. The second one (mountain), at 1320 m, was mainly composed of *Festuca rubra* and *Agrostis capillaris*. Two factors, combined in a split-plot design with three replications, were tested: moisture (Drought [D] *vs* Control [C]; main plot treatments) and cutting frequency (High [H] *vs* Medium [M]; subplot treatments). Post-hoc tests (Tukey's HSD method) were used to determine different means after ANOVAs. The drought stress was simulated with rain shelters for a duration of about 7 weeks (July and August). During the coverage period, 183 mm of water were subtracted at the lowland site, respectively 162 mm at the mountain site. These quantities represented about 55% of the total rain that fell in 2014 from June to August at each site. Number of cuts per year was differentiated, in lowland [M] = 5 and [H] = 7, in mountain [M] = 3 and [H] = 4, in accordance with local turn-out dates for grazing and mowing frequency.

The 5 m^2 plots were cut by means of a motor mower and weighted. Samples were collected and oven-dried for determining dry matter (DM) content. The vegetation surveys were conducted at (i) the beginning of the growth season (spring), (ii) just after the drought (summer) and (iii) during the recovery period (autumn). On each plot, botanical composition was determined along two transects of 4 m with records every 20 cm (Daget and Poissonet, 1971). Traits values (specific leaf area, SLA and leaf dry matter content, LDMC) were assessed according to standard protocols of Cornelissen *et al*. (2003). The community weighted means (CWMs) were then calculated at subplot scale, by weighting the measured values of the main species by their specific contribution (Garnier *et al*., 2004).

III – Results and discussion

1. Dry mass production

The drought did not impact the total annual yield (Table 1). Nevertheless, the drought treatment lowered the yield of the cut harvested just after the stress event. At the lowland site, both MD and HD plots suffered from the stress. At the mountain site, only the HD-plots showed a significant decrease (table 1). In both locations there was an interaction between drought and intensity of use (p<0.001 for both sites).

2. Botanical composition

In spring (data not shown), no differences were observed in the botanical composition of the subplots, neither in the lowland site nor in the mountain site.

Table 1. Yield (dt DM/ha; n = 3 ± SD) in the two experimental sites. Significant differences are indicated by different letters (Tukey post-hoc tests)

Lowland site, 540 m	**Medium cutting frequency (M)**		**High cutting frequency (H)**	
	Control (C)	**Drought (D)**	**Control (C)**	**Drought (D)**
Total (annual) yield	101 ± 8.2 [a]	95 ± 7.0 [ab]	81 ± 7.9 [ab]	71 ± 1.8 [b]
Yield after the drought	24.7 ± 0.6 [a]	17.3 ± 3.1 [b]	14.8 ± 2.3 [b]	03.7 ± 0.6 [c]
Mountain site, 1320 m	**Medium cutting frequency (M)**		**High cutting frequency (H)**	
	Control (C)	**Drought (D)**	**Control (C)**	**Drought (D)**
Total (annual) yield	44 ± 7.1	44 ± 1.6	42 ± 3.1	35 ± 4.6
Yield after the drought	19.1 ± 3.4 [a]	14.3 ± 2.7 [a]	12.4 ± 0.9 [a]	03.8 ± 0.4 [b]

In summer, a strong effect of drought on plant senescence was observed at the lowland site, dead parts accounted up to 40% (HD treatment, Table 2). Consequently, the abundance of many plant species tends to diminish. With regard to the mowing frequency, *Poa pratensis* diminished in extensively used subplots (p<0.01), whereas *Lolium perenne* and *Dactylis glomerata* showed an increase (p<0.05 and p<0.01, respectively). At the mountain site, the proportion of litter increased significantly, but not to the same extent than in the lowland site. No significant changes in the abundance of the main species were observed.

Table 2. Abundance (specific contribution; n = 3; ± SD) of the main species in the lowland and the mountain site, just after the drought treatment. Significant differences are indicated by different letters (Tukey post-hoc tests)

Lowland site, 540 m	**Medium cutting frequency (M; 5 cuts)**		**High cutting frequency (H; 7 cuts)**	
	Control (C)	**Drought (D)**	**Control (C)**	**Drought (D)**
Lolium perenne	22.6 ± 0.9 [a]	20.7 ± 2.6 [ab]	21.0 ± 1.0 [a]	15.4 ± 1.7 [b]
Poa pratensis	20.8 ± 3.6 [b]	12.6 ± 1.0 [c]	27.8 ± 1.1 [a]	21.7 ± 1.0 [ab]
Taraxacum officinale	16.4 ± 6.5	07.8 ± 4.4	22.0 ± 8.0	08.9 ± 2.1
Dactylis glomerata	12.4 ± 6.7 [a]	08.8 ± 3.2 [a]	06.8 ± 5.4 [ab]	02.7 ± 1.5 [b]
Plantago major	06.2 ± 4.2	03.0 ± 2.0	06.9 ± 1.8	03.1 ± 1.3
Trifolium repens	03.3 ± 2.9	05.4 ± 4.9	04.8 ± 2.6	02.3 ± 2.4
Senescent plants	02.6 ± 2.3 [a]	25.4 ± 7.9 [b]	00.7 ± 0.7 [a]	38.9 ± 3.5 [b]
Mountain site, 1320 m	**Medium cutting frequency (M; 3 cuts)**		**High cutting frequency (H; 4 cuts)**	
	Control (C)	**Drought (D)**	**Control (C)**	**Drought (D)**
Festuca rubra	27.6 ± 3.7	21.6 ± 3.7	27.8 ± 4.5	24.6 ± 1.6
Agrostis capillaris	23.0 ± 3.2	16.5 ± 7.8	21.0 ± 1.8	22.6 ± 2.8
Alchemilla vulgaris	14.0 ± 4.8	13.4 ± 3.8	12.4 ± 1.0	06.6 ± 4.6
Trifolium repens	05.1 ± 5.1	04.1 ± 1.7	02.9 ± 2.2	02.7 ± 1.9
Ranunculus ac. fries.	05.0 ± 1.5	04.4 ± 2.1	05.2 ± 2.7	02.2 ± 2.2
Poa pratensis	04.3 ± 2.1	01.6 ± 1.6	06.6 ± 5.4	00.1 ± 0.2
Senescent plants	01.4 ± 1.3 [a]	13.6 ± 2.7 [b]	05.1 ± 2.3 [a]	22.8 ± 4.6 [c]

In autumn (data not shown), the mowing frequency influenced the abundance of *P. pratensis, L. perenne* and *D. glomerata* in the lowland site. The first species was favoured by an intensive cutting (p<0.001), whereas the two other species benefited from the medium cutting frequency (p<0.05 and p<0.01, respectively). On the mountain site, the botanical composition remained comparable for all treatments.

3. Functional traits

After the stress, the drought treatment induced an increase of the community LDMC and a lowering of the community SLA, especially in the lowland site (Fig. 1). These responses clearly reflect a slowdown in the metabolism of the plants, as well as a shift from a strategy of resource acquisition towards a strategy of resource conservation (Díaz *et al.*, 2004). These responses seemed to be less pronounced in the mountain site where the important presence of so-called conservative species (e.g. *Festuca rubra*) could explain the weaker response. No more differences between treatments were observed in autumn.

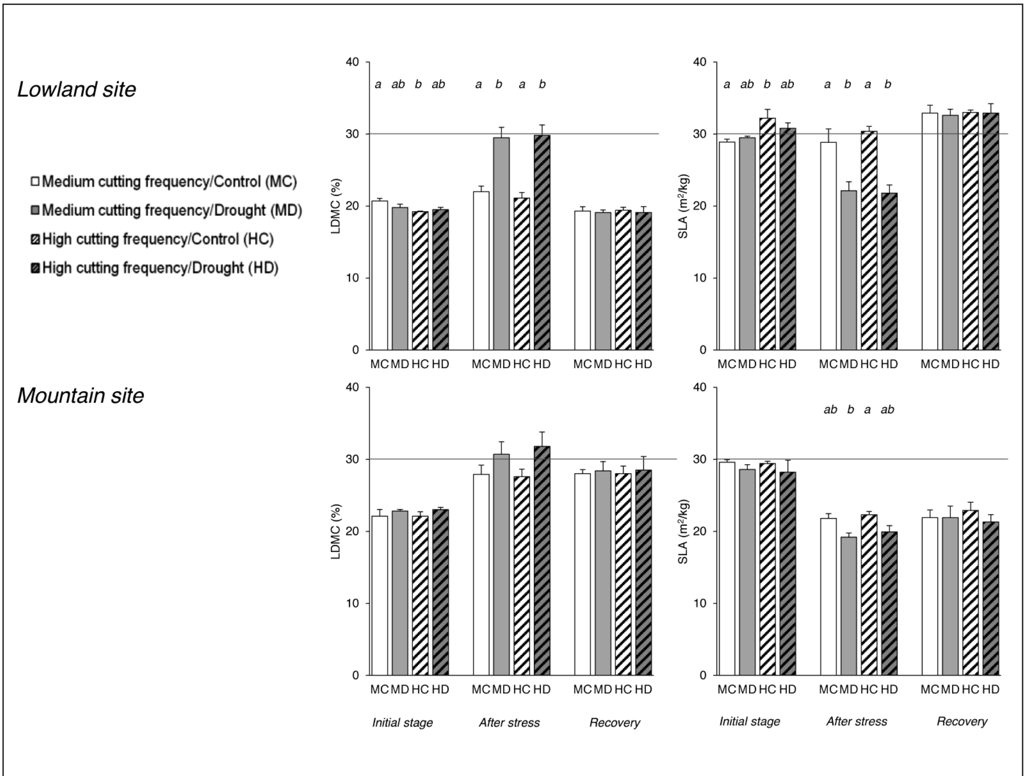

Fig. 1. Community weighted mean traits in the two sites: LDMC (Leaf dry matter content, %) and SLA (Specific leaf area, m²·kg^{-1}), for the different treatments (see legend on the figure). Mean values (n = 3; ± SD) are given for the three periods: initial stage, after stress and recovery.

IV – Conclusions

The drought had more impact on the community trait values than on the botanical composition, which remained rather stable. The effect of drought on the productivity was exacerbated by a more frequent use during the period of stress (interaction “drought × cutting frequency”). Even in absence of a statistical comparison, it seems that the responses at the mountain site were less marked than those observed at the lowland site. Further researches will be undertaken to gain insight into the potential buffering role of altitude in grassland response to drought.

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Restoration of degraded rangeland by the use of *Cenchrus ciliaris*, a high value perennial forage grass, in Hail region (Saudi Arabia)

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Abstract. Saudi Arabia (KSA) is one of the countries that suffers from the degradation of natural rangelands aggravated by severe drought. Rangelands with wild forage species decreased and refuged in difficult accessible zones such as mountains and deep Wadi. *Cenchrus ciliaris* L., a high value pasture plant of the Saudi Arabian mountains, is one of the endangered species that becomes very rare in its natural habitats. In this work five accessions of *Cenchrus ciliaris* were collected from different zones in Hail region (North of KSA), to select the most vigorous ecotypes to be introduced in the degraded lands. In the first part of this study, the germination capacities of different accessions were estimated. The second part focuses on the study of the vegetative vigour of different accessions by the assessment of morphological parameters. In the last part of this study, a selection of the resistant accessions to overgrazing by a protocol of repeated cuts, was conducted. This study permitted to select the most productive and drought tolerant accessions of *Cenchrus ciliaris*.

Keywords. *Cenchrus ciliaris* – Overgrazing – Degraded rangelands – Forage – Mountains – Saudi Arabia.

Restauration des parcours dégradés par réintroduction de* Cenchrus ciliaris*, graminée pérenne de haute valeur pastorale dans le région de Hail (Arabie Saoudite)

Résumé. *L'Arabie Saoudite est un pays qui souffre énormément de la dégradation des terres de parcours aggravée encore par un climat désertique. Les parcours naturels contenant des espèces fourragères autochtones ont été fortement diminués et se trouvent actuellement refugiés dans quelques zones d'accès difficiles comme les sommets des montagnes ou les lits des profonds oueds.* Cenchrus ciliaris*, graminée pérenne de haute valeur pastorale, est l'une des espèces les plus menacées d'extinction. Cette espèce devient de plus en plus rare dans son habitat naturel et est supposée, selon des travaux récents, en voie de disparition dans la région de Hail, au Nord de l'Arabie Saoudite. Dans ce travail, cinq accessions de* Cenchrus ciliaris *ont été collectées dans la région de Hail en vue de sélectionner, parmi-elles, les plus productives et les plus résistantes au surpâturage pour une éventuelle réintroduction et réhabilitation des parcours dégradés. La première partie de ce travail a servi à tester les capacités germinatives des différentes provenances. Dans une seconde partie, la vigueur végétative des provenances a été évaluée en se basant sur un ensemble de paramètres morphologiques. Enfin, une sélection des accessions les plus résistantes au pâturage a été réalisée sur la base du poids de la matière sèche accumulée après 3 coupes séparées par des intervalles de 30 jours. Cette étude a permis de sélectionner les accessions de* Cenchrus ciliaris *les plus vigoureuses et les plus résistantes au pâturage.*

Mots-clés. Cenchrus ciliaris – *Surpâturage – Parcours dégradés – Fourrage – Montagne – Arabie Saoudite.*

I – Introduction

Buffelgrass (*Cenchrus ciliaris*) is one of the most important wild forage species, known by its high pastoral value (*Visser et al*., 2008). In the world, this species is known for its high diversity (Kharrat *et al*., 2004; Mseddi *et al*., 2002) and adaptability to different environments as well as by its high resistance to drought and warm climates. The high productivity of this species allows to cultivate it in several regions of the world, such as Australia, the United States and Pakistan, as a primary source for animal feed (Mseddi *et al*., 2004a; 2004b).

As the Kingdom of Saudi Arabia (KSA) is suffering from a shortage of groundwater because of its frequent use in irrigated agriculture (cereal and vegetable crop) and especially the cultivation of alfalfa (livestock feed) that consume a high volume of water, this research project defined the following objectives: (1) Establishing a sustainable development system through the use of some "economic" plants, such as buffelgrass, known by its high productivity and forage quality despite its low water consumption; (2) the rehabilitation of disturbed grassland in KSA by seed dispersion of the resistant varieties of this species; and (3) the conservation of the natural resources and the genetic heritage of this area.

II – Materials and methods

Plant material: *Cenchrus ciliaris* is a C4 perennial grass belonging to the family of *Poaceae*. Seed collection was undertaken at the end of the summer 2012. A total of 10 accessions were collected in Hail area and finely 5 accessions were retained because of the short distance between some accession sites. Geographic coordinates were taken by GPS. Accessions were named as: Jameen, Aja, Zaitoun, Gaed and Industrial zone. Seed Germination trials were conducted in 9-cm sterile Petri dishes lined with two Whatman No. 1 filter papers. Five salinity concentrations (0 g/l, 2 g/l, 4 g/l, and 8 g/l) were used based on a preliminary test for salt tolerance of the species. The Petri dishes were placed in an incubator for 25 days at constant temperatures of 25°C [optimal temperature for *Cenchrus ciliaris* (Mseddi *et al*., 2002)]. Physiological and morphological parameters that were assessed in this work are reported in Table 1. Data were analysed using SPSS, version 16.0.

Table 1. Parameters assessed, their codes and units

Unit	Code	Parameters
cm	PL	Plant length
cm	PD	Plant diameter
kg/m^3	DEN	Density
cm	ST	Stem length
m^3	BV	Biovolume
Numeric number	BN	Branch number
cm	LL	Leaf length
cm	SL	Spike length
g	DM	Dry matter
g	OVG	Resistance to overgrazing
Numeric number	GER	Percentage of germination

III – Results and discussion

1. Germination

Seed germination of *Cenchrus ciliaris* of all accessions was highest in distilled water (0 g NaCl/l). The highest germination rate was observed at Aja accession with 100% of germination. The increase of salt in water was followed by a decrease in germination percentage. Aja was the most tolerant accession to salt; it can fully germinate at 2 g NaCl/l after 20 days. Whereas, Jameen was the most sensitive accession to salt with a 0% germination in 2 and 4 g NaCl/l (Fig. 1).

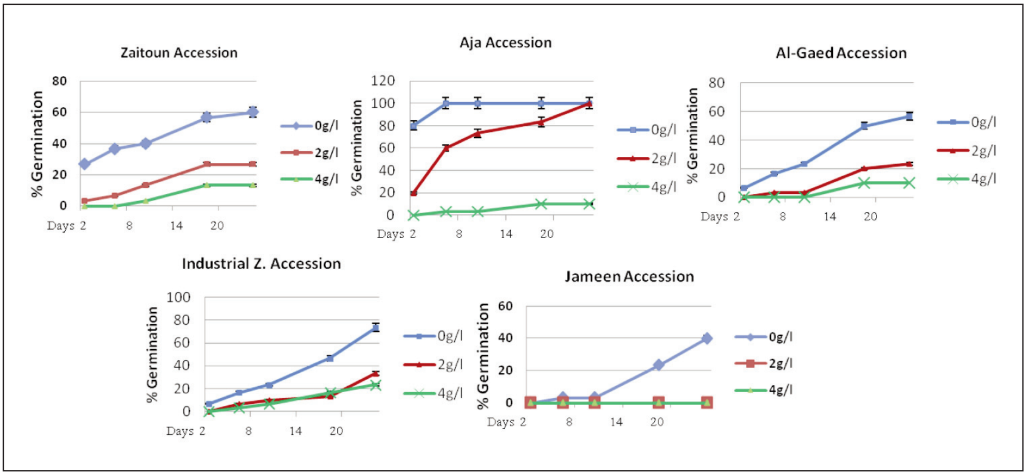

Fig. 1. Effect of salinity concentrations on the germination of different accessions of *Cenchrus ciliaris* in Saudi Arabia (Hail Region). Bars represent means + 1SE.

2. Morphological parameters

The means of all morphological parameters are reported in Table 2. Jameen Accession was the most developed accession with PL of 110 cm and PD of 86 cm. Small plants are recorded for Industrial zone accession with PL of 69.7 cm and PD of 54 cm.

Table 2. The means of all morphological parameters

Ac	PL	PD	ST	LL	BN	SP
Indust. Z.	69.7 ± 9.1	54.0 ± 7.9	72.7 ± 7.6	16.0 ± 1.0	7.0 ± 1.0	10.0 ± 1.0
Gaed	105.0 ± 5.0	96.7 ± 2.9	71.7 ± 3.2	24.0 ± 1.0	5.3 ± 0.6	11.7 ± 0.6
Jameen	110.0 ± 17.3	86.7 ± 11.5	104.0 ± 7.9	34.0 ± 1.0	4.0 ± 1.0	11.7 ± 2.1
Aja	86.7 ± 5.8	73.3 ± 2.9	78.3 ± 7.6	25.0 ± 2.0	3.3 ± 0.6	12.7 ± 1.2
Zaitoun	67.0 ± 2.6	66.0 ± 1.0	59.3 ± 5.1	12.3 ± 2.5	6.7 ± 1.2	7.0 ± 0.0
Average	87.7 ± 19.9	75.3 ± 16.5	77.2 ± 16.3	22.3 ± 8.0	5.3 ± 1.7	10.6 ± 2.3
F	.000	.000	.000	.000	.002	.001

3. Dry matter yield and resistance to overgrazing

As reported in Table 3, Jameen was the most productive accession with accumulation of 513.3 ± 25.2 g of dry matter, whereas it's density was about 0.8 ± 0.3 kg/m^2. The lowest productivity was observed for Industrial-Zone accession with a 254.7 ± 9.5 g but followed by a high density about 1.7 ± 0.7 kg/m^2. Accumulation of dry matter after 3 cycles of cutting shows that Gaed and Jemeen accessions were the most tolerant to overgrazing with respectively 940.3 ± 37.4g and 866.7 ± 32.5 g of accumulated dry matter (Table 3).

Table 3. Dry matter yield and resistance to overgrazing (OVG) for different accessions

Ac	BV	DM	OVG	DEN
Indust. Z.	0.166 ± 0.064	254.7 ± 9.5	501.7 ± 25.6	1.7 ± 0.7
Gaed	0.772 ± 0.081	492.7 ± 8.0	866.7 ± 32.5	0.6 ± 0.1
Jameen	0.675 ± 0.299	513.3 ± 25.2	940.3 ± 37.4	0.8 ± 0.3
Aja	0.368 ± 0.052	392.7 ± 6.4	654.6 ± 14.9	1.1 ± 0.2
Zaitoun	0.229 ± 0.016	337.3 ± 22.7	580.8 ± 36.4	1.5 ± 0.2
Average	0.442 ± 0.277	398.1 ± 100.8	708.8 ± 29.3	1.2 ± 0.5
F	0.000	.000	.069	.027

4. Correlation between parameters

Dry matter yield (DM) was highly and positively correlated with plant length (PL) and plant diameter (PD). Whereas a negative correlation was observed with the number of branch per stem (BN) (Table 4). No correlation was observed between germination percentage (GER) and all the morphological and yield parameters assessed.

Table 4. Correlations between parameters assessed

	PL	PD	ST	LL	BN	SP	DM	DEN	GER
PL	1								
PD	.915**	1							
ST	.725**	0.437	1						
LL	.821**	.638*	.863**	1					
BN	-.578*	-0.478	-.566*	-.744**	1				
SP	.549*	0.411	.594*	.700**	-.568*	1			
DM	.892**	.925**	.565*	.794**	-.587*	0.454	1		
DEN	-.859**	-.902**	-.515*	-.633*	0.427	-0.512	-.783**	1	
GER	-0.21	-0.113	-0.251	-0.194	-0.343	0.062	-0.217	0.049	1

**: Correlation is significant at the 0.01 level.
*: Correlation is significant at the 0.05 level.

IV – Conclusions

Cenchrus ciliaris, a very endangered species in Saudi Arabia, showed a high diversity in germination parameters as well as in morphological and yield traits. From the five studied accessions, Aja accession has the highest percentage of germination in distilled water and in low salt concentration, so it can be introduced on moderate salty soil. Regarding dry matter yield, despite its poor germination, Jemeen is considered as the most vigorous accession with a productivity of 513g/individual. This yield was higher than reported by Mseddi *et al*., (2003). This work allows to select Jemeen and Gaed as the most tolerant accessions to overgrazing. These two accessions suggested to be introduced in degraded rangelands.

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Grazing as a tool to maintain floristic diversity and herbage production in mountainous areas: a case study in north western Greece

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Abstract. Transhumant farming is a common practice in the Mediterranean region. Small ruminants grazing intensity effects on floristic diversity and herbage production in a mountainous area were studied. The research was conducted in the areas of Samarina and Dotsiko, located in northwest Greece. Both areas are grazed mainly by transhumant sheep and goats. Four experimental sites were selected: (i) two lightly grazed rangelands and (ii) two heavily grazed rangelands. An area of 9 m^2 in each rangeland was fenced in the spring of 2012, in order to be protected from grazing. Four transect lines were established in every grazed rangeland. The vegetation cover and the herbage production were measured in June 2013, and the Shannon- Wiener diversity index was calculated. Thereafter, the utilization percentage was evaluated to be on average 26% in the lightly grazed area and 91% in heavily grazed one. No significant differences were detected for ground cover and herbage production between the lightly grazed plot and the protected one. However, herbage production was significantly lower in the grazed than in the protected plot in the heavily grazed area. Different grazing intensity significantly decresed Shannon diversity index in the heavily grazed area, while in the lightly grazed one there were no significant differences. It seems that heavy grazing intensity decrease herbage production and species diversity.

Keywords. Overgrazing – Plant cover – Species diversity – Grasslands.

Le pâturage, un outil pour maintenir la diversité floristique et la production des herbages dans les zones montagneuses au nord-ouest de la Grèce

Résumé. *La transhumance est une pratique courante dans la région méditerranéenne. Les effets de l'intensité de pâturage des petits ruminants sur la diversité floristique et la production fourragère dans une région montagneuse ont été étudiés. La recherche a été menée dans les domaines de Samarina et Dotsiko, situés dans la préfecture de Grevena, au nord-ouest de la Grèce. Les deux zones sont pâturées principalement par des moutons et des chèvres transhumants. Quatre sites expérimentaux ont été choisis : deux prairies pâturées modérement et deux prairies pâturées intensivement. Une surface de 9 m^2 a été mise en défens dans chaque prairie pendant le printemps 2012, afin d'être protégée des animaux. Quatre transects ont été établis dans chacune des prairies. La composition floristique, la couverture végétale et la production fourragère ont été mesurées en juin 2013. L'indice de diversité de Shannon-Wiener a été calculé. Le pourcentage d'utilisation a été évalué à 26% en moyenne dans la zone pâturée modérément et à 91% dans la zone intensivement pâturée. Aucune différence significative n'a été détectée pour la couverture végétale et la production fourragère dans les prairies légèrement utilisées entre la zone pâturée et la zone mise en défens. En revanche, la production fourragère a été significativement plus faible dans la zone protégée dans les prairies fortement pâturées. L'absence de pâturage n'a pas modifié l'indice de diversité de Shannon-Wiener dans les prairies modérement pâturées tandis que celui-ci a significativement diminué dans les prairies fortement utilisées dans la zone pâturée compartivement à la zone mise en défens.*

Mots-clés. *Pâturage – Couverture végétale – Diversité – Production-prairies – Chevres-moutons.*

I – Introduction

Transhumance is the seasonal movement of livestock from lower pastures in winter, to higher in the summer in order to overcome difficult environmental conditions (Vallentine, 2001), which has been used for decades. However, during the last century, changes in the agricultural management and livestock farming have affected traditional forms of farming, and have led to abandonment of mountain areas as less-productive or less-accessible grasslands (Farina, 1998; Fischer *et al.,* 2008; Fava *et al.,* 2010).

Mediterranean grasslands are rich in species that contribute to high floristic diversity and herbage production (Karatassiou and Koukoura, 2009). According to Noy-Meir *et al.* (1989) livestock grazing is considered as an important tool to maintain species diversity. It is known that protection from grazing can lead to less diversity in plant species (Koukoura *et al.,* 1998). Moreover, grazing can affect positively or negatively species diversity in herbaceous plant communities, due to the foraging behavior of herbivores (Zhang, 1998), and in many cases species diversity has decreased when grazing has stopped (Noy-Meir *et al.,* 1989). On the other hand, heavy grazing pressure has been reported to reduce the diversity of herbs and shrubs in the grasslands (Zhao *et al.,* 2006) and regarded as a dominant factor of grassland degradation (Zhang, 1998). Moreover, overgrazing has altered the botanical composition and herbage production the last decades and led to disappearance of some species or to their survival through morphological or other physiological adaptations (Wang *et al.,* 2002). The aim of this study was to evaluate the effects of light and heavy grazing by small ruminants to floristic diversity and herbage production in mountainous areas.

II – Materials and methods

The study was conducted in the region of Samarina (1438 m) and Dotsiko (1047 m), two neighboring mountainous villages, which are located in Grevena prefecture, northwestern Greece. The climate of both study areas is classified as a sub-Mediterranean and belongs to humid bioclimatic floor with severe winter (Mavromatis, 1978). For decades, both areas have received high grazing pressure mainly by transhumant sheep and goats from May to October. Last years, the transhumant number of animals have been decreased in Dotsiko (data not shown), and thus there is a low grazing intensity in the area. In the contrary, there is no animal reduction in Samarina, where the grazing intensity is heavy. Four experimental sites of similar herbage functional groups of vegetation consist of grasses, legumes and forbs, but with different grazing intensity were selected: (i) two lightly grazed sites in Dotsiko village (L_1 and L_2) and (ii) two heavily grazed sites in Samarina village (H_1, and H_2). In each experimental grassland, a plot of 9 m^2 was fenced in the spring of 2012, in order to be protected from grazing.

The vegetation cover and the floristic composition were measured by using the line-point method (Cook and Stubbendieck, 1986) in June 2013. Four transect lines of 20 m long were established in every grazed grassland. Contacts were obtained every 20 cm (100 contacts per transect). The herbage production was measured in the same period by harvesting the above ground biomass of the vegetation from three 0.5 m x 0.5 m quadrats in the protected plots. Herbage production in the grazed areas was measured in the same way with three quadrats along each transect. The samples were oven-dried at 60°C for 48 hours and weighed in order to calculate the utilization percentage (UP) of vegetation as the difference between the protected and grazed production (Cook and Stubbendieck, 1986). Floristic diversity was calculated by using Shannon-Wiener index of α-diversity (H) (Henderson, 2003).

For all measured parameters differences between the study areas were calculated using one-way ANOVA (Steel and Torrie, 1980). All statistical analyses were performed using the SPSS® statistical software v. 18.0 (SPSS Inc., Chicago, IL, USA).

III – Results and discussion

Forage utilization percentage (UP) was calculated to be on average 26% in the lightly grazed area and 91% in heavily grazed one (Table 1). In both lightly grazed areas, there were no significant differences in vegetation cover ($P \geq 0.05$) between protected and grazed plots. Concerning the heavily grazed areas, vegetation cover was significantly lower in the grazed compared with protected in one of them, while in the other there was no significant difference. A reduction in vegetation cover was expected due to high UP (Brady *et al.,* 1989). However, this was not the case in our study, at least in one site most probably because of the deep and fertile soil of the specific area (see also Abraham *et al.*, 2009).

Table 1. Vegetation cover (%), herbage production kg/ha, species diversity index and utilization percentage (UP) in different grazing intensities, light (L) and heavy (H)

Grazing intensity	Cover %		Production kg/ha		Diversity		UP%
	Protected	Grazed	Protected	Grazed	Protected	Grazed	
L1	91.3a	81.0a	243a	227a	1.88a	1.67a	30.0
L2	93.3a	94.3a	494a	255a	1.91a	1.89a	22.5
H1	98.0a	87.3a	2270a	320b	1.71a	1.42b	89.6
H2	95.7a	66.7b	1770a	280b	1.97a	1.40b	92.2

* Means for the same parameter in the same row followed by the same letter are not significantly different ($P \leq 0.05$).

Herbage production was significantly lower in grazed sites, compared to protected sites in the heavily grazed area, while there was no significant difference between grazed and protected sites in the lightly grazed area (Table 1). According to Ali-Shtayeh and Salahat (2010), there is a direct effect of grazing on the vegetation growth through the foraging behaviour and trampling of animals. Despite the short time of animal exclusion in the protected plots, plant diversity was found significantly decreased in the grazed sites compared to the protected ones in heavily grazed areas. According to Noy-Meir (1998) the total biodiversity tends to be higher in grazed than in protected plots, except extremely heavily grazed areas as in our study. Moreover, heavy grazing can lead to low plant diversity (Noy-Meir *et al.,* 1989; Olsvig-Whittaker *et al.,* 1993). On the other hand, in the lightly grazed areas there were no significant differences between the grazed and the protected sites. Under-grazing could have similar negative effects to biodiversity like overgrazing (Metera *et al.,* 2010), while long-term grazing abandonment can led to the decrease about 60% of grassland species in these grasslands (Peco *et al.*, 2006).

IV – Conclusions

The results of the current study suggest that heavy grazing intensity decreases herbage production and species diversity despite the short time of animal's exclusion. Additional experiments and observations involving other areas would provide more information to support the current datasets.

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Seasonal variations of herbage yield and quality in Karst pastures for sustainable management: first results from the BioDiNet project

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Abstract. The project Network for the Protection of Biodiversity and Landscape (BioDiNet) started in autumn 2011, pursues the aim of preserving the natural and cultural heritage of the Karst Edge. One of the scheduled activities scheduled was the study of the herbage yield and quality of Karst pastures for defining grazing management guidelines. The preliminary findings obtained in the study area of Polazzo (Gorizia, Italy) are reported here. Four sites were selected as representative of the most common pastures in the area. The daily herbage yield (t ha^{-1} d^{-1} dry matter [DM]) from April to October 2012 was determined using the Corrall and Fenlon (1978) method and described by a Gaussian model. Herbage nutrient concentrations were also determined. The four sites displayed similar trends for daily DM yield, with a maximum in May, followed by a decrease in August, and a slight recovery in September. However, each pasture showed different total annual DM yield, and different Gaussian growth curve parameters. There were also significant differences in herbage quality. In all sites, the highest concentration of crude protein and lowest concentration of acid detergent fibre coincided with the maximum daily DM yield. These results suggest grazing should be managed according to the productivity of each pasture to reduce the risk of excessive grazing, and provide high quality forage to animals.

Keywords. Daily herbage yield – Herbage nutrient concentration – Grazing guidelines – Sustainable management.

Variations saisonnières de la production et de la qualité de l'herbe dans des prairies du Karst dans un but de gestion durable : premiers résultats du projet BioDiNet

Résumé. *Le projet "Réseau pour la protection de la biodiversité et du paysage" (BioDiNet), commencé à l'automne 2011, vise à préserver le patrimoine naturel et culturel du Karst. La production des prairies et la qualité des pâturages karstiques ont été étudiées pour établir des lignes directrices de gestion des pâturages. Les résultats préliminaires de la zone d'étude de Polazzo (Gorizia, Italie) sont rapportés ici. Quatre sites représentant des pâturages les plus courants dans la région ont été choisis. Le rendement quotidien d'herbe (t* ha^{-1} j^{-1} *de matière sèche [DM]) d'Avril à Octobre 2012 a été déterminé en utilisant la méthode de Corrall et Fenlon (1978) et décrit par un modèle Gaussien. Les concentrations en nutriments de l'herbe ont également été déterminées. Bien que le rendement quotidien en MS des quatre sites fût semblable, les quatre pâturages ont montré des différences dans leurs rendements annuels de DM, ainsi que dans les paramètres de la courbe de croissance de Gauss, et dans la qualité de l'herbe. La plus forte concentration en CP (protéines brutes) et la plus faible concentration en ADF (fibres) ont coïncidé avec le rendement quotidien de MS maximal. Ces résultats suggèrent que chaque pâturage doit être géré en fonction de sa productivité pour réduire le risque de pâturage excessif, et pour fournir un fourrage de haute qualité.*

Mots-clés. *Production journalière d'herbe – Concentration en éléments nutritifs de l'herbe – Lignes directrices de pâturage – Gestion durable.*

I – Introduction

The majority of Karst grasslands were included in the Italian and Slovenian Natura 2000 network for their high environmental value. However, the low production capacity of these grasslands and the changing socio-economic conditions over the last decades led to widespread abandonment in this area (Ivajnšič *et al*., 2013). According to the Slovenian Agri-Environmental Programme, the primary objective of conservation of Karst grasslands is to counter the depopulation of rural regions. In order to preserve the natural and cultural heritage of the Karst Edge region, the project Network for the Protection of Biodiversity and Landscape (BioDiNet) co-financed by the European Regional Development Fund, started in autumn 2011. The sheduled project activities included the study of the productivity of Karst pastures for defining grazing management guidelines. Due to the climatic and topographic characteristics of the Karstic areas, the grassland productivity varies according to very specific spatial and temporal patterns (Škornik *et al*., 2010). Therefore, to meet the project requirements, it is essential to understand the seasonal evolution of herbage yield and quality in these pastures. This paper reports the preliminary findings obtained in the study area of Polazzo (Gorizia, Italy).

II – Materials and methods

The study was carried out in the rural park "Alture di Polazzo" in northeastern Italy (45°86' N, 13°50' E, elevation 114 m a.s.l.) from April to October 2012. Four sites were selected as representative of the most common pastures in the area, based on both botanical and geo-morphological characteristics. Sites chosen were semi-natural calcareous dry grasslands, species-rich ecosystems, and deemed habitats of community interest (92/43/EEC Directive). Botanical surveys were conducted in each site and results showed that the vegetation at all sites is referable to *Danthonio alpinae-Scorzoneretum villosae* (Poldini and Kaligarič, 1997). Three sites were located on a ridge (B, C and D), while the other (A) was in a doline. Soil properties are reported in Table 1.

Table 1. Soil characteristics of four Karstic pastures in the rural park "Alture di Polazzo" northeastern Italy

Properties	A	B	C	D
Sand (%)	18.1	30.1	36.1	36.1
Silt (%)	60	56	50	50
Clay (%)	21.9	13.9	13.9	13.9
Depth (cm)	49	10	41	32
pH	6.8	6.79	6.45	6.88
N content (g kg^{-1})	2.4	4.1	3.2	3.3
C:N (g/100g)	12.23	13.49	17.1	17.99

Four plots (4 m^2) replicated in two blocks were established in each site and harvested in regular rotation once a week to determine daily dry matter (DM) yield (kg DM ha^{-1} d^{-1}) using the Corral and Fenlon (1978) method. At each harvest the entire plot herbage was collected in the field and subsequently dried for 36 h in an oven at 65°C to determine DM yield. Herbage nutrient concentrations were determined using near infrared reflectance spectroscopy (model 5000; NIRSystems, Silver Springs, MD). The following nutrients were determined: ash (ash [% of DM]), neutral detergent fibre (NDF, Van Soest method [% of DM]), acid detergent fibre (ADF, Van Soest method [% of DM]), acid detergent lignin (ADL, Van Soest method [% of DM]), crude protein (CP, Kjeldahl method [% of DM]) and crude lipid (EE, Soxtec method [% of DM]).

The herbage daily growth was then obtained. Gaussian models ($f_{(x)} = a * e - \frac{(b-x)^2}{c^2}$) were were used to fit observed daily DM yield, obtaining a DM yield growth curves for each site. Parameters *a* and *b* were used to describe the fitting curves: *a* is the peak of the curve, *b* is the day of the year (DOY) in which the maximum DM yield occurred; the number of days necessary to reach 90% of the DM yield (ND90) was also calculated and used instead of parameter *c* (distance between curve inflection points). Total DM yield produced throughout the year was estimated in each site calculating the integral of its daily growth curve. Nutrient concentrations were analysed using generalized linear models (GLM). For each site, GLMs were built to analyse the relationship between nutrient concentrations and DOY, including in the models the square of the DOY that represents the curvature of the relationship. Statistical analyses were performed with R software (R Development Core Team, 2013).

III – Results and discussion

The four sites displayed a similar trend for daily DM yield, with a maximum in May, followed by a rest in August, and a slight recovery between 5th September and 22nd October (the trend for site A is shown in Fig. 1). Based on this trend, the seasonal growth was split into two periods (1 and 2) from which the daily growth curves were calculated.

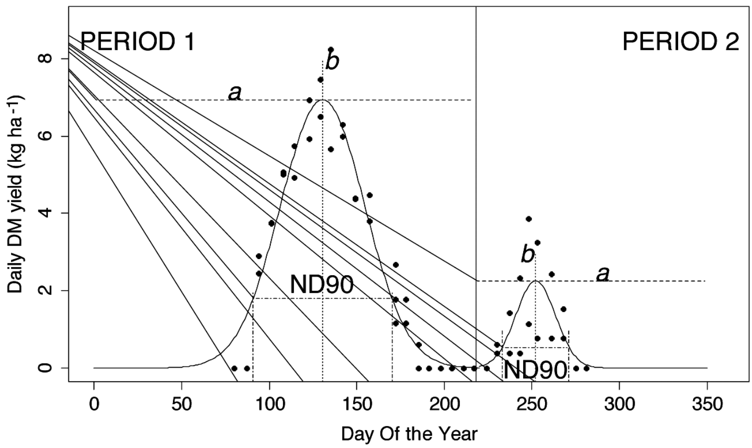

Fig. 1. Seasonal variation of daily dry matter (DM) yield of a Karstic pasture (site A) analysed in two periods. Dots are daily DM yield calculated with Corral-Fenlon method. Curves are the model prediction of DM yield over the periods. The parameters of the curves (*a* and *b*) and number of the days necessary to reach 90% of DM yield (ND90) are reported with letters and lines.

Differences in seasonal yield distribution within sites are shown in Table 2. Sites A and B displayed a low weekly DM yield during period 1, however their DM yield in period 2 was comparable with the others. In period 1, site A reached the maximum production (parameter *a*) on DOY 130 (parameter *b*) and 90% of its production occurred in 80 days (ND90). The other sites reached maximum production in a shorter time and displayed higher ND90. Differences within sites were less pronounced in period 2, with site D reaching a higher daily DM yield value than the other sites (5.83 kg ha^{-1}). In addition, different total DM yields were found, ranging from 0.5 to 1.4 t ha^{-1}.

Significant negative correlations were found between fibre concentrations (NDF, ADF, ADL) and CP (R^2 was 0.43, 0.74 and 0.53 respectively), while correlations between fibre concentrations and EE were not significant. As in the daily yield analysis, the datasets were split into two periods (1 and 2). None of the sites displayed significant changes in NDF over the year. However, models built with ADF and ADL showed a significant effect of DOY and their squares, with positive curvature coefficients, and the squared DOY showed a significant effect on CP content in all sites, with negative curvature coefficients (data not shown). The lower values of ADF and ADL, and higher values of CP, corresponded to the DOY on which the maximum daily DM yield occurred. This could be related to the very short period of high growth rate, in which the new herbage could positively affect the forage quality. Nutrient concentrations in the Karstic pastures studied were in line with other studies of mountain pastures (i.e Isselstein *et al*., 2007). However, this study demonstrates that herbage quality, especially for ADF and CP, increased when pastures were more productive in terms of daily DM.

Table 2. Parameters of the curves (*a* and *b*) and number of days necessary to reach 90% of DM yield (ND90), calculated for periods 1 and 2, and total DM yield of the four Karstic pastures

	PERIOD 1			PERIOD 2			Total DM yield (t ha^{-1})
	a	*b*	ND90	*A*	*b*	ND90	
A	6.94	130	80	2.25	252	38	0.48
B	9.30	120	114	2.26	252	34	0.86
C	13.37	122	104	1.76	258	36	1.11
D	13.42	124	116	5.83	258	42	1.36

IV – Conclusions

The seasonal evolution of herbage yield in the studied Karstic pastures is described by two-phase models, and herbage quality is higher at the maximum DM yield. These results could help optimize grazing management strategies. For a sustainable utilization of these pastures, the differences found within sites suggested that in a morphologically complex landscape like the Karst, morphological aspects have a strong influence on management decisions.

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Modeling spatial distribution of goat grazing as a fuelbreak management tool in Mediterranean ecosystems

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Abstract. Forest fires occur frequently in Mount Carmel, Israel, as well as in other Mediterranean areas. Grazing is known to control wildfires by removal of flammable biomass. In order to optimize the use of grazing as a management tool in fire fuelbreak zones, land managers need to control grazing intensity and spatial distribution according to the given vegetation cover. Effective grazing is most likely to be applied by goat herds, which, as opposed to free-range beef cattle, are usually guided by a shepherd. However, assessing the stocking rates required to maintain effective fuelbreak zones is challenging due to the difficulties in evaluating herd spatial distribution and biomass removal. In an attempt to address this problem we monitored six goat herds using GPS collars, recording goat presence and activity (grazing, walking, and resting) for each area as well as the number of grazing days per area and stocking density. Effective grazing density was derived by modelling vegetation cover dynamics, i.e. the difference between annual biomass removal by grazing and primary production (g/m^2/year). This information may be used to determine the target number of grazing days to be sought by land managers for a given fuelbreak area. Quantifying grazing services for fire management in Mediterranean ecosystems can improve multi-purpose interfacing of pasture land and fuelbreaks.

Keywords. Goat grazing – Fuelbreaks – Mediterranean ecosystems – Grazing services – Modelling.

Modélisation de la distribution spatiale de chèvres sur parcours – un outil pour la gestion des zones de coupe feu dans les écosystèmes méditerranéens

Résumé. *Des feux de forêt surviennent fréquemment dans la région du Mont Carmel en Israël, de même que dans d'autres régions de la Méditerranée. On reconnaît que le pâturage aide à contrôler les incendies en réduisant la biomasse combustible. De façon à optimiser l'emploi du pâturage comme outil de gestion des zones de coupe feu, les gestionnaires de terrains doivent contrôler l'intensité et la distribution spatiale du pâturage en accord avec la végétation du terrain. Un service de pâturage adéquat est plus à même d'être fourni par des troupeaux caprins, qui, au contraire des bovins en pâturage libre, sont habituellement guidés par un berger. Cependant, l'évaluation du ratio requis pour le maintien de zones de coupe feu efficaces reste un défi, car il est difficile de mesurer la distribution spatiale des troupeaux, de même que la réduction de la biomasse. Nous avons tenté de traiter ce problème en contrôlant à l'aide de colliers GPS six troupeaux caprins, notant pour chaque aire la présence et l'activité des chèvres (pâturage, marche ou repos), de même que le nombre de jours de pâturage par aire et la densité du bétail. La densité de pâturage adéquate fut trouvée en modélisant les dynamiques de la végétation, plus précisément la différence entre la réduction annuelle de la biomasse par pâturage et la production primaire (g/m^2/année). Ces données peuvent être utilisées pour aider les gestionnaires de terrains à déterminer le nombre requis de jours de pâturage pour une zone de coupe feu. La quantification des services pastoraux pour la gestion des incendies dans les écosystèmes méditerranéens pourrait améliorer l'interfaçage multifonctionnel des zones pastorales et des zones de coupure de combustible.*

Mots-clés. *Pâturage caprin – Zones de coupe feu – Écosystèmes méditerranéens – Service de pâturage – Modélisation.*

I – Introduction

The Mediterranean Basin has been subject to various human disturbances such as grazing, clearing and prescribed fires for millennia (Naveh and Dan, 1973). Abandonment of traditional herding and agriculture in Mediterranean regions has led to changes in vegetation and land use patterns, consequently increasing wildfire hazard (Perevolotsky and Seligman, 1998). Furthermore, increasing development in exurban and rural areas into fire-prone ecosystems has increased the risk of fires at the wild land-urban interface. Due to an increase in wildfire frequency and severity in Mediterranean regions, during the 20th century (Pausas *et al*., 2008), the importance of active management of forest and scrubland interface is increasing.

Fuelbreaks are established as a part of proactive planning to reduce fire intensity, extent and progress, providing safer access for fire fighters (Omi, 1996). A fuelbreak is "a strategically located wide block or strip, on which a dense cover of flammable vegetation has been permanently changed to one of lower fuel volume and reduced flammability" (Green *et al*., 1977). This is achieved by removal of forest and woodland biomass by mechanical means, which requires costly investments. Due to the successional dynamics of Mediterranean ecosystems, herbaceous and woody vegetation in the fuelbreak area recover rapidly within a short period of time, and therefore require proper maintenance. Generating fuelbreaks in Israel was recommended after the 1989 Mount Carmel fire, but not implemented. The 2010 fire in the same region, claimed 44 lives, caused 17,000 people to be evacuated from their households, and burned nearly 25,000 acres. Subsequently, the need to establish fuelbreaks emerged again (Israel Ministry of Environmental Protection, 2011).

One economical and effective and economical means of maintaining fuelbreaks over time is the use of grazing. Goats exhibit a greater propensity to browse woody vegetation than cattle and sheep, and the mobility of goat herds is easily controlled by a shepherd. Thus, effective grazing for wildfire reduction management is most likely to be applied by goat herds. The benefits of goat grazing for biodiversity and its necessity as a fire hazard management tool are increasingly realized. The main challenge of using goat herds for fuelbreak maintenance in Mount Carmel is that goats are scarce and their spatial distribution is largely unknown.

Our research goals were: (i) to quantify spatial grazing pressure; and (ii) to develop quantitative tools of spatial modeling to determine the duration and intensity of grazing needed for the maintenance of fuelbreaks.

II – Materials and methods

Study area. The Carmel Heights, south of Haifa, Israel, run parallel to the Mediterranean Sea shore and peak at 546 m a.s.l. It covers an area of 250 km^2 (25,000 ha), characterized by Mediterranean climate, with dry summer and cool, wet winter, with an average annual precipitation of 600 mm. The study area is heterogeneous in vegetation types, with natural Mediterranean forest, woodland and scrubland combined with planted Aleppo pine forests (Zohary, 1960).

Grazing monitoring. We monitored the daily grazing routes of 11 herds using GPS. The GPS unit (i-gotU GT-600, Mobile Action Technology Inc., Taiwan) was placed on one individual goat per herd, using a customized collar. The location data was recorded at a high frequency (every 10 seconds) and locations were imported into a geographic information system (GIS). The data enabled calculation of goat presence and activity (grazing, walking, and resting) for each area seasonally and annually. These data were used to calculate the grazing pressure and effective grazing density.

GPS collar representation of a herd in space. The instantaneous spatial distribution of a goat herd depends on vegetation structure and landscape terrain. In order to calculate how a GPS collar represents a herd in space, a preliminary experiment was conducted. The width of a goat herd was measured at the widest point of the herd, by using a laser rangefinder (i-gotU GT-600, Mobile Action Technology Inc., Taiwan) in different vegetation covers and terrains.

Calculating grazing pressure. Grazing pressure was calculated by creating a grid with 1-ha tiles, used for counting the number of GPS locations per cell and the total time that was spend by the flock:

$$\frac{\text{grazing pressure}}{\text{cell}} = \text{count}\left(\frac{\text{gps call}}{\text{cell}}\right) * \frac{1}{1\text{ call frq (gps call/min)}} * \frac{1(\text{grz\_day})}{60\left(\frac{\text{min}}{\text{hr}}\right) * 4\text{ (hr)}}$$

$$\frac{\text{grazing pressure}}{\text{cell}} = \frac{\text{grazing pressure}}{\text{cell}} = \frac{\text{count}}{240}\left(\frac{\text{grz\_day}}{\text{cell}}\right)$$

count: number of GPS calls/cell
Cell: 1 ha (100 m*100 m)
call frq: GPS sampling frequency (GPS call /min)
grz_day: grazing day = 4 grazing hours

III – Results and discussion

Grazing monitoring. Differences between seasonal pasture uses of a herd were revealed. These differences are probably caused by vegetation characteristics and height: open and shady in the summer as opposed to dense and low in the winter. In addition, spatial grazing patterns were compared to existing locations of fuelbreaks around settlements.

GPS collar representation of a herd in space. GPS collar representation of a herd was studied under different vegetation covers: open shrub land, thin shrub land, dense shrub land and walking trail. The herd representation was calculated to be a disk 20 m in diameter around the GPS collar location (Table 1).

Table 1. Calculating GPS collar representation of a herd

Vegetation type	Mean (m)	N	prop	prop*mean(m)
Open shrubland	29.96	60	0.189	5.671
Sparse shrubland	20.534	142	0.448	9.198
Dense shrubland	14.113	97	0.306	4.318
Walking trail	8.395	18	0.057	0.477
Total		317	1	19.66

Calculating grazing pressure. GPS fixes for a GIS grid cell (1 ha) and the total time that was spent by each herd were calculated seasonally (see example in Fig. 1). High herd presence was detected in some areas, which imply that fuelbreaks should be designed in accordance to existing grazing patterns. Additionally, grazing patterns can be manipulated by using incentives such as water facilities in order to adjust the grazing patterns of a herd to existing fuelbreaks. Manipulating grazing patterns must consider fuelbreak area and herd size, location of neighbor herds and distance from the herd's premises.

Effective grazing management could be derived by modeling vegetation cover dynamics, e.g. the difference between yearly biomass removed by grazing and primary production (g/m^2/year). This information may help determine the number of grazing days to be targeted by land managers for

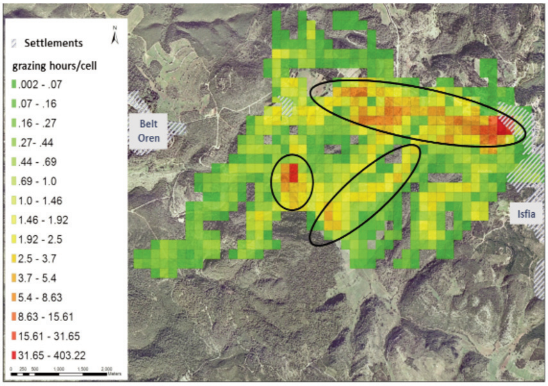

Fig. 1. Goat herd seasonal grazing hours/cell. Circled in black: hig herd presence calls.

a given fuelbreak area. Furthermore, this information could be used for examining different fuelbreak maintenance scenarios such as increasing herd size, adding pasture area, troughs, and subsidizing grazing, on a variety of timescales (Fig. 2).

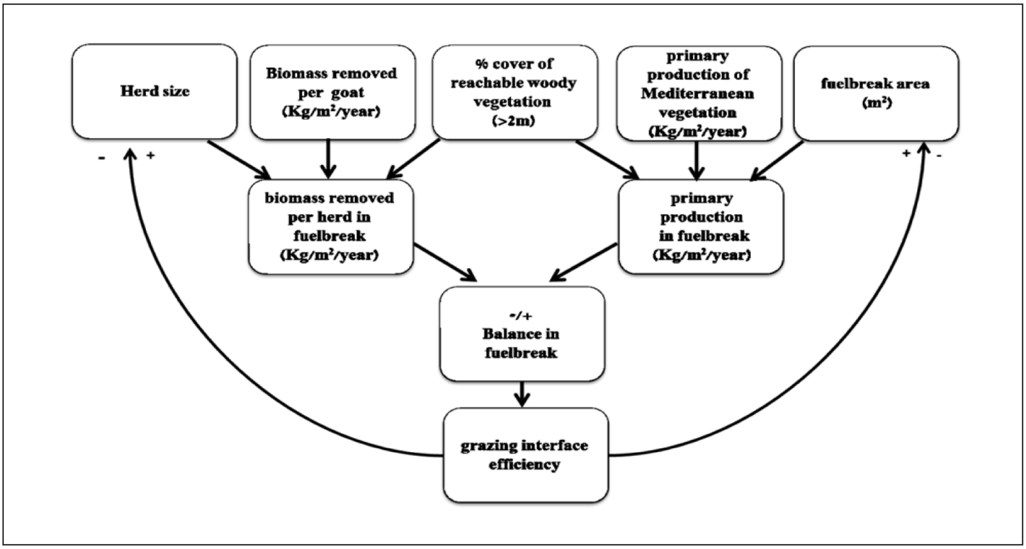

Fig. 2. Theoretical model for effective grazing management.

IV – Conclusions

This study presents an approach that could be used as a decision support tool for planning and maintenance of fuelbreaks by goat herds. GPS monitoring is contributory in quantifying grazing services that local herds can provide to maintain fuelbreaks. Fuelbreaks can be designed in accordance to existing grazing patterns or maintained by manipulating nearby goat herds, using incentives such as water availability. Linking spatial and socio-economic analysis can provide information about the means to preserve local extensive goat grazing by understanding the limiting factors for the presence and size of each herd. In a wide-range timescale there is a need to establish regulations for the continuity of extensive and traditional goat grazing. This study addresses Mount Carmel area but probably can be applied to other Mediterranean ecosystems as a multi-purpose interface of pasture land and fuelbreaks.

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Forage legumes and grasses: more advantages in pure crop rotation or intercropping?

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Abstract. Intercropping of grasses and legumes could represent a viable alternative to rotation because of the ready availability of nitrogen and the complementary distribution of the aerial and root systems. This paper reports two years (2012-2013) forage yield results of some legumes (berseem and squarrose clover, hairy vetch and burr medic) and grasses (ryegrass and oats) grown as pure crops as well as intercrops. In the two years the annual dry matter production was 5 t ha^{-1} but seasonal yield was very different for each species due to inter-annual weather variability. In the second year, except for vetch, that showed a rather stable production, forage yield was delayed increasing hay production. In the first year, total yield of intercropping (except for ryegrass/clover mixture) was often higher than pure crop (Land Equivalent Ratio >1). Seasonal production was instead variable: the mixtures berseem/grass, medic/grass and squarrose/oats for pasture, vetch/grass and squarrose/oats for hay were more favourable than pure crops. In the second year, mixtures was less convenient (LER<1); benefits were evidenced in some case (medic/grasses, berseem/oats and squarrose/oats) only for hay.

Keywords. Forage yield – Intercropping – Rotation – Legumes – Grasses – Sustainable agriculture.

Légumineuses fourragères et graminées : avantage aux cultures pures ou aux associations ?

Résumé. *Des implantations annuelles de cultures mixtes de graminées et légumineuses pourraient représenter une alternative à des rotations de cultures pures, jouant sur la modification des disponibilités d'azote et la complémentarité de distribution des systèmes aérien et racinaire. Cette étude présente les résultats de deux années (2012 - 2013) sur le rendement fourrager de légumineuses (trèfle d'Alexandrie et trèfle écailleux, vesce velue et luzerne annuelle) et de graminées (ray-grass et avoine) cultivées en mélange ou en culture pure. Durant les deux années la production annuelle a été 5 t ha^{-1} de matière sèche mais, influencée par les conditions météorologiques, le rendement saisonnier a été très différent pour chaque espèce. Durant la deuxième année, à l'exception de la vesce plutôt stable, on a observé un retard de production et, par conséquent, un rendement supérieur en foin. Dans la première année, le rendement total de la culture associée (sauf pour les associations ray-grass/trèfle) a été souvent plus élevé que la culture pure (LER>1). La production saisonnière a été variable : les mélanges trèfle d'Alexandrie/graminées, luzerne/graminées et trèfle écailleux/avoine pour le pâturage et les mélanges vesce/graminées et trèfle écailleux/avoine pour le foin ont été plus favorables que les cultures pures. La deuxième année, les associations ont été moins productives (LER <1); des avantages ont été obtenus seulement dans certains cas (luzerne/graminées, trèfle d'Alexandrie/avoine et trèfle écailleux/avoine) uniquement pour le foin.*

Mots-clés. *Production fourragère – Association – Rotation – Légumineuses – Graminées – Agriculture durable.*

I – Introduction

The intensive agriculture even if increases yield per hectare may cause serious environmental problems, principally due to the use of chemical and to overexploitation of soil. According to the Common Agricultural Policy guidelines, some rational agronomic techniques, like crop rotations and the use of legumes, could allow to mitigate the impact of agriculture by preserving soil fertility.

Legumes, in mixtures or rotation with grasses, as well as an important source of vegetable proteins, play a central role for the forage systems sustainability especially for the nitrogen enrichment of soils (Giambalvo *et al*., 2011). A large debate if grass/legume intercropping could be a valid alternative to pure crop rotation is still under way (Willey, 1979; Mariotti *et al*., 2006; Tuna *et al*., 2007).

Intercropping is the agricultural practice of cultivating two or more crops in the same space at the same time (Lithourgidis *et al.*, 2011); the readily available nitrogen of legume's rhizobia and the different spatial distribution of root and air systems could influence a better use of resources (water, nutrients, radiation) than pure stand crop rotation.

This trial takes place in a Mediterranean environment, where drought summer conditions oblige to use annual forage species, with the aim to test the behaviour of several grasses and legumes sown and managed in "intercropping" and "rotation".

The paper reports the forage yield data of the first two years. In the long period it will be possible to deduce the implications of these managements on soil fertility.

II – Materials and methods

The experiment is carried out in Southern Sardinia, near Cagliari (39°10' lat N, 150 m a.s.l.) on a soil classified as *Typic Calcixerept* according to Soil Taxonomy (USDA, 2010). Long term rainfall is 500 mm, irregularly distributed from October to May. Winter temperatures seldom reach 0 °C; average maximum temperature is 32°C in July.

Several annual grasses and legumes (Table 1) are settled in a forage system for grazing in winter and hay yield in spring, in order to test some stable intercropping (sown every year in the same plot) and the respective pure stand crop in annual rotation.

Table 1. List of species in intercropping and pure stand. Seed rates in brackets refer to pure stand; the rate is halved in intercropping

1 - Squarrose clover -*Trifolium squarrosum* L. (25 kg ha^{-1})	3 - Hairy vetch - *Vicia villosa* Roth (160 kg ha^{-1}) 4 - Burr medic - *Medicago polymorpha* L. (25 kg ha^{-1})
2 - Berseem clover - *Trifolium alexandrinum* L. (25 kg ha^{-1})	5 - Ryegrass - *Lolium multiflorum* Lam. (25 kg ha^{-1}) 6 - Oats - *Avena sativa* L. (160 kg ha^{-1})

The experimental design was a randomized block with 3 replications. In both years (2011-2012) sowing took place in mid-November, after P-fertilization (150 kg ha^{-1} of P_2O_5), in plots of 14 m^2. Grasses in pure stand were fertilized with 40 units of nitrogen after each utilization.

The forage yield was evaluated weighting the herbage mechanically cut 10 cm above soil. All 500 g sub-samples were oven-dried for dry matter percentage at 65°C for three days. Mixture samples were previously botanically partitioned.

Productive efficiency of intercropping was determined with the land equivalent ratio (LER) (Mead and Willey, 1980; Willey and Rao, 1980), an index that defines the relative land area required by monocrops to produce the same yield of intercrops.

III – Results and discussion

Total rainfall was 387 mm in 2012 and 510 in 2013 with remarkable differences in distribution. In 2013 the mean temperature in November, month of sowing, was 3°C lower than in 2012. Oppositely, in 2013 winter was colder and spring rainfall was higher than 2012 (Fig. 1).

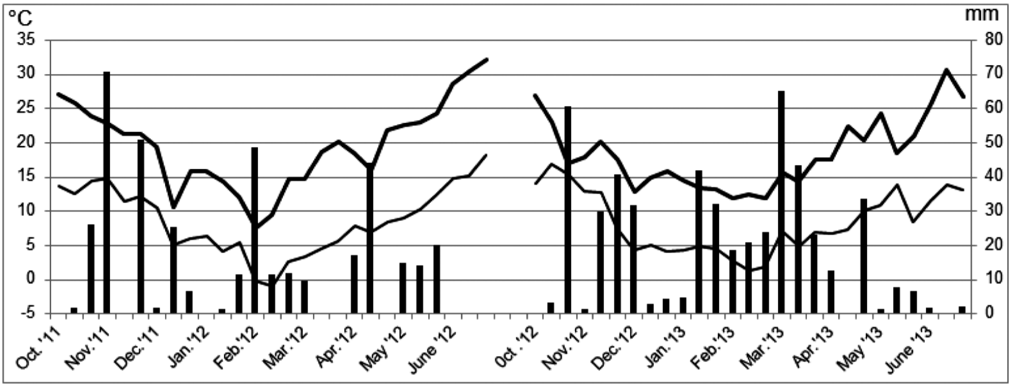

Fig. 1. Weather recording in the two years (lines refer to maximum and minimum temperatures, bars to rainfall).

The winter utilization, before the spring hay cutting, varied from one in vetch crops to four in berseem, according to the crops development.

In both years forage yield average of the experimental field was about 5 t ha^{-1} (Table 2) but, while in the first year the production was balanced between winter (58%) and spring (42%), in the second year, when the emergence and development of crops were slow, it was predominant in spring (77%). Vetch in both years, as winter (pasture) or hay (spring), alone and intercropped, had a rather stable production.

Table 2. Total production (t ha^{-1}) in the two years (in brackets legume percentage of intercropping), hay yield percentage and LER of total production

Intercropping and pure stand of different species	Total yield		Hay %		LER	
	2012	2013	2012	2013	2012	2013
Vicia / Lolium	5.5 A-C (80)	5.0 C-F (56)	80	76	1.00	0.89
Vicia / Avena	5.4 A-C (58)	4.6 E-H (40)	72	68	1.04	0.73
Trifolium squarrosum / Lolium	3.6 D (53)	4.7 E-H (58)	46	91	0.81	0.68
Trifolium squarrosum / Avena	4.8 B-D (53)	7.2 AB (25)	43	83	1.17	0.94
Trifolium alexandrinum / Lolium	4.8 B-D (53)	3.7 F-I (24)	41	90	0.94	0.72
Trifolium alexandrinum / Avena	5.2 A-D (60)	6.4 B-E (10)	39	79	1.10	0.95
Medicago / Lolium	5.5 A-C (66)	3.2 F-I (42)	13	74	1.08	0.84
Medicago / Avena	5.5 A-C (48)	7.0 A-C (3)	12	72	1.14	0.94
Vicia villosa	5.4 AB	4.8 D-G	65	62		
Trifolium squarrosum	3.6 C	6.7 A-C	47	95		
Trifolium alexandrinum	4.6 BC	2.8 G-I	48	86		
Medicago polymorpha	4.7 B-D	2.3 I	–	56		
Lolium multiflorum	6.2 A	7.1 AB	54	77		
Avena sativa	5.0 A-D	8.0 A	33	65		

Means followed by the same letters are not significantly different at P = 0.01 (Duncan test).

Intercropping vs pure stand – In the first year, total yield of intercrops was often superior (excepted for ryegrass/clover mixtures) than pure crops (LER >1) but seasonal trends were variable: while intercropping for vetch was more convenient in spring, for berseem was more convenient in winter; squarrose intercropping with oats was superior in all seasons but never with raygrass; burr medic was more convenient in mixtures than pure crops in winter, but it did not regrowth for hay. In the second year instead, intercropping were always less convenient (LER <1) with the only exception of benefits evidenced for hay in some mixtures (burr medic/grasses, berseem/oat and squarrose/oat).

2012 (1st year)

• Pure stand – Dry matter yield ranged from 6.2 t ha^{-1} in ryegrass to 3.6 t ha^{-1} in squarrose clover. Burr medic produced the most amount of pasture, but did not have any appreciable regrowth for hay. Vetch and ryegrass (3.5 and 3.3 t ha^{-1}, respectively) had the significantly highest hay yield.

• Intercropping – Productive differences between intercrops were less than pure crops. Annual yield was not significantly different (average 5.16 t ha^{-1}) except for squarrose/ryegrass that had the lowest yield (3.6 t ha^{-1}). Vetch was highly competitive with ryegrass, contributing 80% to the mixture composition, but less with oats (contribute 58%) (Table 2). Pasture yield was the highest for burr medic/grasses (4.8 t ha^{-1}) and the lowest for vetch/grasses (1.1 – 1.5 t ha^{-1}). Vetch showed a high competitiveness *vs* ryegrass since the winter season. In the flowering period burr medic ceased its growth and the mixtures with grasses showed the poorest yields. Vetch/grasses mixtures had the highest production of hay.

2013 (2nd year)

• Pure stand – Squarrose clover and the two grasses showed the highest total and hay yield (average of 7.3 and 5.7 t ha^{-1} respectively), burr medic had the lowest one (2.3 and 1,3 t ha^{-1}). Oats showed also the highest pasture yield (2.8 t ha^{-1}) while squarrose clover had the lowest one (0.3 t ha^{-1}). Vetch, berseem and burr medic had the lowest hay yield (average of 2.2 t ha^{-1}).

• Intercropping – Oats was very competitive and its mixtures (except for vetch) reached the highest production despite the nearly disappearance of legumes. Legumes/ryegrass mixtures, on the contrary, achieved a more balanced floristic composition. Vetch was less competitive than the first year, with a contribution on total yield of 56% with ryegrass and 40% with oats.

IV – Conclusions

It seems that forage production is more affected by the weather conditions than the cropping techniques. In the second year a cold winter and a rainy spring determined a slow emergence and development of crops delaying forage production to increase hay yield. Vetch showed the greatest productive stability and a good floristic balance in mixture. Oppositely, the other species showed a greater variability as regards the annual dry matter yield, seasonal production and floristic composition of mixtures. LER values calculated with the collected data did not allow to assess the superiority of one of the two alternatives under investigation and point out the necessity to continue the trial for more years in order to obtain additional information.

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Session 3

Combining and reconciling services on farming system and landscape scales

Keynote articles

Diverse and resilient agro-pastoral systems: a common goal for the Mediterranean regions

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Abstract. The potential of agriculture to maintain or even further intensify production to meet the food and fibre needs of increasing populations without degrading the capacity of the resource base is a major concern worldwide. This review briefly assesses options for the ecological intensification and increased resilience in agro-pastoral systems from the dual perspectives in the southern and the northern Mediterranean by providing examples of successful case studies. Despite the significant disparities in demographic, economic and agricultural land utilization patterns between countries in the north and south Mediterranean, improved animal and crop production is a shared priority with lesser concerns for preserving the natural resources in the southern part of the basin. While intensification may be a more achievable target in favourable areas of the northern Mediterranean, it is crucial to increase the resilience of resource poor agro-pastoral systems through sustainable management in the arid regions of the southern part. As the pressures on land and water resources increase, the major challenge today is how to achieve ecological intensification to be able to sustain the food security without compromising the environmental quality and natural resources that underpin crop and livestock production in the Mediterranean region. Fundamentally, ecological intensification is closely associated with increased efficiency and successful adjustment of seasonal herd management to available feed resources in agro-pastoral systems. Concomitantly, livestock can be used as a tool for the preservation of the natural resources, either by adapting management in conventional systems or through the design of new environmentally-targeted production systems. In addition, in mixed farming systems of the Mediterranean region, inclusion of locally available improved forage legumes in cropping rotations and the use of alternative fodder plants like shrubs and cactus in alley cropping system particularly in marginal areas to increase the availability of high quality feed resources are among the most viable options to achieve diverse and resilient agro-pastoral systems.

Keywords. Crop/livestock farming – Dryland forage legumes – Mediterranean agriculture – Rangelands – *S*ustainable intensification.

Des systèmes agro-pastoraux variés et résilients: un objectif commun pour les régions méditerranéennes

Résumé. *La possibilité de maintenir, voire d'intensifier, la production agricole sans dégrader les ressources naturelles, afin de répondre aux besoins alimentaires d'une population en constante augmentation, est une préoccupation mondiale majeure. Cette revue évalue brièvement, grâce à des études de cas réussies, différentes options permettant d'atteindre une intensification écologique et une augmentation de la résilience dans les systèmes agro-pastoraux avec une double perspective au sud et au nord de la Méditerranée. Malgré d'importantes disparités démographiques et économiques, ainsi que des différences dans les modes d'utilisation des terres agricoles entre les pays du nord et du sud de la Méditerranée, l'amélioration de la production agricole est une priorité partagée, avec toutefois des préoccupations plus faibles concernant la préservation des ressources naturelles dans la partie sud du bassin. Alors que l'intensification agricole peut être plus facilement atteignable dans les régions prospères du nord de la Méditerranée, il est crucial de renforcer la résilience des systèmes agropastoraux du sud à travers une gestion durable des régions arides. Étant donné l'augmentation des pressions qui pèsent sur les terres arables et l'eau, le principal défi actuel est de parvenir à une intensification écologique afin de maintenir la sécurité alimentaire sans compromettre la qualité de l'environnement et des ressources naturelles qui sont à la base de la production végétale et de l'élevage dans la région méditerranéenne. Fondamentalement, l'intensification écologique est étroitement associée à une efficacité accrue et à une adaptation réussie de la gestion saisonnière du troupeau par rapport aux ressources alimentaires disponibles dans les systèmes agro-pastoraux. De manière concomitante, le* *bétail peut être utilisé comme un outil pour la préservation des ressources naturelles, soit en adaptant la gestion dans les systèmes conventionnels, soit par la conception de nouveaux systèmes de production respectueux de l'environnement. En outre, dans les systèmes agricoles mixtes de la région méditerranéenne, l'intégration, dans les rotations culturales, de légumineuses fourragères améliorées et disponibles localement, et l'utilisation de plantes fourragères alternatives, comme les arbustes et les cactus, dans les systèmes de culture en couloirs pour accroître la disponibilité des ressources alimentaires de haute qualité, sont parmi les options les plus viables pour réussir à avoir des systèmes agro-pastoraux diversifiés et résilients.*

Mots-clés. *Systèmes de culture/élevage – Légumineuses fourragères en région aride – Agriculture méditerranéenne – Pâturages – Intensification durable.*

I – Introduction

The Mediterranean region has unique agro-ecosystems with a prevalence of vegetation adapted for arid and semi-arid conditions (Kassam, 1991; Harlan, 1992). Ever since settled agriculture started with the establishment of diverse farming communities, agriculture has been in constant change in the Mediterranean region, albeit with diverging patterns in the northern and southern shores (Landau *et al*., 2000). In the northern part of Mediterranean, traditional crop-livestock farming that used to be extensively practiced over large areas has evolved into more intensive and highly productive crop based agriculture, but often while damaging natural resources (Pretty, 1995). As a result of the increased focus on cropping, the reduced number of livestock in turn caused abandonment of vast grasslands resulting in widespread bush encroachment (Landau *et al*., 2000; Bernués *et al*., 2011). Whereas in the southern part, the rapid increase in human and livestock populations has led to more intensive land use with an unrelenting exploitation of natural resources, particularly the rangelands (Hopfenberg and Pimentel, 2001; Le Houerou, 2000; Ates and Louhaichi, 2012). Socio-economic and political factors are distinctly different in both parts of the basin, and have also played a significant role in forming the structure of the existing agricultural practices (Aw Hassan *et al*., 2010).

The current agro-ecological, environmental and socioeconomic conditions pose a major challenge to increase production and to ensure food security without further degrading the capacity of the resource base. The scale and the type of the challenge may vary in different parts of the region depending upon the power of these prevailing conditions that determines the potential of agricultural production and its sustainability. Gloomy predictions on the impact of population increase, climate change and unsustainable resource management indicate that the constraints on land and feed supply will become increasingly evident in mixed crop-livestock and grazing systems in the region (World Bank, 2008). There is a general consensus that competition for grains between humans and livestock, diminishing capacity of rangelands and trade-offs between crop stubbles for animal feed, soil fertility and biofuels are likely to increase the pressure on livestock production in both high and low input systems (Ben Salem and Smith, 2008; Correal *et al*., 2006; Aw Hassan *et al*., 2010; Smith *et al*., 2013).

Given these worsening constraints on the agricultural resources and the unrelenting pressure on land use, substantial attention has been drawn to improving and sustaining the productivity of crop and animal production (Lal, 2002). In the context of the Mediterranean region, the concept of sustainability has to be considered as a function of whole production system and highly associated with appropriate management of rangelands and inclusion of forage legumes in rotation with cereal crops (Ryan *et al*., 2008; Aw Hassan *et al*., 2010; Ates *et al*., 2013). Forage based feeding can decrease the cost of animal production and reduce the pressure on degraded rangelands (Rihawi *et al*., 2010; Ates and Louhaichi, 2012). However, the area dedicated to forage production has generally been declining as the area of annual cropping of wheat and barley required for human consumption and feed for livestock has increased, thereby downgrading the importance of forages at the expense of efficient livestock and sustainable crop productions (Ghassali *et al*., 1999; Ryan *et al*., 2008).

Despite the inherent fragility of Mediterranean ecosystems and deep-rooted challenges concerning the crop-livestock farming in the region, crop-livestock production can be improved and managed sustainably with appropriate practices (Stewart and Robinson, 1997; Ben Salem and Smith, 2008; Rihawi *et al*., 2010). This paper reports several examples of successful case studies in two sections that draw results together on the options for (i) ecological intensification of livestock production systems in the northern Mediterranean and (ii) increased sustainability and resilience in the southern Mediterranean.

II – Ecological intensification of livestock production systems in the northern Mediterranean

Ecological intensification of agricultural systems has been recently defined by Hochman (2013) as producing more food per unit resource use, while minimising the impact on the environment. In the case of livestock production systems, Dumont *et al*. (2013) suggested that for complying with both premises, sustainable systems should be based on: adopting management practices for improved animal health, decreasing both inputs and pollution, enhancing diversity within farming systems to strengthen their resilience and preserving biological diversity by adapting management practices. Notwithstanding, economic performance is the key to farm survival in the short term, and ultimately these practices will only be implemented if they are not detrimental to farmers' income, and especially if an economic benefit can be achieved (Swift *et al*., 2004), either directly or through stewardship payments. Recently, Firbank *et al*. (2013) demonstrated that such goals were achievable for British farms, which were able to increase both food production and ecosystem services, while receiving public payments through agri-environment schemes.

1. Matching livestock management to feed resources

Technically efficient and sustainable livestock systems need to match animal genotype and management to the available feed resources (Adams *et al*., 1996), in order to achieve the highest possible self-sufficiency, which is crucial for economic profitability and stability of farms (Ripoll-Bosch *et al*., in press). This may become even more important in the future if relations between inputs and productivity keep changing (along with resource availability and price), because it enables the system to cope with potential socio-economic and climate-induced hazards (Bernués *et al*., 2011). This can be achieved through adequate livestock feeding and reproductive management, ensuring that the available resources are enough to meet animal requirements throughout the production cycle.

The seasonality of forage availability is a common characteristic of most extensive systems, and consequently, livestock undergo a cycle of mobilization or accumulation of body reserves during the year. Knowledge of the factors affecting animal performance during the grazing season is needed to design the management calendar that best matches the animal needs to the availability of forage. This includes the choice of lambing/calving and weaning dates, and the provision of supplements when needed. For example, in cattle farming systems in dry Mediterranean mountain areas, Casasús *et al*. (2002) showed that cow gains on pasture were higher in autumn- than in spring-calving cows, which resulted in better reproductive performance (shorter postpartum anestrous interval (Sanz *et al*., 2004)) (Fig. 1). In addition, the use of forest pastures was optimally integrated into the autumn-calving system, with cows weaned at the end of the winter when they have low maintenance requirements and are better able to deliver nutrients obtained from spring pasture for the recovery of body reserves. This option can be further enhanced by the early weaning of calves born in late autumn (from 3 months of age), with no impairment of future calf per-

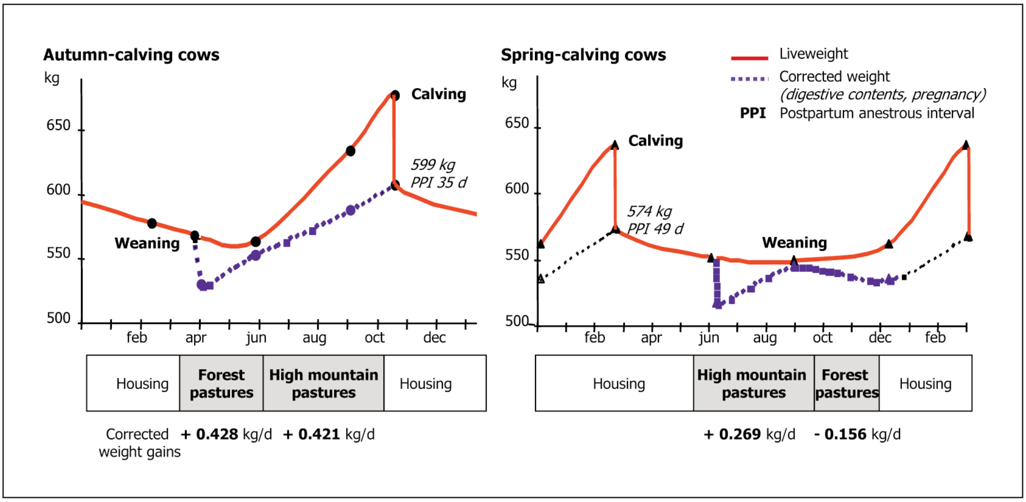

Fig. 1. Patterns of weight change through the annual cycle of autumn- and spring-calving cows in dry Mediterranean mountain areas [adapted from Casasús *et al.* (2002)].

formance (Blanco *et al*., 2009). Spring-calving cows only used these pastures during the autumn, when pasture quality was low and only enough to maintain pregnancy and maternal weight.

Apart from enhancing production efficiency, optimizing economic performance of extensive livestock systems can also be achieved by increasing the added value of products. In fact, society is increasingly concerned about environmentally-friendly and ethical livestock production and product nutritional quality (Bernués *et al.*, 2012), and there is evidence that pasture or forage-based diets can improve environmental, ethical and human health outcomes, compared to feedlot systems (Entz *et al*., 2002; French *et al*., 2000). The choice of pathways to obtain these products will depend on aspects such as the available resources, their seasonal production, or the commercial product types preferred by consumers and retailers in a given area.

Several options have been tested for beef and lamb as alternatives to conventional, intensive finishing on concentrates (feedlots), comparing different forage resources that could be included in fattening diets. Lambs suckled on spring mountain pastures from birth to slaughter (3 months of age) had similar growth performance (Álvarez-Rodríguez *et al.*, 2007), better meat nutritional quality (Panea *et al.*, 2011) and lower production costs than their conventionally produced counterparts. Concerning beef production, heifer finishing diets based on maize silage reduced feeding costs per kg gain up to 13%, while weight gains, carcass and meat quality were similar to those of *ad libitum* concentrate-fed animals (Casasús *et al.*, 2012). Raising entire males on alfalfa pastures (+2 kg/d barley) yielded lower daily gains, similar carcasses but better economic margin (Blanco *et al.*, 2011) and meat nutritional quality (Blanco *et al.*, 2010) than conventional concentrate feeding. Different feeding systems have also been designed for the production of steers on mountain pastures (Blanco *et al.*, 2012), and the available results suggest that there is an opportunity to produce products of a superior quality from systems that include a high proportion of forages. There are even particular methods that allow retailers and consumers to trace animals raised in different production systems, based on the accumulation of pigments from forages in different animal samples (Blanco *et al.*, 2011). Both the distinctive quality and the good practices implemented in these ecologically intensified systems can set the grounds for the development of novel products led by consumer feed-back.

2. Using livestock as a tool for environmental management

The complex interactions between domestic animals and their habitat are not always synergetic, and there is increasing global concern about the detrimental effect that certain livestock production systems can have on the environment (Steinfeld *et al.*, 2006). But some practices can have positive impacts on environmental management and conservation. Such is the case for the northern Mediterranean agro pastoral farming systems, where the positive role of livestock in modulating the landscape is well recognized. However, these systems have gone through significant changes in recent decades, namely decreasing animal numbers and intensification of farming practices, with the concomitant abandonment of large extensively grazed areas (Bernués *et al.*, 2011). The latter is associated with pasture encroachment, and multiple implications on the ecologic values of these areas, such as the colonization of open spaces by a reduced number of competitive shrub species, loss of biodiversity and increased environmental risks.

In this context, adequately managed livestock grazing can control shrub encroachment, preserving the open structure of shrub and forest pastures in the Mediterranean (Landau *et al*., 2000). However, its effectiveness may depend on the vegetation type and current succession status, as well as, on the actual pastoral management and on the socio-economic environment that surrounds livestock farming systems. In order to assess these factors, two similar studies analyzed the effect of livestock on the under-story vegetation in dry Mediterranean mountain forests under different conditions. Changes in herbaceous and shrub vegetation were studied in the presence or absence of livestock, firstly in a pine forest area grazed by cattle at a moderate stocking rate, steadily maintained for a long time. It was concluded that a moderate stocking rate succeeded in preventing shrub encroachment and the accumulation of low-quality, dead inflammable herbaceous vegetation, which were present in the grazing-excluded sites after 5 years (Casasús *et al.*, 2007). A second experiment was conducted in a natural park in the nearby, where the abandonment of extensive grazing of the natural pastures had been identified as a common pattern in many of the existing livestock farms (Riedel *et al.*, 2007). In this second study, sites grazed by sheep or cattle at very low stocking rates and excluded areas were compared. In contrast with the previous study, the observed stocking rates and management regimes were enough to maintain herbage resources but not to prevent shrub encroachment (Riedel *et al.*, 2013). Therefore, further reductions in grazing pressure should be avoided in these conditions, and specific supporting schemes were suggested to promote more intensive livestock utilization of these pastures.

Two study cases will be presented to illustrate how livestock can be used as a tool for landscape management, either by specifically designing new environmentally-targeted production systems, or by adapting management in conventional systems to attain these objectives.

Case 1: Based on studies suggesting that Mediterranean woodlands can sustain a viable beef herd throughout the year with moderate supplementation (Henkin *et al.*, 2005), a pilot study was conducted to check the feasibility of using beef cattle for environmental management in the aforementioned natural park. In a forest area without any pastoral use, a 25-cow Pirenaica beef herd was settled in a 464 ha range, and a management system adapted to natural pastures on offer through the year was designed (i.e. calving in October, weaning in March). The herd grazed forest pastures and dry grassland all year round, on cultivated crops in the winter and summer, and was offered forage supplementation in early lactation. A study of their diets and site preferences throughout the year indicated that the cattle devoted most of their grazing time to grasslands (49%), followed by forage crops (33%) and then browsing shrubs (18%). However, there were large seasonal differences in the selected diets, according both to nutritional requirements and the availability of the different forage resources. For example, fodder crops were highly grazed in the summer, while duration of grazing on browse was higher in the autumn and winter (up to 68% of the diet in January), when other resources were scarce (Casasús *et al.*, 2009). In the medium term, this consumption pattern prevented pasture shrub encroachment. The reproducibility of the system was assessed, as cattle coped with the highly heterogeneous spatial and temporal pasture availability at the expense of large variations in body reserves throughout the year without impairing their technical performance. It was demonstrated that the system was able to provide an adequate economic output and an environmental goal at the same time.

Case 2: It is not uncommon for livestock farming systems to co-exist with other economic activities using, at least partly, the same resources, which may generate some synergies, but also competition. This is the case of some European mountain areas, where tourism and farming activities can interact (García-Martínez *et al.*, 2009), such as in ski stations containing alpine pastures used by livestock during the summer. A study conducted in the surroundings of a Pyrenean ski resort indicated that farming systems were similar to those of other neighbouring areas, except for some practices that reduced the farm workload in the winter to allow more time for tourism-related activities. Farmers were aware of the beneficial effect of the ski station on the valley and that, in turn, it profited from the ecosystem services provided by livestock grazing in summer (Casasús *et al.*, 2014). In an attempt to measure and enhance this mutual benefit, a study was conducted to analyze the spatial and temporal use of pasture by cattle in the ski station. The extent and intensity of grazing differed among vegetation types, due to their pastoral value and geographical location (Casasús *et al.*, 2013). Corrective measures were suggested where needed, involving either a different grazing management or the provision of infrastructures to ensure the most appropriate use of each vegetation type. The objective was to enable optimal livestock performance and avoid non-grazed stubble that would compromise the stability of the snowpack in the winter, strengthening the synergies between the tourism and agricultural activities.

III – Improving the sustainability and resilience of livestock production systems in the southern Mediterranean

In the region, rangelands represent the single largest land use type, covering over two-thirds of the total land area. Historically, the primary use of these rangelands was to provide forage for livestock and wildlife. In the southern part of the Mediterranean the majority of these grazing lands are either state or communally-owned. The significance of land ownership is important in the development of the policies and programs that are urgently needed to minimize the impacts of grazing land management and global climate change. Since the natural resources are in steady deterioration due to numerous anthropogenic and environmental factors, it is best to find alternative options which directly or indirectly minimize their decline and perhaps encourage their rehabilitation. Historically, in the south of the Mediterranean region, the effort to increase food and cash crops, arising from food security concerns, has caused conversion of large areas of rangelands to low input and low output crop production (Dixon *et al*., 2001; Nefzaoui, 2004). A viable strategy to reduce the pressure on the rangelands and overcome widespread feed shortages is to encourage fodder production through including forage legumes into rotations with cereal crops. Intensification of forage production will help farmers grow greater amounts of fodder for the livestock at lower costs and help meet the feed gap.

1. Agro-forestry for sustainable crop-livestock systems in drylands: alley cropping

Alley cropping, also known as intercropping, is an agroforestry system where rows of crops are cultivated alongside rows of trees or shrubs. Alley cropping with barley/saltbush (*Atriplex halimus*) is a common practice in the semi-arid southern Mediterranean region (Ben Salem, 2010). Diversifying the production systems has several benefits that are expressed on various space and time scales, from a short-term increase in crop yield and quality, to longer term agro-ecosystem sustainability, including societal and ecological benefits (Faravani *et al*., 2010).

Generally, forage species are chosen to meet deficiencies in the grazing system based on natural vegetation. The major deficiency in rangeland-based systems is usually the ability of the grazing land to provide either enough quantity or quality of feed to meet the productive needs of the grazing animal. Thus, the selection of species must be according to the objective of the intercropping systems, so that the different species occupy different niches in ecological time and space. In the south of the Mediterranean basin, several native and introduced species have been evaluated. Of particular benefit is the Mediterranean saltbush (*Atriplex halimus*) which alleviates feed shortages that occur during fall and during periods of drought. Alley cropping of barley and Mediterranean saltbush provides not only yield advantages for the barley, but also extra feed from the saltbush for the livestock (Ghassali *et al*., 2011). Alley cropping provides an opportunity to carry significant amounts of feed *in situ* into a period of deficit. However, the integration of these shrub species into existing agronomic practices and grazing systems may prove problematic as constraints such as social acceptance and the long period of establishment (requiring no grazing during the first two years) can significantly reduce the value of the extra dry matter produced leading to more moderate improvements in the system production.

2. Cactus as a multi-purpose species

Opuntia ficus-indica (L.) Mill. (OFI) is a xerophytic cactus species, widely cultivated in arid and semi-arid regions worldwide. OFI have developed phenological, physiological and structural adaptations for growth and survival in arid environments where severe water stress hinders the survival of other plant species. Among these adaptations, the asynchronous reproduction and Crassulacean Acid Metabolism (CAM) metabolism of cacti, which combined with structural adaptations such as succulence, allow them to continue the assimilation of carbon dioxide during long periods of drought reaching acceptable productivity levels even in years of severe drought. Their root characteristics which help avoid wind and water erosion, encourage their growth in degraded areas. The establishment of sustainable production systems based on cactus may contribute to the food security of communities in agriculturally marginalized areas and may led to reductions in soil degradation. Cacti are some of the best plants for the rehabilitation of degraded arid and semi-arid areas because they resist scarce and erratic rainfall and high temperatures and provide valuable animal feed (Nefzaoui *et al*., 2013). The reasons behind the diffusion of cacti include:

- simple cultivation practices required to grow the crop,
- rapid establishment soon after the introduction in a new area,
- ability to grow in harsh conditions characterized by high temperature, lack of water and infertile soils,
- generation of extra income from the much valued fruits, and
- use of cactus pads in human diets and as fodder for the livestock.

Cactus forage has high palatability and digestibility, and reduces the water requirements of animals. However, OFI pads have low crude protein (20 to 50 g/kg DM) and low crude fiber (80 to 150 g/kg DM) contents, and they have high water (800 to 900 g/kg fresh weight) and ash (150 to 250 g/kg DM) contents (Nefzaoui and Ben Salem, 2002). They are rich in readily available carbohydrates and vitamin A, but need to be supplemented with nitrogen. OFI is very useful and cost effective supplement for other poor quality diets, such as for raising sheep and goats on rangelands. The intake of straw from cereal crop residues increases significantly with the increase in cactus in the diet for sheep and goats (Nefzaoui *et al*., 1993). Water scarcity depresses feed intake, digestion, and weight gains of sheep and goats, and therefore, supplying livestock with water during summer and drought periods is crucial in hot arid regions. Therefore, the high water content of cactus is a solution for animal rearing in dry areas. In fact, animals given abundant supplies of cactus cladodes require little or no additional water (Nefzaoui and Ben Salem, 2002) and consume considerably less energy to reach water points.

3. Rangeland rehabilitation using "landscape depressions"

Landscape depressions are broad, often dry basins, or *wadis* (valleys) and gentle landscape lowlands that exhibit localized and unique edaphic and hydrologic properties and elevated vegetation productivity.

These lowlands have the potential to play an important role in the sustainable intensification and diversification of pastoral production and are a favourable environment for biodiversity conservation. This is primarily due to their specific ability to accumulate soil and nutrient deposits throughout the soil profile. These areas present an ideal habitat for production of food (eg. dual purpose cereals) and feed (eg. fodder shrubs) crops. Despite this potential, the current sustainable use of lowlands in the arid and semi-arid rangeland areas is still limited. This is mainly due to the continuous heavy grazing and aggressive agricultural activities (continuous barley cultivation without rotation) which resulted in excessive ecological degradation within these sensitive environments.

A recent study focusing on sustainable development of lowlands demonstrate that if these resources are managed properly (through rotational grazing and allowed to recover without being cultivated), they can provide a valuable source of feed for livestock, especially during the dry season when resources are often limited while preserving the natural resource base. When compared to the farmer practices (continuous grazing), versus improved grazing systems (i.e. rotational grazing), the results were astonishing. The productivity of the protected lowland sites in northern Syria averaged > 2 t/ha/y (Figure 2) and plants density was 28 folds higher in protected compared to the continuously grazed landscape areas (Figure 3). Plant diversity was also higher than that of the continuously grazed depressions (Figure 4) which were colonized and dominated by the invasive and unpalatable species *Peganum harmala* (Figure 2) (Louhaichi *et al*., 2012).

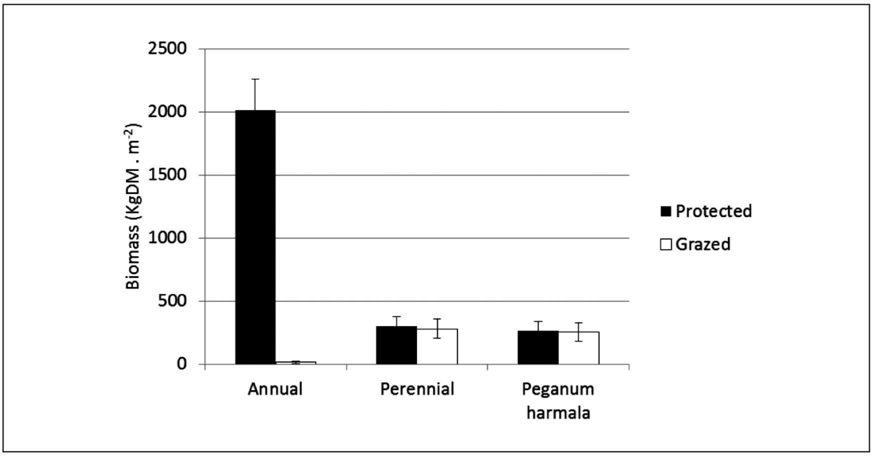

Fig. 2. Biomass production (g DM/m^2) in protected site (light or no grazing for two consecutive years) compared to continuously grazed site. Aleppo Steppe, Syria.

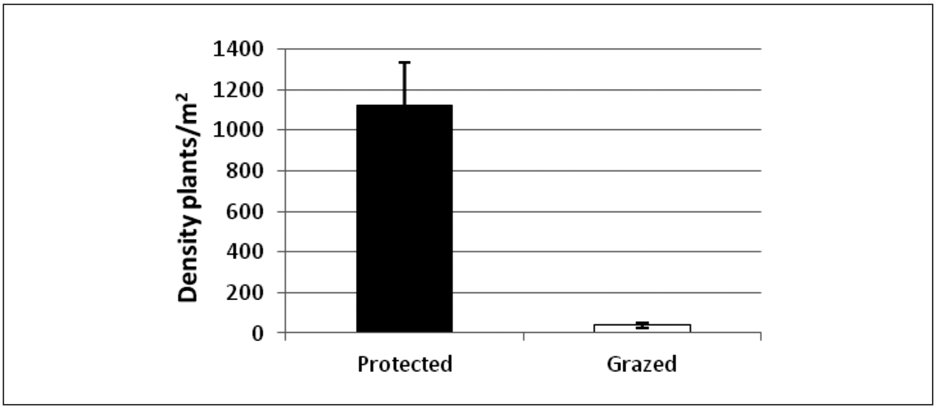

Fig. 3. Differences in density (number of plants m^2) in protected site (light or no grazing for two consecutive years) compared to continuously grazed site. Aleppo Steppe, Syria.

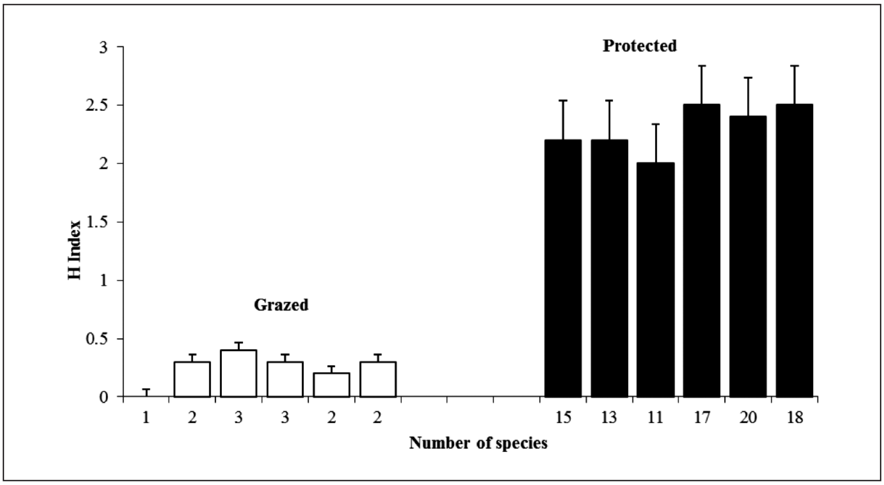

Fig. 4. Shannon diversity index (*H index*) for protected site (light or no grazing for two consecutive years) compared to continuously grazed site. Aleppo Steppe, Syria.

4. Reviving extensive grazing systems

In the Mediterranean area, the livelihood of pastoral and agro-pastoral people depends largely upon the rangelands which are the major feed source for their animals (Louhaichi and Tastad, 2010). Pastoralists, by definition, derive most of their livelihood from raising livestock on natural forages or crop residues, rather than on specifically cultivated and stored fodder or fenced pastures (Sanford, 1983). Pastoral communities have developed traditional knowledge of animal husbandry and natural resource management and this knowledge has allowed them to endure periodic severe droughts on their communally-managed rangelands. In fact, livestock mobility in search of better fodder and water used to be a common practice in the southern and eastern Mediterranean regions. This is mainly due to restrictions imposed by local government, conversion of best rangeland areas to cropland (expansion of cultivation) and also the impact of globalisation on pastoral way of life. The degree of mobility depended on flock/ herd size, and the location of the family or village, as well as the amount of fodder produced in a given year.

The basic management problem for most pastoralists is that there is rarely enough grazing land and water at one location to support the pastoral community. Many factors have resulted in increased pressure on rangeland vegetation leading to widespread rangeland degradation: difficulties in accessing remote places, feeds subsidized by governments (eg. barley grain), barley cropping expanding onto rangelands, recurrent drought, failure to control stock numbers in the pastoral areas, and major shifts in attitudes of pastoralists reflected in increasing interest in educating their children and benefiting from social services provided in towns and villages. Although there are clearly social and ecological challenges for pastoral systems, there are also opportunities to increase productivity and sustainability, while reducing vulnerability to future changes in climate, land use, political and economic factors. Wright (2014) and Louhaichi (2014) highlighted key recommendations to sustain and promote the future of pastoralism in the world's drylands through adaptive measures including:

- Defending livestock corridors to maintain mobility.
- Building infrastructure such as roads, markets, and quarantine stations.
- Developing strategically placed water points for livestock watering to open up underutilized areas for grazing.
- Dissemination of near real-time information about the condition and abundance of forage resources and the availability of crop aftermath/fallow fields would facilitate the migration process and increase efficiencies.
- Developing systems for identification and traceability of livestock.
- Improving animal health care and veterinary services.

IV – Conclusions

Despite the current challenges facing agro-pastoral production systems and the changing climatic conditions of southern and northern Mediterranean regions, ecological intensification and increased resilience can be attained through appropriate and adaptive management practices. Forage legumes will continue to play significant role in sustainable crop-livestock production systems of the Mediterranean region. Introduction of shrubs and cactus as a multi-purpose species in alley cropping system in natural lowlands (wadis) in southern areas could help agro pastoralists better manage livestock feeding throughout the year, improve the natural resources and maximize their net income. More targeted rangeland rehabilitation activities, in particular the improvement of the "landscape depressions", may provide more rapid solutions for feed shortages. The adjustment of flock management to successfully match local environmental and feeding conditions with livestock requirements may improve the efficiency of agro-pastoral production systems. Livestock as a tool of managing the environment may help improving the productivity of fodder resources and their seasonal availabilities in northern Mediterranean areas.

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Multiple services provided at territory scale from Mountain and Mediterranean livestock systems

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Abstract. We propose a grid of services at territory scale from livestock systems, combining the framework of the multifunctionality of agriculture and of the ecosystem services. The grid is divided in three concerns: social, environmental and food security. For the social concerns, three main services are provided: employment, alleviation of families' vulnerability, identity and social cohesion. For the environmental concerns, three services are also distinguished: first maintaining the domestic biodiversity, then through the sustainable use of grasslands and rangelands, the ecosystem services of those spaces may be mediated, such as water purification or carbon sequestration; finally livestock system mediated the cultural service of aesthetic value of landscape. This grid is tested on a local case study in a territory of Mediterranean mountain in South of France. From interviews with various actors of a territory, the roles of the livestock cited by stakeholders may be linked to the services enumerated in the grid. If some services are not required, a bundle of services is pointed, with the role "maintaining open lands" (linked to aesthetic value of landscape, prevention of forest fires, habitat for wildlife) coupled to the role "contribute to farm incomes" (linked to employment and local development. A discussion, based on the common attributes of the territories of Mediterranean and Mountain areas, and on the diversity of socio-economic contexts, illustrate others services in counterpoint of the case study.

Keywords. Livestock system – Territory – Multifunctionality – Services – Ecosystem.

Les multiples services rendus à l'échelle du territoire par les systèmes d'élevage méditerranéens et montagnards

Résumé. *Nous proposons une grille de lecture des services rendus par l'élevage à l'échelle du territoire, en combinant les cadres d'analyse de la multifonctionnalité et des services écosystémiques. La grille est divisée selon trois préoccupations : sociales, environnementales, sécurité alimentaire. Pour les préoccupations sociales, trois principaux services sont rendus : l'emploi, la réduction de la vulnérabilité des familles, l'identité territoriale et la cohésion sociale. Pour les préoccupations environnemtales, trois grands services sont aussi distingués : le maintien de la biodiversité domestique ; l'utilisation durable des prairies et des parcours permettant de moduler les services de support et de régulation de ces espaces, comme la filtration de l'eau ou la séquestration du carbone ; enfin l'élevage contribue à la valeur esthétique du paysage. Cette grille est testée sur une étude de cas, dans un territoire de montagnes méditerranéennes du Sud de la France. A partir d'interviews avec une variété d'acteurs du territoire, les rôles de l'élevage cités peuvent être reliés aux services identifiés dans la grille. Si certains services ne sont pas attendus, un bouquet de services est mis en avant, avec le rôle « Maintien de milieux ouverts » (lié aux services de valeur esthétique du paysage, de prévention des feux de forêt et de maintien d'habitats pour la biodiversité remarquable) couplé au rôle « Contribuer aux revenus des familles agricoles » (lié aux services d'emploi et de développement local). Une discussion, à partir d'attributs communs aux territoires de montagne et de la Méditerranée et de la diversité des contextes socio-économiques de ces territoires, permet d'illustrer d'autres services en contrepoint de l'étude de cas.*

Mots-clés. *Système d'élevage – Territoire – Multifonctionnalité – Services – Ecosystème.*

I – Introduction

Livestock is an important economic sector in Mountain and Mediterranean areas, generally since a long time. Beyond the delivery of animal commodities (meat, milk…), livestock farming systems are known for providing multiples services at territory scale. Manoli *et al.* (2011) distinguish two kinds of approaches in order to characterize the relationships between livestock and territories: i) analysing connection between livestock activities and the stakes about land use and natural resources and ii) understanding links between diversity of livestock systems and pathways to local development. Ryschawy *et al*. (2013) assess the multiple services provided by livestock at the scale of the French territory, with four categories of services (production, vitality, environmental quality, cultural identity and heritage), identified with research and extension services experts and with farmers. In this participatory approach, the services identified are linked to the French context. Two main scientific frameworks are the base of the various categorisations of services: the multifunctionality of agriculture (MFA) from economics (Madureira *et al*., 2007), and ecosystem services (ES) from conservation biology (Virherrvara *et al.,* 2010).

The purpose of this communication is to propose a generic grid of services at territory scale from livestock systems. We build this proposition from the definitions of livestock systems and territory and the examination of the two frameworks (MFA and ES). We test the grid on a case study in a territory of Mediterranean mountain in South of France. We define then some common attributes of the territories in Mediterranean and Mountain areas and propose first elements of discussion about bundles of services in contrasted territories.

II – A grid of services at territory scale from livestock systems

1. Livestock system and territory: some definitions

A. Livestock Farming System as a multi-scale model

A livestock farming system is a conceptual model of the whole livestock farm. It represents a duality between the view of a farm as a human activity system, with a farm family seeking to satisfy specific objectives, and the view of a farm as a production process, with transformation of physical inputs to physical outputs (Gibon *et al*., 1999). The practices are a key component which links those two views of livestock farming systems. The practises are the result of the decision-making in farm family, through the perception of its context, and they drive the production process. We distinguish five categories of practices (fig. 1, from Moulin and Bocquier, 2005).

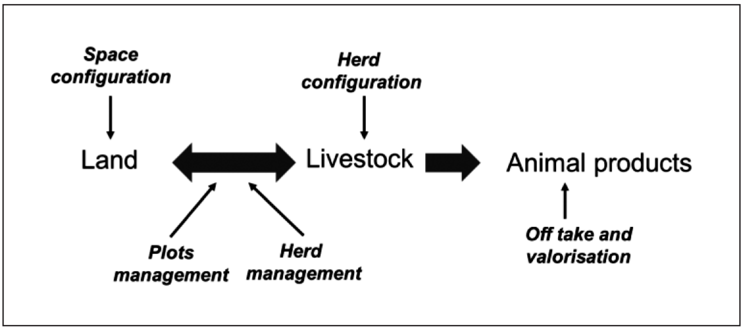


Fig. 1. Practises of livestock farm families.

First, along the years, the farm family configures the herd (choice of species and breeds, culling and replacement, etc.). It also configures the farmland: acquiring or relinquishing of land areas, creating equipment or buildings (fencing, trails, water point, shed,…) and rehabilitation of some plots (stone removal, bush clearance…). Then, throughout an annual cycle, the family farm operates the system. It links the herd and the farmland through rearing practises (breeding, feeding…) and land use practises (assigning a crop to a plot or a batch to a pen). It also collects the outputs of the herd, and markets animal products, eventually after processing.

The concept of livestock system may also be used at other spatial scales, from a plot where interact vegetation, flock and shepherd to a large area, with a geographic space, population of domestic animals, and a human society (Bourbouze, 1988). In that last case, the notion of farmland may be generalized to the notion of territory.

B. The territory as a system

Territory is usually taken to refer to a portion of geographic space that is claimed or occupied by a person or group of persons or by an institution. We chose to highlight the definition proposed by Moine (2006), in geography, because it is consistent with the above definition of livestock farming system. In his definition, the territory presents a dual nature: the material reality of the geographic space, in one hand, and a symbolic or ideational nature, in another hand, linked with the representation systems driving the human societies in the understanding of their environment. So, he defines the territory as a system, with three sub-systems: (i) the geographic space, claimed and planned by human beings, as the support of interacting components, such as ecosystems and institutions; (ii) the system of representation of the space, as filters influencing decision-making of actors and iii) the system of actors who act, conscientiously or non- conscientiously, upon the geographic space.

As a system, a territory is an intellectual construction, changing and fuzzy. In the same space, several territories may overlap or be nested. In relation with livestock activity, the geographic space used by a set of farms providing goods, in a contractual way, to a down-stream operator (cooperative or private) may be considered as a territory. The collecting basins of several operators of the animal commodity chains may overlap and a farmer may be part of several economic organisations for the selling of his different products (milk, meat). Those geographic spaces are also part of nested administrative and politic territories (rural community, program region, member state, European Union, for instance). Finally, they also may be part of the territories of environmental programs (Natura 2000) or institutions (National Park, nature reserve…).

So, the livestock services at territory scale would certainly be differently appreciated, according to the considered territory.

2. Multiple services: what about multifunctionality and service of the ecosystems?

A. The framework of multifunctionality of agriculture (MFA)

Multifunctionality refers to the fact that an economic activity may have multiple outputs and may contribute to several societal objectives at once. Multifunctionality is thus an activity-oriented concept that refers to specific properties of the production process and its multiple outputs. If the notion is not new, the term is. It appears in the European context in 1997 and has been used in the discussion of the negotiation agenda of the World Trade Organization (WTO) at Doha in 2001 (Guyomard, 2004). The primary production sector, such as livestock sector, is considered having a main function of production, and related joint production, including material and non-tangible goods. Multifunctionality of agriculture has been promoted through agricultural policies in some region (Europe, Asia), supporting functions, beyond commodity production, for agricultural landscapes (Lovell *et al*., 2010). The list of the multiple non-marketed outputs and their classification are not stabilised, depending of each countries, in the international trade negotiations (Guyomard, 2004). Because they have distinct public characteristics, Vatn (2001) distinguishes (i) environmental aspects, with landscape, cultural heritage, pollution; (ii) food security, (iii) food safety and (iv) rural concerns (rural settlement, local economic activity). Guyomard (2004) refers to five functions of agriculture: (i) production of marketed goods, (ii) social function of maintenance of employment, (iii) territorial and social function of rural settlement, (iv) environmental function of resources preservation and (v) food security.

We propose a simplified classification with three items: social, environmental and food security concerns. We do not introduce a category of production of marketed goods, considering that this production of private goods is not a service at the territory scale. On the contrary, the delivery of services within the three concerns corresponds to public goods. Of course, the production and the selling of meat, milk, and so on, allow providing services, such as incomes and employment (social concerns) or food security. We chose the term of concern, following Vatn (2001), in order to avoid the confusion linked to the polysemy of the term function. In the framework of the multifunctionality of agriculture, the function is the role of agriculture in production of private or public goods. In the field of ecology, the notion of function relates to the structures and processes underpinning the potentiality for an ecosystem to deliver one service (Lamarque *et al*., 2011).

B. The framework of the ecosystems services (ES)

Firstly developed in the field of the nature conservation during the 1990s, the notion of ecosystem services (ES) is a new way of framing the relationships between biodiversity, ecosystems and human well-being. This framework spreads through several scientific disciplines (Virherrvara *et al*, 2010) then into policy and business circles (Lamarque *et al*., 2011).

The Millennium Ecosystem Assessment (2005) grouped the ecosystem services into four categories:

- Supporting services are necessary for the production of all other ecosystem services, such as primary production, nutrient cycling and soil formation
- Regulating services, such air quality maintenance, water purification, erosion control, climate regulation, regulation of human diseases,
- Provisioning services, such as food, fibre, fuel, fresh water and genetic resources

Cultural services are the nonmaterial benefits people obtain through reflection, recreation and aesthetic experiences.

In their study, Virherrvara *et al*., 2010 notice some discrepancies between this classification and those used in the scientific papers they reviewed. They stress in particular the fuzzy position of concepts such as biodiversity maintenance and habitat provisioning, difficult to assign to any particular ecosystem service category. Considering livestock activity, we will classify the domestic biodiversity as a supporting services as well the capacity of livestock to maintain particular habitats for wildlife.

As crop and rangelands covered a third of the Earth's land area, we have to consider the relationship between farming and ecosystem services (Zhang *et al*., 2007). In the context of integration of ecosystem services with farming, Bommarco *et al*. (2013) pointed the distinction between services as extracted goods and benefits (provisioning and cultural services, or final services), or as underpinning processes (supporting and regulation services, or intermediate services). In that way, agricultural ecosystems rely on a suite of intermediate services to provide food, fibre and fuel as well a range of non-marketed ecosystems services (Swinton *et al*., 2007). In that definition, we find the function of production of marketed goods and the delivery of non-marketed outputs, as in the previous framework of multifunctionality. So it seems interesting to integrate those two frameworks, introducing in the MFA framework the concept of intermediate and final services.

Dale and Polasky (2007) stressed the relationship between agriculture and ecosystem services as the contribution of various agricultural practises to the range of ecosystem services. This last point seems very useful when speaking of the services of livestock systems. We propose to distinguish: i) services directly provided by livestock ecosystems, such as domestic biodiversity, and ii) the way of managing livestock through practises which mediate the delivery of ecosystem services. For example, the way of managing livestock in a territory contributes, with others processes, to the building of the landscape. According to the domestic animal species used and the grazing practices at several scales of time and space, the impacts on the landscape and his aesthetic value (cultural services from the ecosystems with domestic livestock) may be very different. When speaking of livestock services, then we have to consider the way of doing livestock farming.

4. Proposition of a grid of livestock services

We propose to integrate those two frameworks (MFA and ES), in a unique grid, and to specify the services of the livestock activity considered as embedded in an agro ecosystem with domestic animals. Livestock systems provides commodities**,** such like goods (food, fibre; manure…) and services (animal draught, for transport, cultivation or leisure). They correspond to the market function of the livestock activity (MFA) and to provision services of the ecosystem (ES). As they are private, we do not consider them as a service of livestock systems at territory scale. We organise the grid with three categories, corresponding to the delivery of non-marketed outputs or services, as defined through the MFA framework.

Considering the **social concerns**, ***employment*** is the first service of livestock systems, delivering livelihoods to rural families. Economic activities of those farm families allows the activities in other sectors (indirect employment), related to services up-stream and down-stream of livestock farms, but also in health, educative, or trading sectors. So livestock activity contributes to the ***local development*** and the ***maintenance of rural settlements*** in the territory. But husbandry do not only provides incomes. In countries where public institutions do not deliver sufficient social services to protect individuals (illness, unemployment, pension), the stock of animal is an important asset (Siegmund-Schultze *et al*., 2011) for the ***alleviation of the vulnerability of rural families*** and for the support of solidarities between families (Manoli *et al*., 2014). The livestock systems may also contribute to the ***cultural identities*** in a territory, reinforcing social relationships. Those identities may be supported by animals and their products, as a patrimony of the territory. Animals may be involved in religious or socio-cultural practices: ceremonies with ritual slaughter (Brisebarre, 1998) or games (Saumade, 1998). The animal products, with specification linked with local knowledge about processing, participate also to the identities of the territories. The local trade of those animal products, especially through direct selling from farmers to consumers; is also a way to participate to the ***social cohesion*** in the territory.

For the **environmental concerns**, we propose to refer to the ES framework. As a part of the ecosystem, livestock contribute to the nutrient cycling. Focusing on this component of the ecosystem, primary production and oxygen are the inputs. The outputs are food (living animal for meat, milk…), dejections (faeces and urine), and losses, especially gas (dioxide of carbon, methane....). Through the mobility of the livestock along the day and the season, and the transport by farmer of biomass (feed, manure…), various parts of several ecosystems are linked, such as rangelands of spontaneous vegetation and cultivated lands. Livestock activity provides directly ***domestic biodiversity*** at species and breeds levels. By the ***use of rangelands and grasslands***, part of natural or cultivated ecosystems for those last, livestock activity mediate the ***supporting and regulation services*** linked to those lands, such carbon sequestration (climate regulation)

(Sousanna *et al*., 2010) or water purification (MacLeod and Ferrier, 2011), habitat for wildlife (Havstad *et al*., 2007)… The presence of livestock is necessary for maintaining those types of lands. But, as mentioned above, this condition is not sufficient. The maintaining of grasslands will depends on feeding system and the balance between the use of grass (grazed or stored) and of annual forage crop, such like maize. The ecosystem services delivered by grasslands also depend on the couple "nitrogen fertilisation x stocking rate". A moderate intensification of the grassland may increase simultaneously the outputs of animal products and the supporting and regulation services of grasslands (Lemaire, 2013) The modality of use of rangelands will also be determinant for the renewal of the potential of grazed resources (Jouven *et al*., 2010) and maintaining the habitats for wildlife. Finally, livestock activity participates to the building of the aesthetic value of the ***landscape.*** The husbandry directly provides this ***cultural service*** because the livestock, pastoral equipment…, are constitutive of the landscape. It also mediates this ecosystem service, according to the mosaic of lands used and connected by livestock.

The **concerns about food security** (MFA framework) rely of course on the capacity of livestock systems to provide food (proteins) of good quality and safe, for urban consumers, but also to provide income to farm families in order to buy foods on markets. So livestock contributes to the availability of food (for all consumers, especially urban consumers) and to the accessibility to food (self-consumption and incomes to buy others foods, for rural families) (FAO, 2011). Livestock, through supporting and regulation services in mixed farming systems, also contribute to crop production and food security.

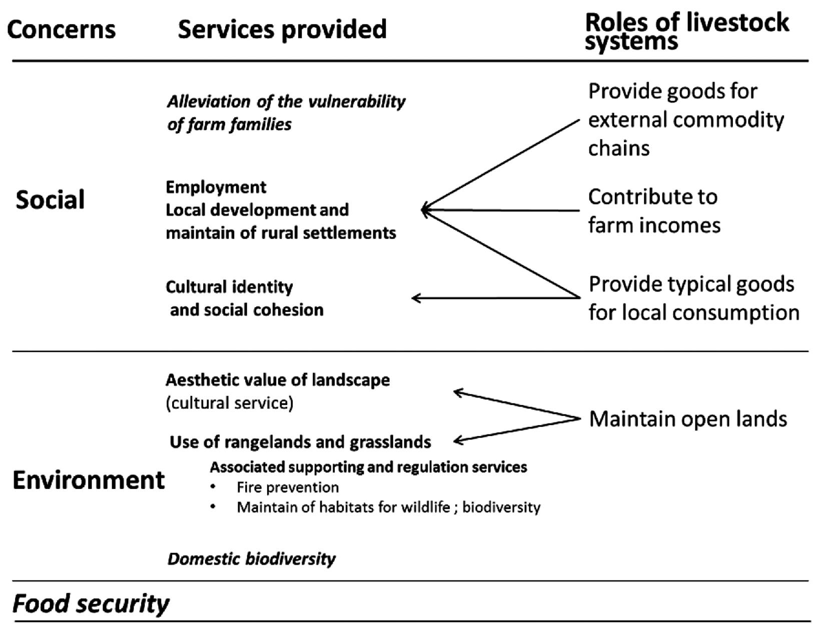
III – A case study in a territory of Mediterranean mountain

The case study takes place in the Languedoc-Roussillon program region in South of France. In this Mediterranean area, we focus on inner areas of mountains (*Cévennes*) and high calcareous plateaux (*Causses*).

1. Identifying the roles of livestock systems from interviews with actors

We conducted 21 interviews with territorial actors from various worlds (livestock commodity chains, agricultural sectors, other rural activities, local communities and natural parks). Then, we identified their perceptions about the changes of the livestock activities in the territory and the expectations about livestock systems, in, a form of items. We aggregate the items cited in a list of five roles expected from livestock activities. We choose the term of role because several services could be delivered by the way of a role. In the same time, a service could be provided by the mean of several roles. Thereby, the role of livestock systems is a mean, while the service is a goal. By the analysis of the contexts in which the roles are expressed in the interviews, we link (fig. 2) the roles and the services that we had listed in our theoretical grid (see above). Thus, those relationships are expressed from the points of view of the actors. We have an analysis in terms of the sub-system of representation of the space, as filters influencing decision-making of actors proposed by Moine (2006, see II.1.B).

The fig. 2 shows that the concern of food security is not a service expected by actors, even if the local livestock systems provides goods and incomes, participating to food security of rural and urban areas. It is not a stake for this territory. As well, alleviation of the vulnerability of families is not an expected service from livestock, because of the other mechanisms of social protection provided by institutions in France. Finally, even if some sheep breeds originated from this region (such the *Raïole* or the *Caussenarde*), the conservation of the domestic biodiversity has not been identified, in that sample of actors, as an expected service from livestock systems.



In italic: concern and services not cited by the actors

Fig. 2. Grid of the services provided by livestock systems and the roles cited by 21 actors of the territory *Causses and Cévennes* (Languedoc-Rousillon, France, year 2012).

2. The roles and the services from livestock systems in the territory of *Causses and Cévennes*

A. The roles and the services in the field of environmental concerns

The table 1 show that the role "*Maintain of open lands*" is the most cited (67p.100 of the actors of the sample). This role is clearly linked with the cultural service of aesthetic value of landscapes, delivered by the various ecosystems in the territory. The grazing of rangelands in order to maintain open landscape is clearly a stake for the actors. Ruminant grazing mediates, with others processes, this aesthetic value. We could notice that livestock in itself, and the presence of patrimonial building linked to agropastoral activities are not cited. The focus is made on the maintenance of open landscape.

Of course, the role "*Maintain of open lands*" is also linked with the expected services of use of grasslands and rangeland and the associated ecosystem services. For instance, in the *Cévennes*, rangelands (non-included forests which are grazed) and grasslands represented 80% of the utilised agricultural lands in 2010. Two associated services are pointed. The first is the prevention of fire, which is an important risk for Mediterranean forests. The grazing under forests prevents the accumulation of herbaceous dry matters in summer, risk factor of spreading of a start of fire. The maintenance of firebreaks by the livestock grazing is also expected. The maintenance of open lands is also a mean to preserve specific habitats for wildlife and conservation of natural biodiversity. This service is expected by actors of the preservation of the nature (parks for instance) but also by hunting federations, attached to little games linked to open lands. The other intermediates services of grasslands and rangelands, such carbon sequestration (and mitigation of climate change); soil formation and regulation (erosion), water purification, are not cited by actors. It seems that there is no stakes perceived by the actors of this territory, about the resources (air, water, soil, and climate), in relation with livestock. Climate change is rather expressed as a factor impacting the livestock systems (dry years of the 2000'). The role of ruminants in GHG emission and the role of rangelands and grasslands in carbon sequestration, corresponding to a global stake, are not expressed (even if public policies incite to a reflexion, such as "climate plan" for the Regional Natural Park).

Table 1. The roles of the livestock systems cited by 21 actors of the territory *Causses and Cévennes* (Languedoc-Rousillon, France, year 2012)

	CC	Ag	RA	LC	Total	p. 100
Number of interviews	*6*	*7*	*4*	*4*	*21*	*100*
Provide goods for external commodity chains	3				3	14
Contribute to farm incomes	1	2		2	5	24
Provide typical goods for local consumption	2	2	1		5	24
Maintain open lands	1	6	3	4	13	67

CC : Commodity Chains operators and advisors

Ag : Agricultural services and professional representatives of agricultural sectors

RA : Services and representatives of others Rural Activities (forestry, hunting, tourism)

LC : political representatives of Local Communities and services of natural parks

TThe role of "*Maintenance of open lands*", and the multiples services linked, is expressed by the majority of the actors (87 p.100) of the categories "Agriculture" (Ag), "other Rural Activities" (RA) or "Local communities and Parks". The livestock farmer representatives express also this point of view. This could be explained by the fact that in the territory, a large amount of the incomes came from the Common Agriculture Policy subsidies: 50% to 70% for various ruminants systems, with a large amount –45% to 60%– linked to the second pillar and Territorial Agro-Environmental measures contracted by farmers.

Obviously, only one of the 6 actors of the animal commodity chains cite the role of maintain of open lands, the main service they expected from the livestock systems being the delivering of animal goods.

B. The roles and the services in the field of social concerns

The role "*Provide typical goods*" (goat and ewe cheeses, beef meat from heifers…, with distinctions of origin and process), is a way to build the local identity. Those typical goods are often linked with a regional consumption of livestock products; with short trade chains (direct selling from farmers to consumers, or short chain with traditional butchery) is also a mean to reinforce social cohesion and local development. Indeed, those typical products participate to the attraction of the territory for rural tourism and hence they support local development.

The livestock systems "*contribute to the farm family incomes*", through the marketed goods but also subsidies from PAC (see above). Thus, livestock systems maintain direct agricultural employment, and support indirect employment in upstream and downstream of farms (slaughterhouses for instance, in the territory, allowing the short trade chains in meat industry) and general trade and services in rural area.

Finally, the livestock systems “*provide goods for external commodity chains*“. Indeed, some operators of the sheep industry, located in neighboured regions (mainly Midi-Pyrénées) are looking for lambs in the territory for providing the national French market (111,000 lambs, a third of the regional production, are sold to operators outside the Languedoc-Roussillon region, Nozières *et al*., 2013). This market is characterized by a decreasing delivery of French lambs (less than 50% of national consumption) and the operators of MP collect lambs in a large basin, in order to keep their positions on the national market and preserve theirs activities (fattening lots, slaughterhouse…). This role of the sheep farming systems of the territory is a way to maintain employment in other territories, expressed by neighbouring operators, part of the actors’ system of *Causses* and *Cévennes*. This is a good illustration of the nested territories mentioned above (II.1.B).

C. *Livestock multifunctionality in the* **Causses** *and* **Cévennes** *territory?*

At the scale of the actor system described through this sample, the multifunctionality of livestock industry is a reality, even if all the potential services are not expected by the actors, or at least not expressed at the time of this case study. Nevertheless, if we examine the roles cited by each actor, we have another vision: 15 actors (upon 21) cite only one role. For 9 of these actors, they only mention the role of “*Maintain open lands*” (Ag, RA or LC actors). When they mention other roles (such as “*provide goods*”), there is an evident relation with the sector they represent. When 2 roles are expressed by an actor, the main couple is “*Maintain open lands*” x “*Contribute to farms income*”, for 4 actors (2 Ag and 2 LC). The last two actors coupled “*Maintain open lands*” with “*Provide typical goods for local consumption*” or “*Contribute to farms income*” with “*Provides goods for external commodity chain*”.

Some recent studies point the importance to consider the relationships between services, in terms of bundles of services (Raudsepp-Herne *et al*., 2010). We have to stress the relationship between the environmental role “*Maintain open lands*” and the services in the field of social concerns. This bundle of environmental and social services is expressed by actors from different worlds: from agricultural sector, local communities and natural parks representatives. Those two roles are here viewed as synergic, in a context of extensive pastoral livestock systems, with a low global stocking rate (0.07 UGB / ha of total space, from RGA, 2010), where livestock industry is perceived as the last agricultural activity before the wilderness, with spreading of forests.

Nevertheless, if we could notice a large consensus upon this expected role of “*Maintain of open lands”*, there are some divergences, between actors, about the capacity of livestock systems to achieve this role. The economic viability of farms is a first issue, allowing maintain of a sufficient global stocking rate in the territory. But a second issue is about the feeding practices, especially the place and the modalities of grazing: balance between stored forage and grazing, shepherding or free grazing in pens… We point here the difference between a general expectation for the livestock systems and the husbandry practices, which mediate the capacity of the livestock systems to deliver those services. Some actors, who support environmental stakes, cite negatively the spread of arable lands, to the detriment of lands with spontaneous vegetation. Those new arable lands are dedicated to cultivated grasslands for securing storage of forage increasing the feeding autonomy of farms: + 569 ha of new arable lands from 2000 to 2010, for instance in *Cévennes*, with an increase of 807 ha of cultivated grasslands, *i.e.* 25% in ten years). Nevertheless the cultivated grasslands still represent a small part (8%) of the grasslands and rangelands (RGA, 2010). Another example of divergence may be stressed, about the expected models of farms. If some actors (CC, Ag, and LC) cite the interest of a diversity of livestock systems, others defend a unique model of farm, with small size, organic farming, direct selling and less dependency from the CAP subsidies.

IV – Illustration of bundles of services for territories in Mediterranean and Mountain areas

We are now going to have a more general view of the services at territory scale of livestock systems, as counterpoint of the previous case study. Facing the diversity of the territories in Mediterranean and Mountain areas, we propose to start from some main common attributes of those territories, and to illustrate some services at territory and their relationships. Then, we take in account the various socio-economic contexts of the considered territories.

1. Rangelands and grasslands: a common attribute, but contrasted situations

The huge space of spontaneous vegetation is a common attribute of the territories from Mediterranean and Mountain areas. This space is shared between forest ecosystems and rangelands. Of course, cultivated lands also exist, in some favourable parts of the territories (Mediterranean plains, valley bottoms in mountain areas). We find here the classic distinction of space in the Mediterranean agrarian system with the *ager*, the *saltus* and the *sylva*. Livestock mobility for grazing is a requirement for the use of those rangelands, with the classic figure of the shepherd.

Biophysical conditions are contrasted along the year, with periods of null growth of the vegetation (winter in mountains and summer in Mediterranean plains). Livestock sector has to invest in shed and storage of feed for long winter (Mountain) or to develop irrigation, especially in Mediterranean plains, in order to grow green forage for summer, like alfalfa or maize. Livestock mobility to long distance, the altitudinal transhumance, is also a classic manner to feed the livestock within complementary spaces in terms of seasonality of primary production.

The presence of rangelands, disappeared in other territories, such temperate plains, is linked to the climatic and geomorphological conditions and the long tradition of livestock activities in those regions. Indeed, those spaces present interesting resources for livestock, especially alpine grasslands in high mountains, above the forest, or crop residues from pluvial cultivated lands and annual forage from irrigated lands in Mediterranean plain.

Concerning the environmental concerns, the use of rangelands and grasslands is one of the main expected services from livestock systems. In mountains areas of developed countries, agriculture is no longer the main economic activity in the territory. Livestock activities have decreased since mid-twentieth century, with the spread of forests. Cocca *et al.* (2012), demonstrate that, in a mountain area of the eastern Italian Alps, the loss of agricultural areas in 69 municipalities was primarily counterbalanced by the maintenance of livestock farming, especially extensive systems. They concluded that efforts are needed to maintain a territorial network of traditional extensive farms to avoid further landscape deterioration in Alpine areas. On the contrary, Navarro and Pereira (2012) argue that current policies to maintain extensive farming landscapes underestimate the human labour needed to sustain these landscapes. They examine the potential benefits for ecosystems and people from rewilding. In the remote areas of developed countries, with an issue of abandonment of farmlands, maintaining the use of meadows and pastures by extensive livestock systems may be controversial. Nevertheless, examining this issue, it is a necessity to consider all the services, in addition of those delivered by grasslands and rangelands, i.e. cultural services (landscape) and social services (identity).

In other territories, like the steppe areas in Maghreb, the situation of the rangelands is completely different. Farming is a strategic livelihood for most of the rural families. A frequent overstocking on the steppe is described (Nasr *et al*., 2000); Several drivers explain a shift from pastoral to agropastoral systems, relying on concentrate rather than grass, the increasing of the number of animals and the degradation of rangelands (Bourbouze, 2000). The stake is here to maintain livestock as livelihoods (social and food security concerns) and a sustainable land use, in a fragile environment (with balance between cultivated land –and new strategies of animal feeding– and space with spontaneous vegetation).

2. Mediterranean and Mountain territories: an old cultural heritage

The Mediterranean basin and some Mountains in the world are very old areas of human settlement (with often a function of refuge area for mountains, even if livelihoods are not so easy). Those territories have been the birthplace of some civilisations, with important cultural heritage (Inca Empire in the Andean mountains, Antique Greek civilisation…).

The domestication of livestock is one of the heritance from those ancient human settlements. In the Fertile Crescent, farmers domesticated various species like cattle, sheep, goat, pig that have spread worldwide. Some mountain areas are also the birthplace of domestic animal species, specialised to the mountain conditions (Andean camelids, Yak). Those domesticated species evolved in numbers of breeds. Conservation of this domestic biodiversity could be difficult, facing the spreading of a little number of improved breeds. Livestock activities relying on those breeds are a manner to keep this domestic biodiversity.

Touristic attractiveness of the territories relies on several assets. The first assets are indeed the landscapes and the cultural patrimony. Livestock contribute to those landscapes and to a part of the rural built patrimony. For instance, the cultural landscape of the agropastoralism of *Causses* and *Cévennes* has been recently recognized as a world patrimony by the UNESCO. The landscape and its multiple attributes (categories of rangelands, trails for transhumance, sheep bridge, cheese cellars…) are an asset for rural tourism (Rafqi, 2013). This cultural landscape may evolve. It is not a fixed conception of patrimony. But maintaining this patrimony alive relies on the capacity of livestock systems to keep on building an agropastoral landscape. Another important asset for tourism activity is the snow and the development of winter tourism in mountains and sea and the seaside tourism of the Mediterranean basin. Livestock activities could take advantage of touristic frequentation, but they also contribute to the identity of the territory and reinforce its touristic attractiveness. The relationship between typical animal products and local breeds, through specifications like those of some protected designation of origin (PDO) in Europe, may be a synergic process for this reinforcement (Lambert-Derkimba *et al.*, 2011).

So, the way the livestock mediates the aesthetic value of landscape, a cultural services from ecosystem, is in a strong relationship with social concerns, through the identity of the territory. The sustainable use of rangelands and grasslands is also linked with supporting and regulation services delivered by those lands. The way of grazing and store forage is the unique level that linked those services. We have here a bundle of services, with various balances depending on the socio-economic contexts (remote areas of developed countries *versus* rural areas of North Africa for instance).

3. A wide range of socio-economic contexts

In fact, beyond some common attributes, territories are very diverse, according to the socio-economic context of the countries. The history of the human settlement led to a wide range of population densities between mountains in the world: 5 people / km² in mountain in Norway *versus* 378 for Central High Plateau in Vietnam, for instance (Pasca and Rouby, 2012 ; Gubry, 2000). Inside the Mediterranean basin, there is also a great diversity between littoral plains, with urbanisation and arable lands and potentiality for irrigation, and inner areas of dry mountains or deserts. So, the expected services from livestock systems are necessarily different between contrasted territories.

According to Huddleston and Ataman (2003), 631 millions of human beings live in mountain areas (above 1,000 meters) in Asia, Pacific, Latin America and Caribbean islands, Africa, and Near-

East (against only 56 millions of mountaineers in developed countries). 70% of this population relies on solely livestock or on mixed farming systems. Food security is thus an important stake for those families. Social concerns, with incomes, alleviation of family vulnerability are also components of the bundles of expected services from livestock. The stake is to ensure livelihoods for rural populations in their territories, and limit the urban population growth by immigration. But livestock products from a given territory also participate, through markets, to the national food security. The comparative analysis between the countries of Maghreb is there very illustrative of the various policies and the role assigned to domestic production for food security. Algeria relied on the export of petrol and gas to import dairy products from international market, in complement of a “modern sector” of intensive dairy production in state farms (Djermoun and Chehat, 2012). The service of food security was not expected from the local livestock systems and these have been neglected (Bourbouze *et al*., 1989). The relationships between Agriculture and Food have been the focus of a social debate in the 80’. The dependency from international market was regarded has a scandal by the consumers and the financial experts (Chaulet, 1991). The level of self-sufficiency was indeed very low for milk (30% in 1981-1985), but the level of consumption pretty high (140 l/year/capita for the same period, Djermoun and Chehat, 2012). In the same times, with different assets, Morocco chose another way. A national dairy plan has been implemented, with taxation of imported milk powder, importation of dairy heifers, development of various dairy livestock systems and dairy industries. Livestock industry has to ensure food security. But the price of milk was rather high for the consumers, and the consumption stay at low level, with 38 liters/year/capita in 2000 (Sraïri *et al*., 2007).

V – Conclusions

The test on a local case study shows the consistence of the proposed grid. Its generic nature allows separating potential services from livestock at territory scale and the expected services for the local stakeholders. The identification of the system of actors is an important issue. It is not evident, because of the nested nature of territories and overlapping of territories according the stakeholders. The analysis of the case study thus pointed the potential services that are not today included in the system of representation of the actors (such as the regulating services of carbon sequestration by rangelands). The distinction between “role” of livestock, related to expression from the discourse of actors, and services identified from scientific framework seems useful. It is a way to identify the lever by which husbandry practices and results of livestock activities provide various services. Finally, the consideration on the way of operating livestock systems is also an important issue, when identifying the expected services of livestock. If final services such as food delivery depends on the presence of livestock farms in the territory, the services related to social, environmental and food security concerns relies on the balance of the various livestock systems and their distribution in the geographic space of the territory.

The bundles of services from livestock closely depend on the context of the territories. For instance, the services of alleviation of the rural families vulnerability is not a stake for livestock systems in developed countries, while they are crucial in others countries. So, it is difficult to have a general view of bundles of services for Mediterranean and Mountain livestock systems. A comparative approach of several study cases would be a pertinent perspective, in order to identify bundles of services and their relationships with local context.

Finally, the research has to assess those bundles of services provided by livestock from an exhaustive point of view (with no limitation to the services expected by the system of actors). It is a way to evolve the local system of representations, the filters by which actors make their decision. The definition of indicators for quantifying those services is there another important issue for research.

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Session 3

Combining and reconciling services on farming system and landscape scales

Oral presentations articles

Mountainous grasslands sustaining traditional livestock systems: The economic performance of sheep and goat transhumance in Greece

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Abstract. This study presents the economic performance of transhumant farms, by taking into account two crucial factors: farm size and environmental impact. The analysis is based on technical end economic data from a sample of 121 transhumant farms from Greece which move towards a wide range of summer pasturelands. The farms were grouped according to number of reared animals, thus formulating three groups: <350 animals, 351-600 animals and >600 animals. Economic results and technical and economic indicators have been calculated for each group in order to investigate potential differences stemming from farm size. There are two main findings from the analysis, the first relating to the role of farm size in the economic performance and the second to interactions between economic performance and environmental protection. Indeed, the relationship between transhumance and the environment is two-fold: transhumant flocks contribute to the protection of natural mountainous grasslands and the use of these grasslands becomes an important factor in sustaining their economic viability.

Keywords. Mountainous grasslands – Transhumant sheep and goat – Technical and economic indicators.

Les prairies montagneuses pour soutenir les systèmes d'élevage traditionnels: performance économique des systèmes ovins et caprins transhumants en Grèce

Résumé. *Cette étude présente la performance économique des exploitations transhumantes, en tenant compte de deux facteurs essentiels: la taille des troupeaux et l'impact environnemental. L'analyse est basée sur des données économiques et techniques recueillies via une enquête auprès de 121 exploitations transhumantes Grecques où les troupeaux sont déplacés vers une diversité de pâturages estivaux. Les fermes ont été regroupées en fonction du nombre d'animaux, pour former trois groupes: <350 animaux, 351 à 600 animaux et >600 animaux. Des indicateurs économiques et techniques ont été calculés pour chaque groupe afin d'enquêter sur les différences potentielles découlant de la taille des exploitations. L'analyse produit deux principales conclusions ; la première portant sur le rôle de la taille des exploitations dans la performance économique et la seconde sur les interactions entre la performance économique et la protection de l'environnement. En effet, la relation entre les systèmes transhumants et l'environnement est double : les troupeaux transhumants contribuent à la protection des prairies naturelles de montagne et l'utilisation de ces prairies devient un facteur important dans le maintien de leur viabilité économique.*

Mots-clés. *Prairies de montagne – Transhumance ovine et caprine – Indicateurs économiques et techniques.*

I – Introduction

Transhumant sheep and goat farming in Greece constitutes a multifunctional system, which sustains the livelihood of mountainous communities, as flocks are moved towards mountainous and marginal areas in the summer in order to take advantage of local pasturelands, thus providing employment to farm family members and incomes where jobs in other sectors are not available.

Transhumant animals account for almost 7.5% of the total sheep and goat population in Greece (Laga *et al*., 2012). This study provides a presentation of the economic performance of transhumant farms, by taking into account farm size and environmental impact.

II – Materials and methods

Data for the technical and economic analysis of the transhumant system were gathered through a questionnaire survey in Thessaly, Central Greece. The Region constitutes the center of transhumance in the country, with almost 35% of the reared animals and 30% of transhumant farms (Laga *et al*., 2012).The 121 sampled farms spend the winter in Thessaly, but they are scattered throughout mountainous areas of Northern and Central Greece during the summer. Depending on the number of reared ewes/dams the sampled farms were divided into three groups: <350 animals (40 farms), 351-600 animals (46 farms) and >600 animals (35 farms). A one-way weighted ANOVA was used to detect potential differences stemming from the farm size. Multiple comparisons for all pairs of means were performed using Tukey-Kramer HSD test; the significance level was set to $P<0.05$.

III – Results and discussion

The cultivated land per ewe/dam increases with flock size (Table 1), nonetheless it remains relatively small, because most transhumant farms do not use any arable land. Despite what would be expected, milk yields decrease as farm size increases, but these differences are not statistically significant; one explanation lies on the fact that difficulties in the supervision of large flocks result in decreased productivity. The labour requirements per ewe/dam decrease as farm size increases because some general managerial chores are allocated to more animals; in addition, smaller farms tend to rely mainly on family labour, while the ratio family/hired labour and the hired labour per ewe/dam are significantly smaller for large flocks. These results imply that large farms use hired labour more efficiently.

Table 1. Main technical data of the sampled transhumant farms: average (standard deviation)

	Group 1 (<350 ewes)	Group 2 (351-600 ewes)	Group 3 (>600 ewes)	Mean farm
1. Number of farms (sample)	40	46	35	121
2. Flock size (ewes-dams)	268	451	809	494
	(54.9)	*(64.2)*	*(174.9)*	*(240.6)*
3. Cultivated land (ha/ewe-dam)	0.015	0.019	0.026	0.020
	(0.043)	*(0.042)*	*(0.039)*	*(0.041)*
4. Milk yield (kg/ewe-dam/year)	108.1	97.5	90.3	96.0
	(44.5)	*(46.9)*	*(37.8)*	*(43.8)*
5. Labor requirements (h/ewe-dam)	21.6[a]	14.5[b]	9.8[c]	13.5
	(7.5)	*(3.6)*	*(3.0)*	*(7.1)*
Family (h/ewe-dam)	16.5[a]	10.2[b]	7.0[c]	9.8
	(7.9)	*(4.1)*	*(2.8)*	*(6.8)*
Hired (h/ewe-dam)	5.1[a]	4.3[ab]	2.8[b]	3.7
	(5.0)	*(3.9)*	*(2.4)*	*(4.0)*

† Means in the same column followed by the same letter are not significantly different ($P \geq 0.05$).

As can be seen in Table 2, milk is the most important element of farm income for all three groups, followed by meat sales. Subsidies account for about 10.4% of the total farm income of the mean farm, nevertheless they vary among groups; smaller farms tend to rely more on subsidies, which was also pointed out by Galanopoulos *et al*. (2011). Note that the Single Farm Payment is not included in subsidies, as it is not coupled to the production process. Cheese production accounts for 1.6%-8.2%, which indicates a scattered and unorganized activity, especially for small farms which do not get engaged because of lack of available labour.

Table 2. Gross output of the sampled transhumant farms by source: average (standard deviation)

	Group 1 (<350 ewes)		Group 2 (351-600 ewes)		Group 3 (>600 ewes)		Average farm	
	€/ewe	**%**	**€/ewe**	**%**	**€/ewe**	**%**	**€/ewe**	**%**
Milk	98.9[a]	59.3	75.7[b]	53.3	75.0[b]	57.5	79.5	56.4
	(48.1)		*(37.3)*		*(36.7)*		*(42.0)*	
Cheese/Wool	2.7[a]	1.6	11.6[b]	8.2	5.1[ab]	3.9	6.9	4.9
	(7.0)		*(23.7)*		*(11.4)*		*(16.6)*	
Meat	45.0	26.7	39.5	27.8	38.4	29.4	40.0	28.3
	(16.4)		*(18.3)*		*(14.0)*		*(16.5)*	
Subsidies	20.4[a]	12.2	15.2[b]	10.7	12.0[c]	9.2	14.6	10.4
	(4.8)		*(4.3)*		*(4.3)*		*(5.5)*	
TOTAL	167.0[a]	100.0	141.9[ab]	100.0	130.5[b]	100.0	141.0	100.0
	(55.9)		*(51.9)*		*(43.1)*		*(52.4)*	

[†] Means in the same column followed by the same letter are not significantly different ($P \geq 0.05$).

Expenses seem to diminish as the flock size increases (Table 3), due to the efficient allocation of inputs. Although capital expenses are the highest, accounting for 67.3%, 68.4% and 74.1% for the three groups respectively, the contribution of labor is higher than reported in other studies (for instance Roustemis, 2012), which justifies that transhumance is labor-intensive. The use of mountainous grasslands boosts the economic performance of these farms, by reducing nutrition costs which vary from 66.0 to 96.4 €/ewe-dam for the three groups –including crop production costs. These findings are considerably lower than what Roustemis (2012) estimated for an intensive Greek sheep farming system (nutrition costs varied from 157.5-181.5 €/ewe).

The economic performance of transhumant farms is illustrated in Table 4. All groups operate with losses which are heavier for the smaller farms (84.2 €/ewe-dam). The rate of capital return is also negative, which demonstrates that transhumance is not a profitable entrepreneurial activity. However, if it is considered for what it is, i.e. a multifunctional farming activity, the positive farm income for groups 2 and 3 shows that there is perspective for medium and large-sized farms, while the positive gross margin shows that farms are capable of surviving in the short-run and expect for better economic possibilities. Note that the gross profit does not include subsidies in order to examine the economic possibilities of the system without policy distortions.

IV – Conclusions

Smaller farms are more productive but they do not seem to combine their available inputs efficiently, which results in very high production costs. On the other hand, larger farms (350-600 and > 600 ewes) are less productive because of problems in managing large herds, especially under the harsh conditions of summer domiciles in the highlands. Transhumant flocks contribute to the

Table 3. Production costs of transhumant farms by input: average (standard deviation)

	Group 1 (<350 ewes)		Group 2 (351-600 ewes)		Group 3 (>600 ewes)		Average farm	
	€/ewe	**%**	**€/ewe**	**%**	**€/ewe**	**%**	**€/ewe**	**%**
1. Land rent	**7.4**	3.2	**5.0**	3.1	**5.8**	3.8	**5.8**	3.4
	(7.9)		(7.6)		(5.3)		(7.1)	
2. Labour	**68.2**	29.6	**46.6**	28.5	**34.2**	22.2	**44.6**	26.1
	(24.1)		(12.3)		(11.3)		(22.2)	
3. Capital	**155.3**	67.3	**111.8**	68.4	**114.4**	74.1	**120.8**	70.5
	(63.9)		(45.7)		(54.2)		(57.8)	
3a. Variable capital	130.3	56.5	91.3	55.8	93.5	60.6	99.4	58.1
	(63.4)		*(37.0)*		*(40.9)*		*(52.6)*	
Purchased feedstuff	89.9		63.4		67.8		70.2	
Animal production	33.9		25.3		22.7		25.6	
Crop production	6.5		2.6		3.0		3.5	
3β. Fixed capital	*24.9*	10.8	*20.5*	12.5	*20.8*	13.5	*21.4*	9.7
	(10.9)		*(14.6)*		*(18.3)*		*(14.7)*	
TOTAL	**230.8**	100.0	**163.5**	100.0	**154.4**	100.0	**171.2**	100.0
	(73.6)		*(51.5)*		*(57.8)*		*(57.8)*	

† Means in the same column followed by the same letter are not significantly different (P ≥ 0.05).

Table 4. Financial results of the sampled transhumant farms: average (standard deviation)

	Group 1 (<350 ewes)	Group 2 (351-600 ewes)	Group 3 (>600 ewes)	Average farm
	€/ewe	**€/ewe**	**€/ewe**	**€/ewe**
Gross profit	146.6	126.8	118.5	126.4
	(48.5)	*(59.2)*	*(45.0)*	*(51.6)*
Total expenses	230.8[a]	163.5[b]	154.4[c]	171.2
	(73.6)	*(51.5)*	*(57.8)*	*(57.8)*
Net profit	-84.2[a]	-36.7[b]	-35.9[b]	-44.9
	(52.7)	*(57.4)*	*(70.8)*	*(60.4)*
Rate of capital returns (%)	-11.1[1]	-4.4[1]	-3.7[1]	-5.5[1]
Farm income	-5.6[a]	20.3[ab]	29.1[b]	19.8
	(79.4)	*(85.1)*	*(55.9)*	*(49.3)*
Gross margin	16.3	35.4	25.0	27.0
	(37.7)	*(50.4)*	*(55.9)*	*(48.5)*

† The superscript ([1]) denotes the rate of capital return (%).

† Means in the same column followed by the same letter are not significantly different (P≥0.05).

protection of natural mountainous grasslands and also the use of these grasslands becomes an important factor in sustaining their economic viability. A next step in this research would be to evaluate the effects of this multifunctional system on other sectors of society and economy, such as the environment –including biodiversity and mountainous pasturelands–, the viability of marginal rural areas and the maintenance of cultural features in these areas.

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Does water availability influence the choice of a forage strategy in Swiss lowlands?

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Abstract. Swiss agricultural policy promotes grassland based forage autonomy of cattle farming. Its implementation in the lowlands should however take into account the high spatial rainfall variability. In rather dry regions, such as the South Jura foothill, full-grassland based farming may be not sustainable. This study compared five forage systems (crop rotations *versus* perennial grass-legumes mixtures) under the Geneva lake climate conditions, with and without additional water supply adapted to the plant needs. Annual crops cultivated in rotation provided the largest DM yields and were less influenced by water availability than the grass-legumes leys. Indeed, 10 mm additional water increased leys performance of 100 kg DM/ha, while the increase was only 50 kg DM/ha for maize. Effects of water availability on mineral content were less significant, but indicated a dilution of N-contents with water supply whereas K-content tended to increase. Although their mineral contents were the most balanced, yield of grass-legumes mixtures decreased significantly over the years, regardless of the availability of water. Globally, results show that annual crops cultivation can help to secure forage supply in areas prone to drought.

Keywords. Switzerland – Forage production – Water availability – Grassland – Crop rotation – Maize.

La disponibilité en eau influence-t-elle le choix d'une stratégie fourragère sur le plateau suisse ?

Résumé. *La politique agricole suisse soutient la production animale basée sur l'utilisation des prairies. Sa mise en œuvre en zone de plaine devrait toutefois tenir compte de la grande variabilité spatiale des précipitations. Dans les régions plutôt sèches, comme le pied du Jura Sud, les systèmes 'tout herbe' ne sont peut-être pas durables. Cette étude a comparé cinq variantes culturales (rotations de cultures vs. mélanges pérennes graminées-légumineuses) dans les conditions naturelles du bassin lémanique, avec et sans approvisionnement en eau adapté aux besoins des plantes. Les cultures en rotation ont fourni des rendements en matière sèche plus élevés et ont moins été influencées par la disponibilité en eau que les prairies. En effet, 10 mm d'eau supplémentaire ont augmenté la production des prairies de 100 kg de MS/ha, tandis que l'augmentation n'était que de 50 kg MS/ha pour le maïs. Les effets de la disponibilité de l'eau sur la teneur en minéraux ont été moins importants, mais ont indiqué une dilution de l'azote avec l'apport supplémentaire d'eau, tandis que la potasse augmentait. Bien que leur teneur en minéraux soit plus équilibrée, le rendement des mélanges graminées-légumineuses a considérablement diminué au cours des années, indépendamment de la disponibilité de l'eau. Globalement, les résultats montrent que les cultures annuelles peuvent sécuriser l'approvisionnement en fourrages dans les zones sujettes à la sécheresse.*

Mots-clés. *Suisse – Production fourragère – Disponibilité de l'eau – Herbages – Cultures en rotation – Maïs.*

I – Introduction

Full-grazing systems are recognised as sustainable in areas favourable for grass growth situated in the north of the Alps (Thomet *et al*., 2011). Therefore, one objective of the Swiss agricultural policy is to reduce maize to less than 20% in the herbivorous diet. However, with climate change, grasslands will be challenged to meet this growing demand for providing forages. Despite the small size of the country, the annual rainfall varies considerably over short distances. In the Jura south foothill, lowland grasslands may be more affected by drought than mountain pastures (Mosimann *et al*., 2012; Meisser *et al*., 2014). In consequence, an extension of the maize crops is observed in the Geneva lake region where the present study was set up. We compared two forage strategies (annual crops in rotation *vs* perennial grass-legumes mixtures) under the rather dry ambient climate and under optimal watering conditions.

II – Materials and methods

The experiment started in 2009 at Agroscope in Changins, Switzerland (385 m a.s.l., 06°15' 25.1''E, 46°23'40.2''N). It was established on a 90 cm deep arable Calcaric Cambisol soil, representative of the Jura foothill. The average annual precipitation is 1000 mm and ranged between 700 and 1200 mm during the four years measurement 2010-2013. The split-plot design comprised 40 plots (12 m x 6 m) with five production variants, two levels of water supply and four replications (Mosimann *et al*., 2013).

The five production variants consisted in crop rotations (V1, V2, V3) and grasslands (V4, V5). V1 and V2 corresponded to a 2-years rotation (maize silage –winter barley– annual forage) and were offset from one another by one year. V3 consisted in a more diversified rotation with cereals and legumes annual forages. Both grassland variants (leys) were sowed in 2009 and differed by cutting frequency (V4: 7 to 8 cuts/year, local turn-out dates for grazing; V5: 5 cuts/year, usual mowing frequency).

Two levels of water supply were tested: (A) ambient conditions (rainfall); (O) optimized conditions (rainfall + additional water). On O plots, water was supplemented thanks to a drip-irrigation system with maximum daily amounts of 15 l/m² according to the soil water tension. Fertilizers were applied accordingly to the Swiss fertilization guidelines (Sinaj *et al.*, 2009).

At each harvest, biomass exported from all plots was weighted. Samples were collected and oven-dried in order to determine dry matter (DM) and mineral (N, P, K) contents. Differences between annual yields of the A and O levels of water supply were compared through pairwise comparison tests within each variant or crop.

III – Results and discussion

The results relate to four years: 2010 and 2011 were characterized by drought and large water supplements on O plots (300-500 mm/year), whereas 2012 and 2013 were much wetter with consequently reduced needs for additional water (100-300 mm/year).

Table 1 indicates that the 2-years rotations V1 and V2 obtained the highest yield, on average 17.9 t DM/ha/year in ambient condition A and 19.2 t DM/ha/year with optimised water supply O. Silage maize highly contributed to such performances (grey cells in Table 1). Mean DM production of grasslands V4 and V5 were 9.0 and 12.6 t DM/year in A and O variants. On the other hand, their yield and their botanical composition (trend not shown here) have deteriorated over time. As a consequence, V5 was resowed in spring 2012 and one year later, the newly established grass-legumes mixture achieved similar DM yield to that measured in 2010.

DM yield was generally improved by additional water supplies. For all crop variants, increase was significant in 2011 (dry year) and non-significant in 2013 (wet year). In 2013, additional water have even caused a reduction in yield for V1, but no significantly. For grassland variants V4 and V5, yield increase reached 49% in dry years (average 2010-11) and 26% in wet years (average in 2012-13). Jeangros and Calame (1992) reported similar orders of magnitude on mountain meadows, underlying the importance of a targeted irrigation.

Figure 1 shows the response of DM yield to water supply, i.e. the relationship between O and A yield differences and amounts of added water. The diagonal line indicates an increase of 1 t DM/ha with an additional water supply of 100 mm. Crops situated above this limit have a high water efficiency. Supplemental water was more profitable to ley than to maize or cereal grain. Due to their summer growth, ley and maize have high water demand during dry years and are situated on the right part of the Fig. 1.

Table 1. Total annual dry matter yield (t DM/ha/year) of the five production variants (V1 to V5), (A) without and (O) with supplemental water supply

Year	V1			V2			V3			V4			V5		
	A	O		A	O		A	O		A	O		A	O	
2010	18.9	22.0	**	19.7	20.8		8.0	9.1		11.0	16.5	***	11.9	16.9	**
2011	22.7	24.8	*	11.6	14.3	**	11.7	15.4	*	8.0	12.8	**	8.5	12.3	***
2012	16.9	17.3		22.7	24.0	**	17.0	17.2		6.3	8.7	*	5.8	10.6	**
2013	17.2	16.3		13.9	14.1		10.0	10.7		6.6	6.7		14.3	16.3	
mean	18.9	20.1		17.0	18.3		11.7	13.1		8.0	11.2		10.1	14.0	

*P<0.05, **P<0.01; ***P<0.001; blank cells: non significant; grey cells: maize cultivation.

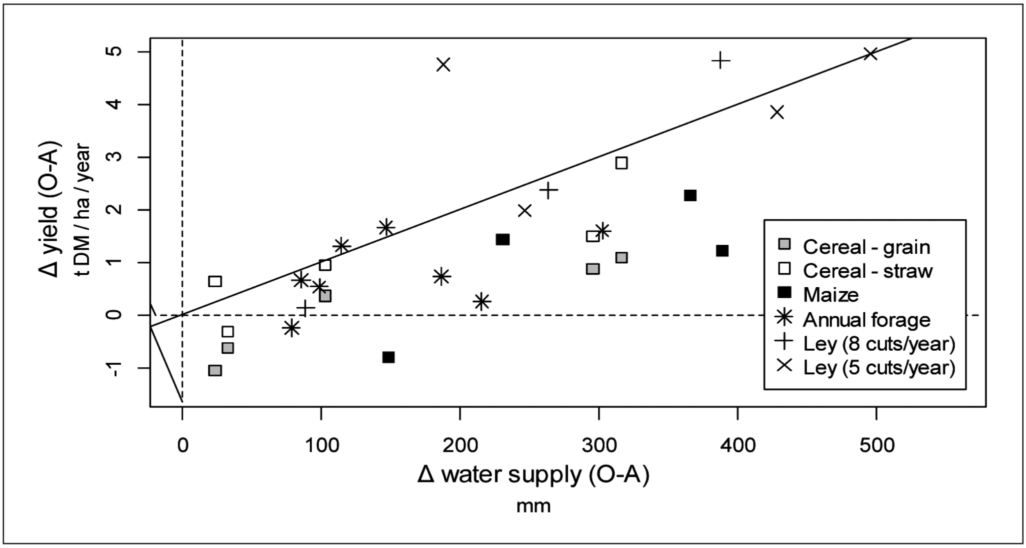

Fig. 1. Response of fodders DM yield to water supply (2010-2013).

Table 2 shows high differences among fodders mineral concentration. N- and K-content of grass-legumes mixtures (annual forage and leys) were much higher than those of cereal and maize. These results confirm the role of legumes in improving the nutritive value of forage. The effect of water availability was significant in a limited number of situations. As already shown (e.g. Jensen *et al.,* 2010), additional water supply on O plots was accompanied by a dilution of N in the biomass. Due to legumes N-fixation, the N-content of annual forage and leys is twice that of maize, while the cereal grain content is intermediate. The K-content was largely enhanced with supplemental water, indicating the liberation of this element by soil. P was less influenced by water status than N and K, confirming the low mobility of this element.

Table 2. N, P and K content of fodders from 2010 to 2013 under the two water regimes (A, O)

	Year	Cereal - grain			Maize			Annual forage			Ley (8 cuts/y)			Ley (5 cuts/y)		
		A	O		A	O		A	O		A	O		A	O	
N-content (% DM)	2010	1.62	1.61		0.98	0.95		2.74	2.78		2.92	2.89		2.75	2.35	
	2011	1.82	1.65	*	1.15	0.99		2.98	2.88		2.76	2.63		2.16	1.80	***
	2012	1.58	1.54		0.92	0.83		3.75	3.36	***	2.46	2.43		2.73	2.94	*
	2013	1.63	1.60		1.03	0.97		2.75	2.88		2.44	2.54		2.41	2.26	*
P-content (% DM)	2010	0.42	0.44		0.17	0.18		0.33	0.36	**	0.37	0.39		0.35	0.38	*
	2011	0.36	0.41	*	0.19	0.20		0.37	0.38		0.40	0.43	*	0.37	0.39	
	2012	0.40	0.39		0.17	0.18		0.40	0.41		0.47	0.48	**	0.38	0.36	
	2013	0.41	0.40		0.23	0.24		0.37	0.36		0.46	0.46		0.34	0.33	
K-content (% DM)	2010	0.55	0.59	*	0.57	0.61		2.83	3.08	**	2.77	3.20	***	2.62	3.02	*
	2011	0.43	0.45	*	0.83	0.79		3.11	3.37	**	3.20	3.58	**	3.03	3.44	*
	2012	0.48	0.48		0.80	0.88		3.40	3.74	**	3.46	3.64		3.22	3.18	
	2013	0.55	0.53		0.85	0.94		3.50	3.43		3.58	3.46		2.91	2.74	

*P<0.05, **P<0.01; ***P<0.001; blank cells: non significant.

IV – Conclusions

The forage strategies practiced on the Swiss lowland reacted diversely to the level of water availability. Silage maize cultivated in rotation with winter barley and alfalfa-ryegrass annual forage provided the largest DM yield and was less influenced by the water regime than leys. Therefore, despite their lowest mineral content, annual crops have to be considered in regions prone to drought. The results clearly showed the sensitivity of grassland to water conditions. During dry years, additional water amounts of 300 to 500 mm have been applied in order to adapt soil tension to plant need. Without water limitation, leys production meets perfectly the objectives of forage autonomy in herding systems. However, the study pointed out the gradual yield loss of leys over the years. In conclusion, the development of perennial grass-legumes mixtures has to be continued in consideration of the climate change.

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Growth performance and meat quality of suckling beef calves as affected by alpine pasture topography

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Abstract. Summer alpine pastures have a heterogeneous topography. Since beef cattle walk long distances for grazing pasture slope could affect both physical activity intensity and energy expenditure, which may further affect muscle metabolism and meat quality. The present experiment investigated the effect of slope inclination on growth performance and meat quality under high-altitude conditions. Two groups of 12 Angus-sired suckling calves each were kept with their dams on summer alpine pastures (2000 m a.s.l.) either on a terrain with steep inclination (S) or on a flat terrain (F) for 2 months. Then, calves were slaughtered and meat quality was assessed on the *longissimus dorsi* (LD) and the *biceps femoris* (BF) muscles after 21 days of ageing. Average daily gains were lower in S-compared with F-calves (1.21 *vs* 1.35 kg/day; P<0.01), but live weights did not differ significantly between groups at slaughter (277 ± 24 kg). Carcass classification and carcass weight did not differ between groups. Shear force of BF was lower in S- than in F-calves (24.5 *vs* 27.5 Newton; P<0.05). Colour of LD tended to be brighter (37.2 and 36.4; P<0.09) and more yellow (1.44 and 0.51; P<0.07) in S- than F-calves; all other measurements showed no difference between S- and F-calves.

Keywords. Slope – Activity – Tenderness – Grazing – Beef.

Performances de croissance et qualité de la viande de veaux allaitants selon la topographie des pâturages alpins

Résumé. *Les pâturages alpins disposent d'une topographie hétérogène qui pourrait influencer l'intensité de l'activité physique ainsi que la dépense énergétique des troupeaux qui doivent y parcourir de longues distances pour pâturer. In fine, ceci pourrait influencer le métabolisme musculaire et la qualité de leur viande. L'étude présentée ici évaluait l'effet de la pente du pâturage sur les performances de croissance et la qualité de la viande dans des conditions de haute altitude. Deux groupes de 12 veaux sous la mère, issus d'un même taureau Angus, ont pâturé sur des prairies alpines (à environ 2000 m d'altitude), soit sur un terrain pentu (S), soit sur un terrain plat (F), pendant deux mois. A l'issue de cette période, les veaux ont été abattus et la qualité de leur viande a été analysée sur les muscles* longissimus dorsi *(LD) et* biceps femoris *(BF) après 21 jours de maturation. Le gain moyen quotidien des veaux S était inférieur à celui des veaux F (1,21* vs *1,35 kg/jour ; P<0,01), bien que cela n'ait pas eu d'influence significative sur le poids vif à l'abattage (277 ± 24 kg). La classification et le poids de la carcasse n'étaient pas différents entre les groupes. La force de cisaillement du BF était inférieure sur les veaux S par rapport aux veaux F (24,5* vs *27,5 Newton; P<0,05). La couleur du LD était tendanciellement plus claire (37,2* vs *36,4 ; P<0,09) et plus jaune (1,44* vs *0,51 ; P<0,07) sur les veaux S que sur les veaux F, tandis que les autres mesures n'ont pas montré de différence significative.*

Mots-clés. *Pente – Activité – Tendreté – Pâturage – Bœuf.*

I – Introduction

Beef cattle are increasingly kept on seasonal alpine pastures (SAV, 2010), likely due to the limited workforce necessary in comparison with dairy cattle. However, this period may affect growth performance, carcass characteristics and meat quality in comparison with beef cattle reared on lowland pastures. Typically, alpine pastures have a variable topography with slopes of various gradients contrasting with lowland pastures, the majority of which have a more even topography. Differences in topography require a different muscular workload depending on the slope cattle are grazing on. The burden of physical activity has been shown earlier to affect maintenance requirements and muscle physiology both in athletes (Tesch and Karlsson, 1985) and in animals. This appears to have consequences for meat quality in beef cattle (Dunne *et al.*, 2011). Nevertheless, physical activity of cattle is often confounded with diet type and altitude-related hypoxia (Leiber *et al.*, 2006). The present experiment therefore aimed at describing growth and meat quality of suckling calves kept either on pastures with high inclination or on flat pastures, with grass of similar quality and at the same altitude.

II – Materials and methods

The experiment was conducted on the alpine pastures of the ETH Zurich research station Alp Weissenstein, located in the Eastern Swiss Alps at about 2000 m a.s.l. Twenty-four suckling calves were distributed over two groups of 12 animals each, balanced for gender, live weight (185 ± 22 kg) and age (4.2 ± 0.6 months) of the calves at the beginning of the alpine period as well as for the genotype and lactation number of the dam. Calves were kept with their dam all along the experiment which started on June 20th, 2013, with the transport of the herd to the alpine site where they stayed until slaughter of the calves. Calves were all sired by the same Angus bull and had Angus × Holstein (n = 19) or Limousin × Holstein (n = 5) dams. A rotational pasture management was conducted, either on pastures with an average inclination of 40% (group S) or on pastures with close to 0% inclination (group F). Representative forage samples were taken every week and analysed for contents of dry matter (DM), gross energy, organic matter, crude protein as 6.25 × nitrogen content (all according to AOAC (1990)), neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) according to Van Soest *et al.* (1991). The pastures selected indeed offered forage of mostly similar nutritional quality (P>0.1) to the two groups except for NDF and ADL contents. On average, contents were: gross energy, 18 ± 0.3 MJ/kg DM; organic matter, 928 ± 1 g/kg DM; crude protein 128 ± 19 g/kg DM; ADF, 291 ± 21 g/kg DM. In the forage of the S group, compared to that of the F group, NDF content was lower (487 *vs* 541 g/kg DM, P<0.05) and ADL content was higher (55.8 *vs* 45.7 g/kg DM, P<0.01).

After approximately 11 weeks on their respective pastures, the calves were slaughtered on September 2nd and 5th in a commercial slaughterhouse, with 6 animals from each group slaughtered on each of the slaughter dates. The hot carcasses were weighed and classified according to the CHTAX system (similar to the EUROP classification). On the day following slaughter, samples of the LD (*longissimus dorsi*) and BF (*biceps femoris*) muscles were collected for laboratory analysis, and ultimate pH value (24 h *post-mortem*) was measured in the LD muscle. Meat composition (DM, protein calculated as 6.25 × nitrogen content, ash, crude fat) was analysed on fresh meat whereas further meat quality analyses were carried out after 21 days ageing in vacuum packaging at 4°C. Meat from both muscles was analysed for meat colour (in the L*a*b colour space), drip loss (48 h at 4°C with the bag method from Honikel (1998)), cooking loss (in water bath at 72°C for 45 min) and shear force (on the meat sample used for cooking loss) obtained with a Warner-Bratzler shear blade mounted on a TAXT2 texture analyser (Stable Micro System, Surrey, UK).

Data were analysed by SAS 9.3 (SAS Institute Inc., Cary, USA) with ANOVA using the GLM procedure for forage and growth data, and using the MIXED procedure for carcass and meat quality data. For both models, group was defined as fixed effect; slaughter date was included as a random effect for the mixed model.

III – Results

Results of growth and slaughter performances of the S- and F-calves are presented in Table 1.

Table 1. Growth and slaughter performances of suckling calves kept on steep pastures (S-calves) or on flat pastures (F-calves)

	S-calves	F-calves	P-value
Initial live weight (kg)	185	186	0.85
Average daily gain (kg/day)	1.21	1.35	0.01
Slaughter live weight (kg)	271	283	0.22
Carcass weight (kg)	146	151	0.45
pH 24h *post mortem*	5.8	5.8	0.38

Carcass conformation was classified mainly as T3 (n = 10) or T+3 (n = 4) independently of the group. Meat composition (DM, protein, ash and crude fat) of both LD and BF muscles did not differ between groups (P>0.1). Fat content of the LD muscle was on average 1.31% and fat content of the BF muscle was on average 2.35% of wet weight. Concerning meat colour, LD of S-calves tended to be brighter than LD of F-calves (brightness L*: 37.2 *vs* 36.4; P<0.09) and more yellow (b-yellowness 1.44 *vs* 0.51; P<0.07), but no difference was found in the redness (redness a*: 19.5 *vs* 19.0, P>0.32). Colour of the BF did not differ between groups with average values of 37.2 ± 0.8 for L*, 21.7 ± 0.9 for a* and 2.38±0.66 for yellowness b* (P>0.32). Drip loss and cooking loss were also similar in both groups and in both muscles (LD: 1.1 ± 0.3% and 24.9 ± 0.3%; BF: 1.1 ± 0.2% and 28.3 ± 1.8%, respectively; P>0.19). Shear force did not differ between groups for the LD muscle (43.1 ± 9.5 N, P>0.85) but differed for the BF muscle. The BF-meat of the S-calves had on average a lower shear force value than that of the F-calves (24.5 *vs* 27.5 N, P<0.05).

IV – Discussion

In the present experiment, the effect of pasture inclination on growth performance and meat quality of suckling calves was investigated. The negative influence of a steep pasture on growth performance was likely due, as hypothesised, to the higher energy demand for grazing on steep slopes. Although milk composition and intake were not recorded, ruminating and eating patterns did not differ between groups (data not presented here), suggesting similar feed intake for both groups. The effect of pasture inclination on live weight gains was, however, limited in magnitude, thus not resulting in significant live weight differences at slaughter, due to the short duration of the experiment (11 weeks) and the initial intra-group variability. Dressing percentage, carcass classification and ultimate pH were not affected by the inclination of the pasture, which translates into equivalent payments to the farmer for S-calves as for F-calves. Regarding meat quality, the inclination of the pasture had an effect in a muscle-dependent way, as was also observed by Vestergaard *et al.* (2000), although the latter could not differentiate the effect of activity from that of the diet. In cattle, LD and BF muscles differ regarding their position and, consequently, their function and metabolism. The LD muscle, located on the back, is rather a posture muscle whereas the BF muscle, located in the upper part of the hind leg, is rather a propulsion muscle. Talmant and Monin (1986) found the BF muscle had a lower glycolytic activity and a higher oxidative activity than the LD muscle, although results may vary from one study to another. The LD muscle, in contrast to the BF muscle, tended to be influenced by pasture inclination in its colour being brighter in the S-calves. Based on the results of Vestergaard *et al.* (2000), this colour difference could be related to a more glycolytic metabolism in S-calves than in F-calves. In turn, the BF muscle, in contrast to the LD muscle, was influenced by pasture inclination in its shear force. The

BF of the S-calves had lower shear force values, indicating higher meat tenderness. This characteristic could be related to several determinants, including muscle fibre type and diameter (Maltin *et al.*, 1997; Maltin *et al.*, 2003) which remain to be analysed.

V – Conclusions

Steep slopes are a typical feature of alpine pastures. Pasture inclination impaired daily gains but this without influence on final live weight and carcass characteristics in the present experimental conditions. Pasture inclination also had an influence on meat tenderness and colour depending on the metabolism and the function of the muscle from which the meat originated. Accordingly, when aiming at a more tender meat and a brighter meat colour, there could be an advantage in rearing fattening calves on steep alpine pastures rather than on flat pastures. Full understanding of the underlying mechanisms will need further analysis of muscle metabolic traits.

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Is the increase in beef cattle in upland farms driving environmentally-friendlier farming?

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Abstract. In France, the last 30 years have seen a steady increase in beef cattle whereas dairy cattle are on the decline. Few studies have attempted to investigate the potential effects of this trend on grassland environment quality. To progress on this point, we led farm surveys on eighteen farms in an upland region of the north-eastern Massif Central to capture and analyse changes in grassland management practices over the last decade since abandonment of milk production. Our analysis finds that the five different types of beef conversion observed create globally favourable conditions for grassland preservation and extensive management in these areas. The main issue for the preservation of grassland landscapes in temperate mountain zones will be the capacity of new suckler farms to increase the labour's income.

Keywords. Dairy farm – Beef production – Changes – Grassland – Environment.

L'augmentation des bovins viande dans les élevages bovins de montagne conduit-elle au développement de pratiques plus respectueuses de l'environnement ?

Résumé. *Dans les montagnes françaises, depuis une trentaine d'années, les effectifs de bovins viande augmentent alors que ceux des bovins lait diminuent. Les conséquences de cette évolution sur les qualités environnementales des prairies sont peu étudiées. Afin d'apporter des éléments sur cette question, nous avons réalisé des enquêtes sur 18 exploitations récemment converties du lait à la viande dans une région traditionnellement laitière au Nord-Est du Massif Central. Nous avons caractérisé les changements de pratiques concernant les prairies depuis l'arrêt de la production laitière et le passage à la production de viande. Nos résultats mettent en évidence que, pour chacune des 5 formes de conversion identifiées, les changements de pratiques sont globalement favorables pour l'environnement et pour une gestion extensive des prairies. A terme, la préservation de ces prairies et de leurs qualités environnementales dépendra fortement de la capacité de ces élevages et de leurs filières à améliorer le revenu des éleveurs.*

Mots-clés. *Exploitation laitière – Production de viande – Changement – Prairies – Environnement.*

I – Introduction

In France, the last 30 years have seen a steady increase in beef cattle, whereas dairy cattle are on the decline (Perrot *et al*., 2005; France Agrimer, 2013). Few studies have investigated the effects of this shift on grassland management and natural resources (biodiversity, water, soil) in agricultural landscapes. However, in lowlands as in mountains, milk and beef production lead to contrasted grazing and fodder practices in terms of grazing rotation, cutting grassland, stocking forage, among other practices. Thus, it is important to look at new suckler farms that have recently turned away from milk production. Their changing grassland practices have to be analyse and qualify in terms of preservation of natural resources.

In temperate French mountain areas, milk production has become increasingly compromised due to market changes, CAP reforms, and changing social expectations (Begon *et al*., 2009; Perrot *et al*., 2009; Chambres d'Agriculture, 2013). The recent decline in dairy cattle stemmed from the cessation of the smallest milk farms and from the conversion of milk farms to beef. The future of livestock activities in mountain areas hinges on two key issues of conversion. The first is a socioeconomic issue: will beef production, which in these regions is essentially oriented to unfattened animals, lead to better farmers income and quality of life? The second is an ecological issue: will beef production succeed in preserving grassland landscapes and their high biodiversity?

To progress on this second ecological point, we led farm surveys on eighteen farms in an upland region of the north-eastern Massif Central to capture and analyse changes in grassland management practices over the last decade since abandonment of milk production.

II – Materials and methods

The studied area is the Livradois-Forez (LF) region, in a Regional Natural Park on the eastern border of the French Massif Central. It is a 322,000 ha upland area culminating at 1630 m, under a sub-continental climate. In 2010, this area counted 2224 farms and a 96 780 ha total farm area, which equates to a mean farm area of 44 ha (versus a 55 ha national average). In this region, agricultural land-patterns are particularly complex, with lots of small fields in areas mixed with forest, grasslands and crops, rivers and wetland patches. As in all French mountains, milk quotas policy (1986) hit this traditional milking area hard, and a major share of small milk farms have gone out of farming. Since 2010 (the last agricultural census), there are as many specialized suckler farms as specialized milk farms, although dairy cows still outnumber suckler cows (23,951 and 20,666 cows in 2010 respectively). The maintenance of opened landscapes and biodiversity are the main environmental issues involving livestock farming.

Our aim was to identify and survey farmers that have recently (i.e.: not more than 10 years) abandoned milk production to specialize in beef. Consequently, we first surveyed five local experts from territorial and agricultural organizations so as to obtain a wide sample of farms in terms of professional profile and trajectory (farmers for 5-37 years), age (26-59 years in 2013), farm size (11-315 ha) and location (350-1100 m farmstead altitude). The final survey sample counted eighteen beef farms: average size was 110 ha Utilized Farm Area (UFA), 102 Livestock Units (LU), and 1.6 Work Units (WU), and average time since abandoning milk production was 4 years (Beyle, 2013).

The farm survey questionnaire tackled three aspects: (i) motivations and conditions behind the recent conversion to beef; (ii) global trajectory of farm structure and management from installation to today (area, labour force, cattle, land-use patterns); and (iii) post-conversion changes in land-uses and practices (grazing and cutting, mineral and organic fertilization).

As the analysis had to handle and mine a very broad set of qualitative data collected on change and heterogeneity of changes between farms, we opted to mobilize the visual tables of Bertin (1977) in order to distinguish the different types of farms according to farm structure, land use and livestock practices changes. Each group was then further characterized in terms of change in grassland use and management.

III – Results and discussion

The first main finding concerns farm-size changes (area, labour, cattle) since conversion to beef: a large majority of farms maintained a similar Utilized Farm Area (UFA) and Work Units (WU) In our sample, while 45% of farms increased total Livestock Units (LU) count, only 25% increased UFA and 10% increased WU. In short, conversion to beef in the LF region does not frequently entail farm-size variation. However, there are differentiable variations in farm structure (see Table 1): group 1 (G1; 4/18) farms increased area and cattle; group 2 (G2; 3/18) farms only increased cattle; group 3 (G3; 5/18) farms maintained similar area, cattle and work units; group 4 (G4; 3/18) farms decreased work units only; group 5 (G5; 3/18) farms had “mixed” trends that are difficult to characterize.

Table 1. Main characteristics of farm changes since conversion to beef and of current situation (2013)

Group of farms (number of farms)	All (18)	G1 (4)	G2 (3)	G3 (5)	G4 (3)	G5 (3)
BUFA variation	9 ha	41ha	0ha	0ha	2ha	-3ha
UFA 2013	110 ha	151 ha	84 ha	108 ha	101 ha	93ha
LU variation	15	42	19	2	0	14
LU 2013	102	142	77	85	118	88
WU variation	0	0,60	0	0	-1	0,3
WU 2013	1.6	2.6	1.3	1.2	1	1.8
Grass/UFA variation	4%	5%	0%	7%	1%	5%
Grass/UFA 2013	90%	92%	80%	98%	82%	93%
LU/Fodder Area (FA) variation	0	0	0.3	-0.1	0	0
LU/FA 2013	1	1	1.2	0.8	1.3	0.8
Farmstead altitude	733 m	840 m	450 m	914 m	492 m	817 m
Average age of the farmer	48 years	39 y	46 y	54 y	47 y	50 y
Average age of milk abandonment	4 years	5 y	2 y	3 y	5 y	4 y

The second main finding concerns grassland use. All groups slightly increased the percentage of grasslands in the farm area (+4% of UFA), except G2 which maintained the same percentage of grassland. All groups conserved the same stocking rate [0.8-1 LU/FA for G1, G3, and G5, and 1.3 LU/FA for G4], except G2 which significantly intensified stocking rate (+0.3 LU/FA, i.e. from 0.9 to 1.2; see Table 1). Since the conversion to beef, one farm abandoned silage maize cultivation whereas six farms continued to cultivate it but on a smaller area than before. Area used for cereal did not change significantly.

The third main finding concerns grassland management. Globally, each farm maintained the same type of fodder system, which continued to vary between the farms studied: 30% with maize silage and other grass fodder, 20% with only hay, 50% with various grass fodders. In terms of grazing management, 30% of farms extended the grazing period (regardless of farm groups) and 50% of farms changed the location of cow batches (not exclusively near the stalling). In terms of cuttings management, 56% of farms reduced nitrogen fertilization on cut grassland (essentially in G3 and G4) and 10% of farms cut the grass later on, at the end of spring. There was no change in manure use.

These three main findings show five types of conversion to beef linked to change in grasslands use. The first type (G1) concerns large farms (151 ha, 2.6 WU, 141 LU) with average stocking rate (1 LU/FA); farmers have frequently less than 50 years (3/4) and are located in higher zones of the LF region (3/4 farmsteads above 750 m.). The second type (G2) corresponds to average-size farms (84 ha, 1.3 WU, 77 LU), with high and increased stocking rate (1.2 LU/FA), limiting the extension of grassland in the farm area; they are located in the lower zones of the LF region (3/3 below 750 m.). The fourth group (G4) corresponds to larger farms with lower labour force than G2 farms (101 ha, 1 WU, 119 LU), with a significantly high stocking rate (1.3) on a decreasing area of permanent grassland; farmers have frequently less than 50 years (2/3) and are located in lower zones of the LF region (3/3 below 750 m.). G4 farms reduced nitrogen fertilizer on cut grasslands. The fifth group (G5) concerns farms with no significant change in grassland use; farmers have frequently more than 50 years (2/3) and are located in higher zones of the LF region (2/3 farmsteads above 750 m). The third type (G3) corresponds to large farms (108 ha, 1.2 WU, 85 LU) with an average stocking rate (0.8); farmers have frequently more than 50 years (4/5) and are located in the upper zones of the LF region (5/5 above 750 m). G3 farms had reduced nitrogen fertilizer on cut grasslands.

The majority of post-conversion trends in practices can be qualified as favourable to soil, water and biodiversity preservation according to grassland scientists (Marriott *et al*., 2004; Huyghe, 2009) and agro-environmental experts (INRA, 2013), i.e. more grassland in the farm area, maintaining a moderate stocking rate, less maize silage, less nitrogen fertilizer on cut grasslands, cow batches more scattered over the farmland. However, this result has to be balanced against some farmers' practices on hedgerows and trees, as we also found several cases where G1 farms regularly removed these natural habitats.

IV – Conclusion

Looking at the changes in farm practices and structure following conversion from dairy to beef, our survey indicates that the different patterns of conversion create globally favourable conditions for preserving grassland and extensive farming in these areas. The main issue for the preservation of grassland landscapes and their biodiversity in temperate mountain areas will be the capacity of new suckler farms to sustain in the long term and to increase the currently-low levels of farmer income.

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The role of grazed pasture in dairy Mediterranean sheep farming system

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Abstract. In Mediterranean environment the traditional dairy sheep farming system is based on pasture. The aim of this work was to compare a pasture grazing system with an indoor management in dairy sheep to better understand the role of grazed pasture as principal feed source. The trial was carried out in N-W Sardinia, between July 2011 and May 2013. In both years, for each season, a 4 week observation period was assessed. Two groups of 16 animals belonging to Sarda breed, were raised with two contrasting managements: Traditional management (TM) and Confined management (CM). The TM group was managed 24 h at pasture and it received a supplementation of hay and commercial concentrate, CM group was raised indoor, with any access to pasture, and fed with hay and commercial concentrate. Preliminary results indicate better performance (milk yield and body condition score) in TM than CM group. Overall, the herbage on offer ranged between 0.2 t DM/ha in winter to 1.7 t DM/ha in spring, covering between 15 and 70%of total animal energy requirements.

Keywords. Grassland – Hay – Sheep – Milk – Cortisol – Temperature humidity index.

Le rôle du pâturage dans les systèmes d'élevage méditerranéens de brebis laitières

Résumé. *En milieu méditerranéen le système traditionnel d'exploitation des brebis laitières est basé sur le pâturage. Le but de cette étude était de comparer un système traditionnel basé sur les prairies permanentes (TM) à un système dans lequel les brebis sont en stabulation toute l'année (CM), afin de mieux comprendre le rôle joué par les prairies. L'essai a été réalisé dans le NO de la Sardaigne, à 650 m d'altitude, entre Juillet 2011 et mai 2013. Deux groupes de 16 brebis de race Sarde ont été gérées dans chacun des deux systèmes. Les observations ont été réalisées durant 4 semaines par saison pendant deux ans. Le groupe TM a été géré 24 h au pâturage et il a reçu une complémentation de foin et de concentré, le groupe CM a été géré à l'intérieur et nourri avec du foin et du concentré. Les résultats préliminaires montrent une meilleure performance (production de lait et état corporel) dans le groupe TM que dans le groupe CM. Dans le système TM, la disponibilité d'herbe a varié entre 0,2 t MS/ha en hiver et 1,7 t MS/ha au printemps, couvrant entre 15 et 70% du total des besoins énergétiques de l'animal.*

Mots-clés. *Prairies – Foin – Brebis – Lait – Cortisol – Index de température et d'humidité.*

I – Introduction

In Mediterranean environment sheep are traditionally managed extensively and they have to face with an unbalance of quantity and quality of pasture with hypothetical detrimental effect on milk production. Meteorological variability can as well affect the thermal and physical comfort of the animals (Dwyer, 2009). However, grazing pasture can improve the production quality and animal welfare (Cabiddu *et al.*, 2005; Napolitano *et al.*, 2005). With the aim to understand the role of grazed pasture in the ewe performance a comparison between grazing management and indoor management was carried out during 2011 and 2013 in dairy sheep.

II – Materials and methods

The trial was carried out in N-W Sardinia, between July 2011 and May 2013, in the experimental farm of Agris Sardegna (lat 39°N, long 9 °E), at 670 m a.s.l. The climate is Mediterranean with hot, dry summers and mild and rainy winters (mean of maximum temperature of hottest month = 32.9°C; mean of minimum temperature of coldest month = 4.1°C; total annual rainfall = 1000 mm). In both years, for each season (A = autumn; W = winter; Sp = spring; Su = summer), a 4 week observation period was assessed. Two groups of 16 animals belonging to Sarda breed, were raised under two contrasting managements: Traditional management (TM) and Confined management (CM). The TM group was managed 24 h at pasture while CM group was raised indoor, with any access to pasture. Both groups received hay and commercial concentrate. The feed diets were calculated according to animal requirements of their physiological state (early lactation in W, late lactation in Sp; dry in Su and end of pregnancy in A) and, for TM, to herbage availability. The supplement consumption were measured daily in both groups. The pasture productivity and quality was evaluated during each observation period monitoring herbage on offer (HO, t DM ha^{-1}), by cutting 12 samples ha^{-1} (0,50 m^2) and sward height (SWH, cm; 150 records ha^{-1}). Fresh forage was dried at 65 °C, the samples were analysed using a Foss NIRSystems (Hoganas, Sweden). Body Condition Score (BCS), milk yield and milk composition were measured weekly. In the same occasion individual blood cortisol level was detected as stress marker. Because of the wide range of basal cortisol value, the variation of cortisol level was calculated as a difference between the last and the first blood sampling for each season (ΔCortisol). Outdoor and indoor meteorological factors were monitored continuously during the trial and were analyzed hourly to make a more accurate study. Temperature humidy index (THI) was calculated according to Peana *et al*. (2007) in which the last three discomfort classes were the same used for Livestock Weather Safety Index LWSI (Alert; Danger and Emergency; LCI, 1970). Permanence of THI was finally considered in different discomfort classes. Data farming were analyzed with the GLM procedure of SAS using the season (S), the management (M) and their interaction (SxM) as fixed effects. Differences between means of meteorological data within the same season were determined using Welch Two Sample t-test.

III – Results and discussion

The indoor condition has not mitigated cold temperatures in winter and has enhanced warm conditions in spring and summer (Table 1). Hay and concentrate offered were different between TM and CM and they covered on average 51% for TM and 136% for CM of the total energy ewe requirement per day (Table 2).

Table 1. Meteorological data recorded in TM and CM and their comparison within the same season (A = autumn; W = winter; Sp = spring; Su = summer; Lsmeans ± std. err)

	TM				CM			
	A	W	Sp	Su	A	W	Sp	Su
T_{max}	15 ± 2.4^a	12.2 ± 4.4^a	17.5 ± 3.6^a	28.3 ± 4.7^a	15.6 ± 2.4^a	13.1 ± 4.9^a	19.5 ± 4.1^b	30.8 ± 4.4^b
T_{min}	8.9 ± 2^a	4.4 ± 3.3^a	8.7 ± 2.6^a	15.8 ± 2.8^a	9.4 ± 2.1^a	5.3 ± 2.9^a	9.8 ± 2.3^b	17.1 ± 2.4^b
THIavg	52.8 ± 3.3^a	47.0 ± 6.3^a	54.9 ± 4.5^a	67.1 ± 3.9^a	53.9 ± 3.3^a	48 ± 6.2^a	56.9 ± 4.4^b	69.2 ± 3.3^b
THIAC	0	0	0	2.3 ± 3^a	0	0	0	3.5 ± 1.9^b

T_{max}, T_{min} = Maximun and minimum temperature (°C); THI_{AC} = THI in Alert class (h/d); a, b: different letters within same season differ for P<0.05.

Table 2. Daily concentrate (Con; kg/head/day), hay supplementation (kg/head/day) consumed, animal energy requirements (ER, UFL/day) and percentage of energy requirement covered by supplements (ES,%) in TM and CM groups (A = autumn; W = winter; Sp = spring; Su = summer; Lsmeans ± std. err)

	TM				CM				Effect of treatments		
	A	W	Sp	Su	A	W	Sp	Su	S	M	SXM
Con	0.43 ± 0.01^{a}	0.44 ± 0.01^{a}	0.33 ± 0.01^{c}	0.27 ± 0.01^{d}	0.43 ± 0.01^{a}	0.44 ± 0.01^{a}	0.42 ± 0.01^{ab}	0.40 ± 0.01^{b}	0.01	0.01	0.01
Hay	0.49 ± 0.04^{d}	0.29 ± 0.04^{e}	0.00 ± 0.04^{f}	0.27 ± 0.05^{e}	1.17 ± 0.04^{c}	1.59 ± 0.04^{a}	1.55 ± 0.04^{a}	1.30 ± 0.04^{b}	0.01	0.01	0.01
ER	0.88 ± 0.01^{c}	1.16 ± 0.01^{a}	1.10 ± 0.01^{b}	0.79 ± 0.01^{d}	0.75 ± 0.01^{e}	0.89 ± 0.01^{c}	0.88 ± 0.01^{c}	0.64 ± 0.01^{f}	0.01	0.01	0.01
ES	75 ± 2.53^{e}	50 ± 2.56^{f}	30 ± 2.56^{g}	47 ± 2.56^{f}	129 ± 2.43^{c}	139 ± 2.53^{b}	118 ± 2.53^{d}	156 ± 2.59^{a}	0.01	0.01	0.01

Values within row with different superscript letters differ at P<0.05.

Table 3. Sward height (SWH), pasture production (HO) and quality in TM pasture (A = autumn; W = winter; Sp = spring; Su = summer; Lsmeans ± std. err)

		A	W	Sp	Su
SWH	cm	3.4 ± 0.40^{C}	2.7 ± 0.38^{C}	18.0 ± 0.40^{A}	9.7 ± 0.56^{B}
HO	tDM ha^{-1}	0.53 ± 0.04^{C}	0.20 ± 0.04^{D}	1.73 ± 0.04^{A}	0.98 ± 0.06^{B}
DM	%	37.74 ± 1.48^{B}	18.81 ± 1.73^{C}	20.32 ±1.72^{C}	63.44 ± 1.62^{A}
CP	%	10.00 ± 0.43^{B}	17.30 ± 0.50^{A}	10.77 ± 0.50^{B}	7.55 ± 0.47^{C}
NDF	%	73.23 ± 1.11^{A}	55.23 ± 1.30^{C}	59.03 ± 1.30^{B}	72.38 ± 1.22^{A}

Values within row with different superscript letters differ at P<0.001.

Table 4. Milk yield and milk composition of Sarda dairy ewes in TM and CM groups (W = winter; Sp = spring; Lsmeans ± std. err)

	TM		CM		Effect of treatments		
	W	Sp	W	Sp	S	M	S x M
Milk yield (ml/head/day)	871 ± 20	726 ± 21	664 ± 20	586 ± 21	0.001	0.001	0.10
FCM† (ml/head/day)	805 ± 22	721 ± 23	603 ± 22	577 ± 23	0.05	0.001	0.21
Fat (%)	6.41 ± 0.08	6.50 ± 0.08	6.26 ± 0.08	6.48 ± 0.08	0.06	0.29	0.40
Protein (%)	5.56 ± 0.04^a	5.37 ± 0.04^b	5.60 ± 0.04^a	5.66 ± 0.04^a	0.09	0.001	0.01
Lactose (%)	4.74 ± 0.03^a	4.48 ± 0.03^c	4.68 ± 0.03^a	4.57 ± 0.03^b	0.001	0.66	0.05
Urea (mg/dl)	47.4 ± 0.9^a	28.1 ± 0.9^d	42.2 ± 0.9^b	39.3 ± 0.9^c	0.001	0.01	0.001

† FCM = 6.5% fat corrected milk yield. Values within row with different superscript letters differ at P<0.05.

Table 5. Blood Cortisol level of Sarda dairy ewes in TM and CM groups (A = autumn; W = winter; Sp = spring; Su = summer; Lsmeans ± std. err)

	TM				CM				Effect of treatments		
	A	W	Sp	Su	A	W	Sp	Su	S	M	SXM
Cortisol g/dl	3.87 ± 0.3	2.41 ± 0.3	3.33 ± 0.29	2.39 ± 0.41	3.90 ± 0.29	2.14 ± 0.29	3.28 ± 0.29	3.71 ± 0.41	*	ns	ns
ΔCortisol	-0.58 ± 0.4	1.37 ± 0.4	-0.03 ± 0.37	1.04 ± 0.52	-1.28 ± 0.37	1.37 ± 0.37	-0.15 ± 0.37	-0.38 ± 0.52	*	ns	ns

The pasture production and herbage quality show a typical Mediterranean pattern (Table 3). The daily herbage availability (DHA) per ewe ranged between 0.78 ± 0.14 and 6.77 ± 0.15 kg DM $head^{-1}$ in winter and spring, respectively. The crude protein level (CP) was generally low especially in summer. The percentage of energy requirement covered by pasture, estimated as difference between requirements and integration supply, ranged from 25% in autumn to 70% in spring. Milk yield as well as fat corrected milk showed higher values in winter than spring ($P<0.001$, Table 4). Grazing sheep, during the whole experiment, produced more milk than confined ones ($P<0.001$). Concerning milk composition no effect of management was detected on milk fat whereas TM group in spring showed the lowest values of milk protein ($P<0.01$) and milk urea ($P<0.001$) than the counterparts probably because of an unbalance between energy and protein diet supply (Molle *et al*., 2009). In this period, in fact, although the high DHA per ewe, the quality of the pasture, related to the reproductive phase of grasses, was decreasing and characterised by a low CP content (Table 3). BCS trend in both groups was in line of what usually found for Sarda dairy sheep, with higher values ($P<0.05$) in TM group in autumn (2.94 ± 0.02 *vs* 2.86 ± 0.02) and spring (2.78 ± 0.02 *vs* 2.68 ± 0.02).

The cortisol level (Table 5) showed values that are within physiological range (Fazio *et al*., 2011). The ΔCortisol did not show a variation that would justify the discomfort of animals (Caroprese *et al*., 2010). The management did not affect plasma cortisol and its variation but they were significant affected by the season throughout the experiment. In particular a great variation was observed in winter. This finding is in agreement with Al-Busaidi *et al.* (2008), who reported that the increase in cortisol concentrations occurred most commonly during winter than during summer season.

Otherwise the TM group showed an increase of plasma cortisol level (1.04 ± 0.52 μg/dl) during summer while CM group was characterized by a decrease (-0.38 ± 0.52 μg/dl). These results, although almost significant ($P = 0.059$) and limited in absolute value, could be related to a deficiency of energy and protein supply from pasture (Table 2). Further research are needed to better understand this difference considering also that temperature and THI during summer season were, on average, higher indoor than outdoor (Table 1).

IV – Conclusions

In TM meteorological variability did not affect animal performance whereas grazed pasture exerts a beneficial effect in terms of milk production, even though the low herbage quality offered in spring negatively influenced the milk characteristics. During spring and summer it would be advisable to increase the amount of concentrate supplementation in order to cover the energy and protein unbalance of the pasture. TM results in a higher gross margin than CM due to a lower feed costs, saving the 14% of concentrate and the 84% of hay, and a higher milk production. The good level of self-sufficiency showed by TM system, except in autumn, could be increased by an agronomical improvement of the pasture.

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Portuguese annual Mediterranean pastures: an economic approach to understand sown pastures failure

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Abstract. After Portugal joined the EEC, in 1986, huge land use changes occurred: Cereal crops area was strongly reduced; native pastures (low productive) area sharply increased (2.1 fold); sown pastures (high productive legumes and grasses mixtures) area remain unchanged. Thus, pasture production potential is far from fulfilled. Farmers resist sowing improved cultivars, arguing their low persistency. Therefore we tested the hypothesis that the low persistence of improved cultivars reduces the profit of the sown pastures. Based on experiments data on representative ecological sites – high soil fertility (HSF), medium (MSF) and low (LSF) levels – we determined costs and income for a pastures-cattle system, comparing sown pastures (SP) to natural pastures (NP). Results showed a higher NP profit than SP in all sites. Fertiliser costs (phosphorus – P) were determinant in profit level. The increase from 20% to 30% on the P-uptake efficiency rate induced a higher SP profit than NP, on the HSF and MSF levels. We suggest that SP failure might be due to lower profit. The use of P-fertilisers below the quantity that supports biomass productivity at pasture carrying capacity level could affect persistence and make farmers give up SP techniques.

Keywords. Mediterranean grasslands – Rain fed pastures – Phosphorus uptake efficiency.

Prairies méditerranéens annuelles au Portugal : une approche économique pour comprendre l'échec des pâturages semés

Résumé. *Depuis que le Portugal a rejoint la CEE, en 1986, des changements importants se sont produits dans l'utilisation des terres et leur répartition territoriale. La surface des cultures de céréales a été fortement réduite. Les pâturages naturels à faible productivité ont vu leurs surfaces multipliées par deux alors que les prairies semées, à plus forte productivité potentielle, n'ont pas vues leur proportion augmenter. Ainsi, le potentiel de production des prairies n'a pas réellement augmenté. Les agriculteurs semblent être réticents à utiliser les semis de cultivars améliorés, en faisant valoir leur faible persistance. Dans ce travail, nous avons testé l'hypothèse selon laquelle la faible persistance des cultivars améliorés est la cause de la réduction des revenus que l'on peut espérer tirer de ces prairies temporaires. Nous avons déterminé les coûts de production et les revenus générés pour des systèmes d'élevage bovin au pâturage. Nous avons comparé les pâturages semés (SP) avec de pâturages naturels (NP), en nous basant sur des données expérimentales obtenues sur des sites écologiques représentatifs. Nous avons considéré trois sites en fonction de la fertilité du sol: haute (HSF), moyenne (MSF) et faible (LSF). Les résultats ont montré que le revenu était plus élevé en NP qu'en SP, pour tous les sites. Les coûts des engrais (phosphore – P) ont été déterminants dans le niveau de revenu généré. Dans les sites HSF et MSF, une augmentation de 20% à 30% du taux d'assimilation du P par les plantes permettrait d'augmenter le revenu des SP au-dessus de celui des NP. Nous suggérons que l'échec des SP pourrait être imputable au faible revenu permis en comparaison de celui généré par les NP. L'utilisation d'engrais P en-dessous du niveau permettant la production correspondante au chargement animal possible pourrait affecter la persistance des SP et conduire les agriculteurs à les abandonner.*

Mots-clés. *Prairies méditerranéennes – Pâturages annuels – Efficience d'absorption du phosphore.*

I – Introduction

Three quarters of Portuguese territory is under a Termo-mediterranean climate. Most of its representative soils are shallow, acid and with low organic matter content and water field capacity. Since 1899 until 1986, Portuguese agriculture developed under a protectionism policy based on strong import barriers and subsidised cereal production, independent from ecological limitations to these crops. As a result, soil erosion was high, and even today, its risk is classified from Moderate to High all over the country (European Environment Agency, 2003). In 1986, Portugal joined the European Economic Community. Since then, huge changes in the agricultural production systems occurred: cereal crop areas decreased from 896,507 ha in 1989 to 345,556 ha in 2009; in contrast grassland increased sharply from 828,691 ha in 1989 to 1,738,185 in 2009 (INE, 2012). There has been a clear replacement of cereal marginal areas by natural pastures (1,336,707 ha in 2009, INE, 2012), i.e. rainfed pastures composed of annual native species. Sown pastures (mainly subterranean clover, other annual legumes and ryegrass mixtures), despite having higher productivity than natural pastures (Almeida, 2002), benefitting from Common Agricultural Policy support investment measures, Agri-environment annual payments and Portuguese Carbon Fund payments, decreased from 480,000 ha in 1989 to 401,000 ha in 2009 (INE, 2012). Available cultivars in Portuguese market are mainly from Australian origin, which is likely to explain the low adaption to drought years (Almeida, 2002). Farmers also argue that these cultivars have a low persistence. Persistency of these annual species was suggested to be dependent on high soil phosphorus (P) availability (Bolland and Paynter, 1990; Thomson and Bolger, 1993), which could be explained by low nutrient assimilation efficiency, since P taken up from fertiliser is quite low, i.e. 15% (Isherwood, 2000).

Low persistence of sown pastures could decrease the income and increase investment risk of this pasture system. Therefore we tested the hypothesis that persistence time of improved cultivars significantly reduces the profit of the sown pasture system as compared to the natural pastures. Our main objective was to perform an economic analysis to access the relative importance of the major cost components and income and how variation in cost structure affects profit. Also, since P assimilation efficiency is considered to be very low, we estimated the sensitivity of P fertiliser costs on profit.

II – Material and methods

From a field experiment on comparative pasture production (Barradas, 2009) we select 3 representative ecological sites: Coruche, Elvas and Cercal. Coruche site has low soil fertility (LFS) on a cambisol (dystric), Elvas a medium fertility (MSF) on a Calcic Luvisol and Cercal high soil fertility (HSF) on a Leptosol (Aridic). Natural pastures (NP), fertilised natural pastures (FNP) and sown mixtures of annual clover and ryegrass pasture (SP) productivity was compared (Table 1).

Table 1. Annual rainfall, soil characteristics and pasture productivity of three sites (Barradas, 2009). NP: Natural pasture; FNP: Fertilized Natural pasture; SP: Sown pasture

Site	Annual rainfall mm	pH H_2O	Organic Matter %	P_2O_5 mg/kg	K_2O mg/kg	NP kg DM/ha year	FNP (kg DM/ha year)	SP (kg DM/ha year)
Cercal (HSF)	566	5.3	3.0	80	79	6 145	6 553	10 642
Elvas (MSF)	526	7.2	1.8	42	250	4 999	5 539	9 016
Coruche (LFS)	605	5.5	0.7	10	53	993	1 689	3 902

† Egner-Riehm; DM – Dry Matter.

For each pasture, a specific economic account was developed, after estimating the need for fertilisers, seeds and traction per ha.

From the pastures production averages (Table 1), we calculated stocking rates (Unit Live Stock –UL– per ha) according to Dikman (1998). Applying standard technical criteria (600 kg live weight; 85% cow fertility rate; 400 days parturition interval; 5% young calves mortality; 132 kg carcass weight) to stocking rates, we calculated calf production for each site and pasture type. Supplementation of animals was calculated from each stocking rate, as the difference between daily intake and the observed daily seasonal growth.

Costs and income were estimated using current Portuguese market prices (2013): traction 35 €/hour, 1.19 €/kg N, 1.44 €/kg P_2O_5, 0.46 €/kg K_2O, mixture of annual legumes-ryegrass 125 €/ha, 1 Unit labour 8215 €/year, hay 0.12 €/kg and 4 €/kg carcass; we use the CAP direct payments for Cattle as 200 € per UL. From the pasture accounts and the market prices, we calculated the following economic indicators, in a surface basis (ha): (a) Initial sowing investment (traction, fertilisers and seeds), included in the final cost as a fraction of pasture persistence (10 years by default); (b) Annual costs (fertilizers, traction, labor and animals supplementation, i.e. hay); (c) Income (annual carcass production and CAP direct payments); (d) Profit (Income – Annual costs – Initial investment/persistence); (e) Capital efficiency [Income/(Annual cost + Initial investments/persistence)].

For the cost sensitive analysis, we decreased SP persistence from 11 to 5 years. P fertiliser cost dependency on assimilation efficiency was analysed by recalculation fertilisation quantities after varying the phosphorus efficiency assimilation rate from 20% up to 30%.

III – Results and discussion

At Elvas (MFS) and Coruche (LFS) SP profit was lower than NP and FNP (Table 2). In contrast, in Cercal (HFS), SP profit was at the same level as NP and higher than FNP. However, in all sites, irrespective of soil fertility, SP capital efficiency was always lower.

Table 2. Estimated Economic indicators per hectare. NP – Natural pasture; FNP – Fertilized Natural pasture; SP – Sown pasture

Site	Pasture type	Initial investment	Annual cost	Income	Profit	Capital efficiency
Elvas	NP		51 €	224 €	173 €	4.43 €
Elvas	FNP		88 €	248 €	161 €	2.83 €
Elvas	SP	589 €	202 €	390 €	129 €	1.50 €
Cercal	NP		47 €	275 €	228 €	5.85 €
Cercal	FNP		104 €	294 €	190 €	2.82 €
Cercal	SP	415 €	207 €	477 €	229 €	2.22 €
Coruche	NP		7 €	45 €	38 €	6.83 €
Coruche	FNP		57 €	76 €	19 €	1.33 €
Coruche	SP	478 €	149 €	134 €	-62 €	0.68 €

† Considered as 1/10 (10 years persistence) for profit calculation.

On the other hand, if CAP direct payments are removed from income (data not shown), then SP profit would fall below other pasture types, indicating that SP are more dependent from external subsidies than the other pastures.

Fertiliser costs were the most important in all situations corresponding to: 48% and 51% in Coruche (LFS), 38% and 51% in Elvas (MLS) and 55% and 57%, in Cercal (HFS), respectively to FNP and SP, as a percentage of cost. The high cost of fertilisers could explain the higher profit of NP (no fertilisers) in general, despite the lowest productivity of NP pastures. Avoidance of P fertiliser use by farmers in SP pastures is expected to cause a decrease in productivity, a lower seed production and, therefore, a decrease in cultivar persistence (Bolland and Paynter, 1990; Thomson and Bolger, 1993). The sensitive analysis to a decrease of 5 years in persistence showed a sharp reduction of SP profit -77% at Coruche (LSF), -46% Elvas (MFS) and -18% at Cercal (HFS).

To test the effect of P assimilation efficiency rate of plants on profit, we did a sensitive analysis on this factor. Increasing the assimilation rate from 20 to 30% resulted in an SP profit increase of 31% at Coruche (LSF), 47% at Elvas (MSF) and 10% at Cercal (HSF).

These results clearly show that P nutrition is a major constraint of technical and, thus, of economic results of SP pastures. The option for improvements in P assimilation efficiency has been considered an important issue for plant breeding programs, from the time when the genotype variability was identified in many pasture species (Klimashevsky, 1990).

IV – Conclusions

Our results show that persistence time of improved cultivars reduces the profit of sown pasture systems as compared to natural pastures. Considering ten years persistence, the economic performance of sown pastures was lower than that of natural pastures. These results might explain the decision by farmers to increase natural pasture surface in detriment of sown pastures. P fertilisers seem to be the major constraint of SP development. Therefore, we suggest that improving P plant assimilation efficiency should be a priority of Portuguese pasture plant breeding programmes.

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Supporting herders and improving forage production in the South side of Alps – A development project

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Abstract. Meadows and pastures play a vital and economic role for both agriculture and tourism along the Southern side of the Alps. In 2007, an interdisciplinary project was launched aiming at supporting herders and improving forage production in the South side of Alps by implementing specific tools. Therefore it is not a fundamental research project, but rather applied research. Specific activities were implemented in two different axes: the grassland characterization and the analysis of farm systems. Regarding grassland characterization, it was highlighted a great seasonal variability in terms of biomass production, phenological development and nutritive quality. The botanical composition was also analysed and 9 types of vegetations have been identified. This leads to serious repercussions on the harvesting that should be adapted according to specific meteorological conditions of each year. As concerns the analysis of farm systems, we found that the agricultural income of all farms depends heavily on subsidies paid by the Swiss Confederation and that high performing farms are often not viable and autonomous. With the purpose of improving the agricultural income and the productive efficiency, farmers could intervene on animal breed and on related feeding, consisting in type, given amount and quality of food.

Keywords. Grassland – Grass-growth – Phenology – Farm typology – Farm efficiency.

Soutien aux éleveurs et amélioration de la production fourragère au Sud des Alpes

Résumé. *Prairies et pâturages jouent un rôle primordial pour l'agriculture et le tourisme au sud des Alpes. En 2007, un projet multidisciplinaire qui vise à soutenir les éleveurs et l'amélioration de la production fourragère au Sud des Alpes a été lancé en mettant en œuvre des outils spécifiques. Donc, il ne s'agit pas d'un projet de recherche, mais plutôt d'une recherche appliquée. Des activités spécifiques ont été mises en œuvre dans deux axes différents : la caractérisation des prairies et l'analyse des systèmes agricoles. En ce qui concerne la caractérisation des prairies, on a remarqué une grande variabilité saisonnière en termes de production, de développement phénologique et des valeurs qualitatives. La composition botanique a été aussi analysée et 9 typologies de végétation ont été identifiées. Cela a des répercussions sur la récolte qui doit être adaptée en fonction des conditions météorologiques spécifiques de chaque année. En ce qui concerne l'analyse des systèmes agricoles, nous avons constaté que le revenu agricole des exploitations agricoles dépend largement des subventions versées par la Confédération Suisse et que les exploitations très performantes ne sont souvent pas autonomes. Dans le but d'améliorer le revenu agricole et l'efficacité productive, les agriculteurs pourraient intervenir sur la race animale et sur l'alimentation du bétail, pour ce qui concerne le type, la quantité et la qualité des aliments.*

Mots-clés. *Prairies – Croissance de l'herbe – Phénologie – Typologies de fermes – Efficience de ferme.*

I – Introduction

In 2007, local partners and the Swiss Grassland Society (APF) launched a research & development project aiming at supporting herders and improving forage production in the South side of Alps by implementing specific tools (Nucera *et al*., 2013). Since then, some new activities were lunched linking research results, political and legal concerns into the real system at both farm and territorial level, according to stakeholders needs. The need for a better understanding of permanent grassland composition and behaviour was also highlighted, as consequence of a lack of knowledge in the southern side of Alps, despite they represent about 80% of UAA (USTAT 2013). This paper presents results of the botanical characterisation of semi-natural grassland over years and of an inquiry realized in two main agricultural valleys of Ticino. The objective was to define farms typologies and to evaluate their autonomy and the efficiency of some practices to better understand the role of local forage resources in such a systems.

II – Materials and methods

The activities were implemented in two different axes: (1) the grassland characterization; (2) the analysis of farm systems

1. Grassland characterization

Different surveys were conducted in diverse sites to improve the knowledge of this topic with the objective to disseminate and to discuss the results with farmers and other stakeholders. They concerned: (i) grass growth; (ii) phenology development; and (iii) botanical composition.

(i) Grass growth was evaluated by a simplified Corral – Fenlon device (Corral and Fenlon 1978, Mosimann, 2011) in three different sites at various altitudes. The experimental design was used to quantify the DM yield of permanent pastures. On each plot, botanical composition was determined along 7.5 m transects of 25 points (Daget and Poissonet, 1971).

(ii) The springtime phenology of 25 semi-natural meadows distributed among the principal thermic levels was observed according to the method developed in Switzerland (Meisser *et al*., 2008). The results allowed the characterization of the average stage of meadow development.

(iii) Botanical surveys on 58 farm meadows and pastures were carried out according to linear point quadrat method (Daget and Poissonet, 1971) in order to characterize the vegetation, considering also the applied management practices. A hierarchical cluster analysis was performed to classify botanical surveys in typological groups.

(iv) Various samples of grazed grass were collected to analyse grassland chemical composition with NIRs instrument. Each sample was collected in livestock fence in order to determine the effective pasture quality, expressed in MJ of NEL (Net Energy for Lactation).

2. Analysis of production systems (PS)

In order to understand the characteristics of farms using grassland as main forage resource, 38 interviews were conducted in two main agricultural valleys where grassland analyses were implemented, with the purpose of (i) identifying different types of farms, and (ii) evaluating farm efficiency and forage self-sufficiency.

(i) Farms were grouped in PS according to comparable resources, organization, tasks and results. In order to analyze and to compare different PS we used the agricultural income: an economic indicator that identifies the effective revenue for the farmer.

(ii) Through the same interviews we also detected for each farm: the livestock daily ration, the use of concentrate (meal) and the average purchased fodder during the year. To compare collected data, each ration was converted into MJ of NEL (Net Energy for Lactation) and in kg of protein. In addition, to assess the degree of farm forage self-sufficiency, purchased animal feeds were converted into “equivalent hectares” according the method developed by the Swiss Grassland Society.

III – Results and discussion

1. Grassland characterisation

(i) Pasture production among five years showed high seasonal variability (Table 1). The three study sites expressed three different levels of production: high (Cadenazzo – Ti, deep soil), medium (Semione – Ti, medium deep soil) and low (Lostallo – GR, superficial soil).

Table 1. Yearly and average biomass production (ton $DM*ha^{-1}$), and standard deviation for each site

Site	2009	2010	2011	2012	2013	Average production[1]	Standard deviation
Cadenazzo (203 m.a.s.l)	14.2	13.1	13.6	13.7	14.9	13.9	0.62
Semione (370 m.a.s.l.)	/	/	8.7	9.8	6.9	8.4	1.23
Lostallo (421 m.a.s.l.)	/	3.8	3.6	7.2	7.6	5.0	1.95

During five years of observation we noticed that biomass production is fairly the same, however a variation in the seasonal distribution of production was observed (data not shown). Especially in Cadenazzo (the most productive plot) the spring growth peak (80 kg $DM*ha^{-1}*d^{-1}$, average) had been lower than the summer one (93 kg $DM*ha^{-1}*d^{-1}$, average) for three years, due to the C4 species (especially *Setaria* spp.).

(ii) During the years (2009-2013) of observation a great variability was registered with a delay between 2010, the latest year, and 2011, the earliest year, in the achievement of the “full earing” stage, respectively 3-5 May and 15-17 April (data not shown).

(iii) 9 main vegetation types were identified through hierarchical cluster analysis, according to botanical composition, ecological conditions and managing practices. As a consequence, the great variability of semi-natural grassland of the South side of the Alps was brought out.

(iv) As concerns the grazed grass chemical composition, the analyses showed a different quality almost due to different management practises, as number of days in the same fence or grazing in a phenological tardy stage.

2. Analysis of farm systems

(i) The interviews led to identify 4 main production systems (Armellino and Levitre, 2013): “cow’s milk with silage” (PS1); “cow’s milk without silage” (PS2); cow’s milk transformed in the farm” (PS3); “small ruminants” (PS4).

The results showed that for all farms in the study area, despite the important variability, the agricultural income depends heavily on subsidies paid by the Swiss Confederation (Table 2).

Table 2. Income, expressed in 10^3 CHF, with and without subsidies for each production system (PS)

Economic indicators	PS1 (n = 11)	PS2 (n = 12)	PS3 (n = 4)	PS4 (n = 11)
Income – no contribution	-24 to -8	-8 to 50	-14 to 39	-26 to 24
Income – with contribution	30 to 63	30 to 65 (84)	25 to 86	45 to 68 (62)

(ii) Nutritive value of the ration was very variable, with NEL value between 7 MJ and 525 MJ for bovine unit per year (160 MJ as average) and protein value between 70 kg and 1200 kg per bovine unit per year (400 kg as average).

Thus, we could affirm that abundant rations, which often coincide with high costs, do not always correspond to milk production increase and to a lofty income. From these observations it is clear that choices regarding animal breed and related feeding, given amount and quality of food, are between the main factors that a farmer can modify to improve productive efficiency.

In addition we found that examined farms buy quantities of forage and concentrates, which corresponds to 192.15 equivalent hectares: an area equal to one-sixth of the surface they already manage (1200 ha of utilized agricultural area).

Farms belonging to PS3 (on farm transformed cow milk) often are more viable and more autonomous. Thanks to transformation activity they can get more add value, despite a higher work charge, and they don't need big quantities of milk. Similar consideration could be done for PS2: large part of farms belonging to this system deliver their milk to mountain dairy, capable of valuing product (especially cheese) on the market, even if in this system we recorded many high input farms. No silage milk production is encouraged by the Confederation with 0.03 CHF/kg milk, and transformation in cheese with 0.14 CHF/kg transformed milk. Farm belonging to PS1 normally deliver their production to industrial (or semi-industrial) dairy out of mountain zones (than for the Swiss designations "mountain" and "alp" (ODMA, 2011), they cannot use the denomination "mountain" for the transformed product) and most of them are going to switch to PS2, especially in mountain areas. Farms belonging to PS4 are very varied: there are milky goat farms, which are very autonomous and economically viable thanks to direct sale and low cost production. For sheep farm the only agricultural income is the sale of lambs, very seasonal, which gives rise to a low income. They are therefore very dependent on the contributions (Armellino and Levitre, 2013).

IV – Conclusions

During the last five years we tried to define the image of Ticino farming system starting from grassland resources to the farming system: we highlighted the great diversity of semi-natural grassland of South side of Alps and their role in the farms strategy. A deeper comprehension of grasslands characteristics and services is needed in order to advise farmers about the best utilization strategy and to explain the important potential of meadows and pastures, as fundamental principle of a *terroir,* able to create the basis for a market differentiation for dairy products.

Among the production systems we noticed that high specialized farms are often not viable and autonomous, and farms which have other activities, such transformation and direct sale, don't need great production and high input to be more viable, despite the high work charge.

What is the future for mountain and alpine Ticino's farms?

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The performance of the strategy of differentiation of dairy farms in France

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Abstract. In France, the dairy sector in mountain areas is largely oriented to producing cheese with quality signs such as the Protected Designation of Origin (PDO). Despite this strategy of differentiation, a strong disparity concerning efficiency exists between French dairy farms. The objective of this paper is to highlight the economic performance of dairy farms involved in the differentiation strategy compared to those which are massively engaged in a cost leadership strategy. We show the performance of these two case studies by analysing Farm Accountancy Data Network with the Data Envelopment Analysis (DEA). This non-parametric method helps carrying out a diagnosis of farm performance dissociating the pure technical efficiency and the scale efficiency, both components of the measured levels of the total efficiency. Farmers from the plains are more efficient than those from mountain areas. However, when considering the performance including real milk price and not only physical outputs, farmers from Franche-Comté (massively engaged in the PDO Comté) are as efficient as farmers from Bretagne unlike farmers from Auvergne and Rhône-Alpes regions.

Keywords. Dairy farm – Efficiency – Mountain areas – Data Envelopment Analysis – Strategy of differentiation.

Performance de la stratégie de différenciation des exploitations laitières en France

Résumé. *En France, le secteur laitier des régions de montagne s'est largement orienté vers une stratégie de production de formage sous signe de qualité comme les appellations d'origine protégées (AOP). Malgré l'adoption de cette stratégie de différenciation, de grands écarts existent en termes de d'efficience des exploitations laitières. Cette communication propose d'avancer quelques éléments de réflexion sur la performance des exploitations engagées dans une stratégie de différentiation par rapport à celles engagées dans la stratégie de domination des coûts. Nous analysons ces deux situations par la méthode DEA sur la base du traitement de données du RICA. Cette méthode non paramétrique nous permet de réaliser un diagnostic de la performance des exploitations en distinguant leur efficience technique pure de leur efficience d'échelle. Nous montrons que les exploitations de plaine sont plus efficientes que celles des zones de montagne. Toutefois, si l'on calcule les scores d'efficience totale en tenant compte des valeurs réelles des outputs, alors les exploitations laitières de Franche-Comté se rapprochent des niveaux d'efficience des fermes bretonnes à la différence des exploitations des autres régions de montagne.*

Mots-clés. *Analyse d'enveloppement des données – Efficience – Exploitations laitières – Stratégie de différenciation – Zones de montagne.*

I – Introduction

In France, numerous dairy-processors and cheese makers have developed their competitive advantage through a cost leadership strategy. Dairy Farmers, especially located in plain areas, engaged in this kind of dairy chain, have also developed a strategy based on cost leadership through rationalization of the production process, production volume expansion and modernization. However, at the same time, cheese-makers and farmers from mountain areas turned strongly to a strategy of differentiation based on Protected Designation of Origin (PDO). Even if they adopted a strategy of differentiation, over a long time, in average, the economic performance of the dairy sector in mountain areas is lower than in plain areas (Agricultural Income per dairy farmer is closed to 24,900 € in mountain area than 32,600 € in plain area (RECP, 2012). Thus, the relevant questions we would like to discuss in this paper are: How to explain these differences in performance levels? Are the more competitive the more technically efficient?

So, this paper highlights the determiners of the economic performance of the dairy farms observed on six French contrasted cases studies, three located in mountain areas and three in plain areas. In a first part, we develop the theoretical framework and the methods. In a second part, we describe the data and the results. The discussion concludes by giving some reasons to explain why there are disparities of efficiency.

II – Theoretical framework and methods

1. The efficiency measurement with the DEA method

The researches in farm competitiveness are mainly oriented on the analysis of the efficiency of the strategy based on cost leadership (Latruffe, 2010). At the opposite, researches based on the strategy of differentiation are very scarce. Differentiation is a way to get a competitive advantage. It is the ability of designing a set of meaningful differences to distinguish the company's supply from competitor's supply (Kotler *et al.*, 2009). This work is included in the general research on economic efficiency (Battesse, 1992) which was initiated by Farrell in 1957. The inefficiency of a farm indicates that is possible to produce the same level of outputs with fewer inputs or more outputs with the same amount of inputs. In this paper, we only evaluate total efficiency. Total efficiency combines pure technical and scale efficiencies. Pure technical efficiency corresponds to the ability of the farmer to make the best choice in a way to reduce the inputs and still produce the same outputs without taking into account the price of the inputs and the outputs, and conversely. Scale efficiency corresponds to the ability to have the relevant scale. We have to precise that the measure of the total efficiency is made with outputs in quantity of goods (milk, meat, cereals) and inputs in quantity. The price of the milk for example is not taken into account in a first step to determine the total efficiency, but in a second step we take into account the real milk price at farm gate to evaluate if the scores of efficiency change due to the ability to dairy farmers involved within the strategy of differentiation to capture added value. It is the specificity of our approach.

To evaluate total efficiency of the dairy farms we use the Data Envelopment Analysis (DEA). It is a nonparametric approach for the estimation of production frontiers. The DEA approach to pure technical and scale efficiencies measurement leads to a mathematical optimization. Our study uses benchmarking to make inter-farm comparisons of the performance. We consider with the DEA method that if a farm can produce a level of multiple outputs utilizing a level of multiple inputs, it is possible for another firm of equal scale of doing the same (Berg, 2010). We carried out the evaluation of efficiency to search for the points with the lowest unit cost for any given output, connecting those points to form the efficiency frontier. Any farm not on the frontier is considered inefficient. A score (numerical coefficient) is given to each firm, defining its relative efficiency. A dairy farm is efficient if the coefficient is equal to 1. Controversy, inefficient farms are identified by an efficiency rating of less than 1. We need to collect data to describe the farms concerning 6 French regions: 3 concern plain areas (the study concerned only the dairy farms (Otex n°45, ex n°41) located in mountain areas (down to 600m) (Bretagne, Lorraine, Nord-Pas-de-Calais), 3 concern mountain areas (up to 600 m) with PDO Cheeses (Auvergne, Franche-Comté and Rhône-Alpes). For estimating the efficiency of the dairy farms one major source is used to: the FADN database (Farm Accountancy Data Network) for the year 2011.

III – Empirical application

1. Data description

The empirical application is on a sample of 417 dairy farm observations for year 2011. The farms are specialized in milk cattle production and are located in six regions of France. In the efficiency models, the economic (good) outputs are the quantity of meat production and the milk production. Five inputs have been retained for the construction of the frontier: land [Total Utilized Agricultural Area in hectares (ha)], labour [annual work unit (AWU)], herd size (in livestock units), capital (depreciated and financial charges) and intermediate consumptions.

2. Analysis of the efficiency of dairy farms in six regions

A. Evaluation of the efficiency by taking into account physical outputs

We analyse the economic performance of dairy farms by measuring efficiency scores given by the DEA. The total efficiency is presented and broken down in scale efficiency and pure technical efficiency.

In a first step, all calculations have been carried out with physical outputs: amount of milk, amount of meat. This evaluation allows to measuring the ability of dairy farmers to be efficient, *i.e.* by producing physical outputs with minimum inputs (see Table 1 “physical output” column).

Table 1. Efficiency Scores of dairy farms in the six regions of the sample (2011)

	Total efficiency (physical outputs)	Total efficiency (output in real monetary value)	Scale efficiency (physical outputs)	Scale efficiency (output in in real monetary value)	Pure technical efficiency (physical outputs)	Pure technical efficiency (output in real monetary value)
Auvergne	0.77	0.76	0.87	0.89	0.89	0.87
Franche-Comté	0.72	0.88	0.89	0.95	0.81	0,93
Rhône-Alpes	0.74	0.77	0.87	0.88	0.86	0.89
Bretagne	0.92	0.90	0.97	0.97	0.95	0.93
Lorraine	0.84	0.84	0.96	0.96	0.88	0.88
Nord-Pas-de-Calais	0.89	0.88	0.96	0.95	0.93	0.93

Source: Treatment FADN Data (2011) from authors – Input Orientation.

Indeed, if we calculate the total efficiency scores from the outputs by volume, the total score concerning Franche-Comté dairy farms is 72%. This result deviates strongly from the best score (Bretagne region with a total efficiency close to 92%) and it is exceeded by the scores from Auvergne (77%) and Rhône-Alpes (74%) regions which are both involved in PDO cheese productions. This result means on average that the dairy farms located in Franche-Comté could have reduced their inputs by 28% (1–0.72) for the same output level, if they have adopted the best combination of inputs. If we decompose the total efficiency, one the one hand, a better management of the use of the multiple inputs could explain 19% (1-0.81) this progress towards the benchmark. On the other hand, if the dairy farms have been adapted to their optimal size (scale efficiency), the progress towards the benchmark could be in order to 11% (1-0.89).The total efficiency concerning dairy farms located in mountain areas are lower than those located in plain areas as if the strategy of differentiation would not be a relevant choice. To discuss this issue, we have to take into account in the analysis the real monetary value of the outputs instead of their physical nature.

B. Evaluation of the efficiency by taking into account the real monetary value of the outputs

In a second time, all calculations have been made with the value of the outputs to their market price (milk and meat products in Euros). We thus try to intersect these measures of the total technical inefficiency with previous results. The least total efficiency scores are represented by the dairy farms from Rhône-Alpes and Auvergne (respectively 0.77 and 0.76) (see Table 1. below column "output in real monetary value"). They are distant from another group of four regions in which we find three plain areas and one mountain area (Franche-Comté). For these four areas, we observe a larger share of the pure technical inefficiency in the total efficiency, as if the farms were close enough to the optimal size. By taking into account the real milk price at farm gate, the performance of dairy farms in Franche-Comté has been improved, whereas efficiency of the dairy farms in Auvergne, Bretagne and Nord-Pas-de-Calais has been decreased slightly (see Table 1) compared to the previous results (section A.). The case of dairy farms from Franche-Comté is interesting to discuss the performance of the strategy of differentiation. The total efficiency has increased from 72% to 88% and allows these farms to reach the efficiency level of dairy farms involved in the cost leadership strategy concerning the three plain areas. Farms from Franche-Comté have gone up sharply their pure technical efficiency (from 81% to 93%) and their scale efficiency (from 89% to 95%).

IV – Discussion

By analyzing the efficiency from the real monetary value of the outputs, it appears that farms succeed in capturing added value by implementing a strategy of differentiation to bridge the gap efficiency, like farms of Franche-Comté which are involved in PDO Comté. However, these results do not apply in the same terms in Auvergne and Rhône-Alpes whereas they are characterized by many PDO cheese productions. Their scores of total efficiency remain stable after taking into account the real value of the milk price at farm gate as if they cannot capture added value from the PDO cheese market. We assume that dairy farms of Franche-Comté have developed their practices and their assets in order to distinguish the final product (PDO Comté) to improve the willingness to pay from the final consumer and thus to capture this added value. It means the performance gap must also be caused due to higher milk prices for the Franche-Comté region that reaches a milk price at farm gate to 0,413 €/l (for 2011). It is clear that only the Franche-Comté manages to achieve its strategy of differentiation through a milk prices 20% higher compared to other regions (Bretagne and Nord-Pas-de-Calais: 0.340€/l; Lorraine: 0.338€/l). Among these, we find the Auvergne and Rhône-Alpes, which despite producing many PDO have milk prices to producers fairly close to the regions involved in the cost leadership strategy (Auvergne: 0.337€/l; Rhône-Alpes: 0.362€/l). The milk price depends as well on the bargaining skills of the dairy farmers (as they also control most of cheese-making cooperatives) when discussing within the collective organization about the calculation ratio for fresh cheeses they sell to the ripeners (Barjolle *et al.*, 2012). The differentiation we analyse above appears as a relevant strategy to improve the total efficiency of dairy farmers.

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Session 3

Combining and reconciling services on farming system and landscape scales

Posters articles

Study on range plants of Al-arshkol Mountains in semi-arid zone, White Nile State, Sudan

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Abstract. This study was conducted at Al-arshkol mountains in semi-arid zone, White Nile State, Sudan during rainy season. The sites selected included the Al-arshkol Mountains and open area nearby. The study aims to provide information that defines the range plants of the area and contributes to a better understanding of the utilization of range plants by domestic herbivores in constrained environments. A taxonomic study on range plants was conducted which was based on fresh plant specimens collected from the Al-arshkol Mountains. These specimens were prepared, examined, identified, described and documented. Traditional pastoralists' perceptions towards range plants utilization were assessed using interviews and group discussions. The taxonomic study of range plants revealed 85 species, belonging to 56 genera and 31 families. The five species that had high preference according to perceptions by pastoralists were *Cenchrus biflorus*, *Echinocloa colonum*, *Desmodium dichotomum*, *Leptadenia pyrotechnica* and *Ceratotheca sesamoid*. It was concluded that goats can select a diet superior to the average quality of the range plants. These findings may be considered as a basis for an informed management system in the Al-arshkol Mountains Locality which will be invaluable in developing sustainable management strategies for use by pastoralists.

Keywords. Range plants – Pastoralists – Interviews – Goats.

Etude des plantes de parcours des montagnes de l'Al-arshkol en zone semi-aride, dans l'état du Nil blanc au Soudan

Résumé. *Cette étude a été menée dans zones semi-arides de la montagne de l'Al-arshkol, dans l'état du Nil blanc, au Soudan pendant la saison des pluies. Les sites choisis étaient l'Al-arshkol et les espaces montagneux ouverts à proximité. L'étude avait pour objectif de fournir des informations pour mieux comprendre l'utilisation des plantes de parcours par les herbivores domestiques dans des environnements contraints. Cette étude comprenait une étude taxonomique des plantes de parcours qui se fonde sur des échantillons frais prélevés de plantes de la montagne de l'Al-arshkol. Ces spécimens ont été préparés, examinés, identifiés, décrits et documentés. Les perceptions des éleveurs traditionnels envers les plantes des parcours ont été évaluées au moyen d'entretiens et de discussions de groupe. L'étude taxonomique des plantes de parcours a révélé 85 espèces, appartenant à 56 genres et 31 familles. Les cinq espèces préférées par les pasteurs étaient* Cenchrus biflorus, Echinocloa colonum, Desmodium dichotomum, pyrotechnica Leptadenia, *et* Ceratotheca sésamoïde. *Il a été conclu que les chèvres peuvent choisir un régime alimentaire de qualité supérieure à la qualité moyenne des plantes de parcours. Ces résultats peuvent être considérés comme une base pour un système de gestion de la connaissance des localités montagneuses de l'Al-arshkol qui permettra de développer des stratégies de gestion durable des parcours par les éleveurs*

Mots-clés. *Plantes de parcours – Pasteurs – Interviews – Chèvres.*

I – Introduction

Grasslands in the wider sense are among the largest ecosystem in the world. Their area is estimated at 52.5 million km^2, or 40.5% of terrestrial area excluding Greenland. Although east African countries are in the tropics, yet their grasslands are quite diverse. Extensive grasslands are mostly in arid and semi-arid zones (Reynolds, *et al.*, 2005).

White Nile State is characterized by its strategic location in central Sudan; it is bordered by Khartoum State in the north, North Kordofan State in the west, South Kordofan State in the south east, Al-Gazira & Sinnar States in the east and the Republic of South Sudan in the south east. The state area is 39,701 km^2 and its climate is characterized by a hot, humid rainy summer and a warm dry winter. This paper provides information that contributes to a better understanding of the utilization of range plants by domestic herbivores in constrained environments at AL-arshkol Mountains in the White Nile State.

II – Materials and methods

The Al-arshkol mountains are located in EL- Dueim province, at 35 km west of the White Nile. Al-arshkol hills extend from latitude 14˚ 10’ 15’ to 14º 12’ 00’, and longitude 32º 6’ 25’ to 32º 7’ 25’. Al-arshkol and El Hilla El Jadeeda villages lie at the foot of the mountains, which forms the catchments of the Al-arshkol mountains. The rainy season lasts from May to October, but 90% of the total rains fall in the months of July and August. Rain falls in the form of showers of varying intensity and duration which does not exceed few hours (PLAN Sudan, 1997).

First plant specimens were collected fresh from the field, during September 2007/2008, from sites representing all the study area. Whole plants were collected in case of herbs, whereas twigs with leaves and flowers or fruits in case of shrubs and trees.

Plant species were first verified using sets of keys (Anderws 1950, 52, 56), (Hutchinson and Dalziel 1963), (Arbonner, 2004), (EL safori, 2000) and (Baraun *et al*., 1991).

Group discussions and personal observations were then conducted to obtain an insight of resource utilization.

III – Results and discussion

Rainfall has a major role in determining the types, forms, density, and abundance of the plant species. Generally, three strata of plant cover were observed. Some broad leaved trees have less grazing importance form the higher or top stratum while the shrubs (mostly Acacias) form the second or medium stratum. Grasses and herbs dominate the lower stratum.

The vegetation of Al-arshkol Mountains was described as part of the vegetation zones of Sudan by Anderws (1948), Smith (1949), Harrison and Jackson (1958), Noordwijik (1984), and Wickens (1991).

The dominant tree species were *Acacia tortilis* sub-spp *raddiana, Acacia oerfula* and *Balanites agyptiaca.* Other common woody species *were Acacia mellifera, Leptadnia pyrotechnica* and *Ziziphus spina christi.* Associated grasses were *Schoenfelda gracilis, Aristida* spp*,* and *Cenchrus* spp (see Fig. 1).

In the present study, 85 species, belonging to 31 families were documented. Moreover a brief botanical description of 17 important range plants species was presented (see Table 1).

Livestock are the main assets of the pastoralists in the study area upon which the livelihoods of the pastoralists depend. Livestock in the study areas are used as a source of food (milk and meat), social functions, as a means of saving, income source, risk minimization and power. All pastoral groups in the study area keep more than one species of animal mainly, goats, cattle, and sheep where advantages can be taken of the various adaptation strategies of the different animal species to diseases, feed, water shortage, and drought.

Table 1. List of the important plant species

Scientific Name	Family	Local Name	Habit
Amaranthus graecizans L.	Amaranthaceae	Lissan EL-tairr	H
Aristolochia bracteolataLam.	Aristolochiaceae	Um Galagil	H
Celosia argentea L.	Poaceae	Danb Elkadis	G
Celosia trigyna L.	Amaranthaceae	El-Bueida	H
Cenchrus biflorus Roxb.	Poaceae	Haskanit	G
Celosia argentea L.	Poaceae	Danb Elkadis	G
Commelina kotschyi Hassk.	Commelinaceae	Ibrig Elfaki	H
Corchorus tridens L.	Tiliaceae	Khudra	H
Crotalaria senegalnsis (Pers.)	Fabaceae	Sofria	H
Echinochloa colonum (L.) Link.	Poaceae	Difera	G
Euphorbia aegyptiaca Boiss.	Euphorbiaceae	Um Malbeina	H
Indigofera hochstetteri Bak.	Fabaceae	Sharaia	H
Ipomoea cordofana Choisy.	Convolvulaceae	Tabar	H
Portulaca oleracea L.	Portulacaceae	Rigla	H
Senna alexandrina Mill.	Caesalpiniaceae	Senna Mekka	S
Solanum coagulans Forssk.	Solanaceae	Gubbein	H
Tribulus terrestris L.	Zygophyllaceae	Dereisa	H
Acacia tortilis sub-spp raddiana	Mimoseae	Sayel	T

Key: H = herb. G = Grass. S = Shrub. T = Tree.

Fig. 1. Plate 1 show the north side of AL-arshkol Mountains (source. Field survey, abdelkreim, 2007).

IV – Conclusions

About 85 plant species, belonging to 31 families were documented in Al-rashkol mountains west of EL-Dwium town, White Nile state. In addition 15 species considered as very important were described. A majority of these species have economic value, providing fodder to the animals besides the traditional uses. Due to human misuse some plants disappeared such as *Commphora africana, Cymbopogon nervatus, Cymbopogon proxmus,* and *Grewia tenax.*

The dominant annual herbs and grasses were *Cenchrus bilforus, Setaria acromelaena, Cleome viscose, Aerva javanica, Aristida rhiniochloa, Zaleya pentandra* and *Indigofera hochstetteri.* The dominant woody species were *Acacia toritilis sub-raddiana, Acacia oerfula, Balanites aegyptiaca* and *Ziziphus spina chiristi* and the other woody species found in the study area *were Capparis decidua, Leptadenia pyrotechnica,* and *Acacia mellifera.* This study recommended that giving due respect to the perceptions and awareness of local people and pastoralists should improve the conservation, protection, and management of the range plans in the mountains, and more ecological studies should be carried out in this area.

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The profitability of seasonal mountain dairy farming

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Abstract. The economics of seasonal production of cheese in the mountain is compared with keeping the cows at the farm, investing in a common pasture, or in co-operative dairy farming on rural Norwegian dairy farms. The comparison is based on a linear programming (LP) model supported with Stochastic Dominance with Respect to a Function (SDRF). Mountain dairy farming involves free ranging cows on alpine pastures for about 70 days. The contents of polyunsaturated fatty acids, CLA and various antioxidants in the milk increase when cows graze alpine species rich pastures affecting the health properties, processing properties, chemical content and possibly also the flavour of dairy products. Seasonal mountain cheese production is found to be generally preferable to the other alternatives. The risks are partly related to price but also to yield and output as well as to policy since the profitability depends strongly on subsidies and premiums, and exemption for farm-processed milk in the quota. Investments in farming co-operatives were unprofitable due to less subsidy payments. The effects of calving time, introducing fertilized pastures or night pens, and supplementary feeding to extend the mountain period and sustain milk yields are examined. The premium price for "mountain products", animal welfare, and farmer co-operation on marketing are discussed.

Keywords. Linear programming – Mountain dairy products – Stochastic dominance – Risk analysis.

La rentabilité de la production laitière en montagne

Résumé. *L'intérêt économique de la production de fromage en montagne norvégienne est comparé au maintien des vaches sur l'exploitation, à l'utilisation de pâturages collectifs, ou à l'utilisation de coopératives laitières agricoles. La comparaison est faite avec un modèle de programmation linéaire (PL) basé sur la « Dominance Stochastique avec Respect de la Fonction » (SDRF). L'élevage laitier de montagne est basé sur le libre accès des vaches à des pâturages de montagne durant environ 70 jours. Les teneurs du lait en acides gras polyinsaturés, CLA et divers antioxydants augmentent quand les vaches pâturent des prairies riches en espèces de type alpin. Ceci a un impact sur les propriétés sanitaires, la transformation fromagère, la composition chimique et peut-être la flaveur des produits. La transformation fromagère est en général préférée à une autre utilisation du lait. Les risques sont en partie liés aux prix, mais également au niveau de production laitière et aux politiques publiques, le résultat économique des fermes dépendant avant tout de l'importance des subventions et de la non prise en compte dans les quotas du lait transformé en fromage. Les investissements dans les structures coopératives sont peu rentables car peu subventionnés. Nous avons étudié l'incidence de la date de vêlage, de l'utilisation de pâturages fertilisés et de parcs de nuit, d'une alimentation supplémentaire pour prolonger la période de production en montagne et maintenir la production de lait. L'importance de la surprime pour les « produits de montagne », du bien-être animal et de l'intérêt des coopératives pour la commercialisation des produits sont discutés.*

Mots-clés. *Programmation linéaire – Produits laitiers de montagne – Dominance stochastique – Analyse des risques.*

I – Introduction

Seasonal mountain dairy farming in Norway, based on grazing by milking cows on natural ranges, developed as a strategy for using large mountainous grazing areas while the agricultural area in the valley was limited. Mountain dairy farming has declined substantially over time. Roughly 57 thousand dairy cows (21% of the national herd) grazed outlying pasture in 2004. In the most important alpine dairy region Valdres, 74% of the cows grazed mountain ranges in 2007. Typical farms have from 10 to 20 cows, raise the calves, and are located at 400-700 m altitude with the alpine summer farm at 800-1100 m. The cows graze 70 days from the end of June and ca. three weeks before and one month after in the valley. They are free ranging daytime and supplementary fed concentrates. Small-scale local processing concentrate on sour cream and cheeses, but most of the milk is delivered to a dairy plant. The mountain milk is richer in polyunsaturated fatty acids regarded as beneficial to human health, i.e. the ω3 fatty acids and conjugated linoleic acid (CLA) compared to milk from both pasture and indoor feeding, and low in saturated fatty acids. A governmental support motivated by concern for cultural, historical and biological values was introduced in the 90s.

This paper is about the economics of dairy farming in mountain areas, and its objective is to compare and discuss the relative profitability of alternative systems to clarify whether local processing in the mountain has a future as a niche in the larger dairy production. The examined systems are: (i) retaining the cows on farmland pasture (FP); and (ii) maintaining or developing a mountain farm dairy business (MF). We have investigated production of 500 kg of sour cream (sold fresh) out of 5 tons of milk, or manufacturing a hard white cheese out of 20 tons. The whey is made into “brown cheese” by boiling and adding cream. Farm-processed milk is exempted in the milk quota and surplus whey and skim milk is used for feed. By investing in a (iii) Common pasture (CP) farmers would save work in the grazing season while by establishing a (iv) Farming cooperative (FC) substantial work can be saved throughout the year.

II – Materials and methods

A linear programming (LP) model representing small dairy farmers in the area has been developed. The LP technique is based on constrained optimization, reproducing the reality of farmers who maximize income while facing several constraints. The mathematical model is:

$$\text{Max } Z = c'x \text{ subject to } Ax \leq b,\ x \geq 0$$

where Z is the farmer’s objective function i.e. total gross margin (TGM) minus variable costs; x is a vector of activity levels determined in a solution; c’ the vector of marginal net returns per unit of each activity, and b a vector of constraints. The yields as well as amount of fertilizers were stipulated based on research at Bioforsk Løken. Standard values for feed requirements were employed. The feed for milk is distributed according to a lactation curve and calving on October 15 or March 15. Protein requirements are specified according to Madsen *et al.* (1995). The milk quota allows for ca. 15 cows, and processing would permit between one and five more cows. Space for cows can be obtained by selling baby-calves instead of finished bulls. All prices reflect 2010-conditions. Farmers are paid a premium per ha of farmland and animal premiums. The average milk price is NOK 5.06 per kg, with supplementary payments in the summer. For the hard cheese we assume NOK 235 a kg and subtract the variable costs of electricity, packaging, rennet etc. As for the “brown cheese”, the price is NOK 159 a kg after subtracting NOK 40 for firewood for cooking. Surplus whey and skim milk are valued as feed.

The fixed costs are stipulated based on 36 farm records (Asheim *et al.,* 2010). A fixed annual direct payment to milk producers, split among the members of a FC, is incorporated. Investments for a small production of cream encompass a cream separator, churner and a cold storage chamber. A facility for hard cheese would need water purifying equipment and a formal approval by the Food Safety Authorities. The investments for the CP consist in a milking barn (25 years), milking machines and equipment. For the FC, we investigate 60 cows and Automatic Milking System (AMS). Based on the records the available family work time is set to 2,801 h, plus 290 h for MF

(October) and 350 h (March) for moving the animals to and from the mountain, overhead work with processing etc. The CP work time saving is assumed to constitute half of overhead work and work with the animals after accounting for some work at the CP. Similar savings are assumed throughout the year for the FC. We assume 1.5 h per portion (200 l) of milk for cream, including cleaning of equipment and sale. Manufacturing the hard cheese would require 3.5 h for 200 l, and boiling of "brown cheese" 3 h for 170 l whey.

The model was specified and solved in Excel and stochastic simulation conducted in Simetar© (Richardson *et al.*, 2008), incorporated the solver. The stochastic variables encompass the farm yields assumed to be normally distributed with 10% standard deviation (SD). Moreover, for each per cent yields increase above expected yield, the energy and protein values were lowered by 0.2% due to delayed harvesting. The prices of concentrates and milk are normally distributed with SDs 15% and 10%. For the mountain cheeses and cream, a 10% price increase is possible while minimum is the price obtained for industrial products. This has been modelled as GRKS functions. The stochastic outputs of cream, hard cheese, and "brown cheese" incorporate risks of *i.a.* "misfermentation". Regarding the outlook for agricultural subsidies, premiums and other direct support we have used a GRKS function with a maximum of +10%, a most likely outcome of –30%, and a minimum of -50%. We also assume a 50% chance that the milk quota will be abolished over the period, however unless fresh milk and cheeses can be imported without customs farm milk production will then be constrained by farm building capacity, deemed to be 20% higher. This has been modelled using a Uniform function. All investments are depreciated assuming 3% real interest rate and a 1/3 chance it will go down to 2% or increase to 4%.

III – Results and discussion

If farmers choose to retain the cows at the farm roughly half the farm area will be used for pasture, the other half for winter feed and renewal. The mountain agricultural area is used for silage which is baled and transported to the farm (Table 1). Compensation per h for seasonal mountain farming by delivering the milk is slightly lowered due to extra work. Mountain farming as "a way of life", might be a reason for this choice. Extending the mountain period by feeding does not improve the economy (data not shown), however processing a small amount of sour cream to be sold directly improve the farm profit per h to NOK 110. The "break even" price seems to be about half of the sale price. Unsold sour cream can be processed into butter and the skim milk is sometimes made into Cottage cheese or the autochthonous cheeses "Gamalost" or "Pultost", a young, semi-hard cheese with caraway (*Carum carvi*). However, the market is limited due to short durability and pasteurization might be needed.

Table 1. Model solutions for FP compared with MP without processing, processing 5 tons into cream or 25 tons into cheese, and with the CP and FC alternatives. March calving

	FP	MP	MP 5 t	MP 20 t	CP	CF
Farm silage (pasture), ha	9.2 (9.9)	15.5 (3.7)	15.3 (3.8)	14.7 (4.5)	16.6 (2.5)	10.8 (8.4)
Mountain silage (pasture), ha	6.0 (0)	0 (6.0)	0 (6.0)	1.6 (4.4)	0 (6.0)	6.0 (0)
Dairy cows, heads	14.9	14.9	15.7	18.7	14.9	14.9
Gross output, incl. support, NOK	926,006	962,477	1,017,078	1,434,618	926,006	873,855
Support mountain farming, NOK	0	32,000	32,000	32,000	0	0
Gross Margins, NOK	520,284	565,714	598,411	1,031,242	532,699	472,989
Fixed costs and hired work, NOK	224,602	237,388	250,705	354,396	230,970	308,384
Farm profit, NOK	295,682	328,326	347,706	676,846	301,729	164,606
Farm profit per h, NOK	106	104	110	215	108	77

The hard cheese production makes the highest profit as our basic prices are about 65% higher than needed to break even. A considerable amount of work has to be hired. A common storage for cheese from several farms would lower work with turning, which could be mechanized. Co-operation on marketing cheese sold off-season is also possible. Branding of mountain products like in some European countries (Santini, 2013) are available to farmers under the Norwegian "Matmerk" system. The CP seems to improve the economy slightly and more so if some support for mountain farming can be obtained. Particularly farmers giving priority to vacation during the summer should consider the CP. Due to loss of subsidies and substantial investments the FC seems uncompetitive in spite of substantial work time savings.

The cumulative distribution functions (CDF) of farm profit in Fig. 1 show that the MF-cheese production alternative is more risky with a wider range in the solutions however, the considered risks still places MF-cheese on the upside of the others. The probability of a farm profit above NOK 200,000 is estimated to 0.41 for the FC, compared with 0.94 for the CP and 0.91 for the FP alternative. For FC the chances of a negative result is somewhere between zero and one per cent. An analysis of SDRF gave the following preferences: (i) MP 25 tons; (ii) MP 5 tons; (iii) MP March (milk); (iv) CP March; (v) FP March; and (vi) FC March. The ranging was the same for risk neutral decision makers (RAC = 0) and extremely risk averse decision makers (RAC = 4) (Anderson and Dillon, 1992).

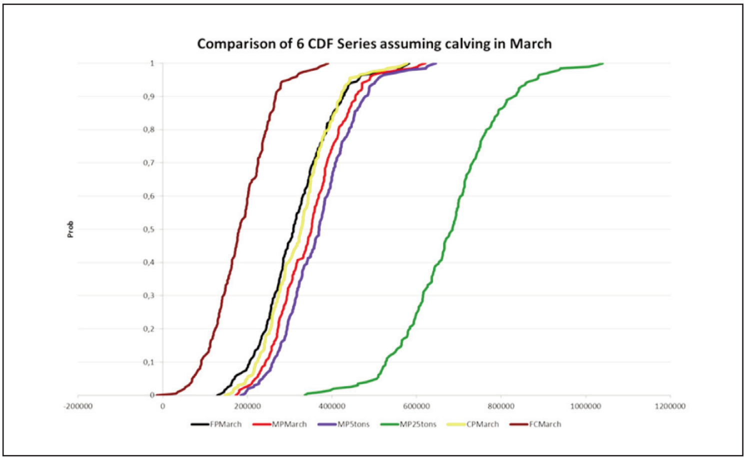

Fig. 1. The CDFs of farm profit for the systems, simulating the stochastic variables 200 iterations.

IV – Conclusions

Smaller family dairy farms should consider maintaining the seasonal dairy business activity if they need to find more employment since the activity pays about similar wage per h as retaining the cows at the farm. Alpine pasture products are typically richer in PUFAs regarded as healthy and important to prevent cardiovascular diseases and have a lower content of unfavourable, saturated fatty acids, but this is not reflected in the price paid by the dairy. The study indicates that developing the mountain processing business might be a profitable and not particularly risky strategy. This is partly due to the support for such production but also due to the high market prices obtained for mountain products and exemption for farm processed milk in the quota. Marketing and co-operation on marketing might become critical for a long run mountain business development.

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Manure nitrogen excretion from dairy cattle on the valley floor of Valle d'Aosta (NW Italy)

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Abstract. The determination of nitrogen excretion in breeding systems is essential for establishing suitable agro-environmental measures. In 2013, a study was carried out to evaluate the amount of N excreted by livestock on the valley floor in Valle d'Aosta, where cattle breeding is based on cow milk production for cheese making. Data were collected through a survey carried out on 32 farms, representing 6.5% of the cows bred in the region, mostly of rustic local breeds Aosta Red Pied, Black Pied and Chestnut. N excretion in the manure was determined as the difference between inputs (forages + concentrate feeds) and outputs (milk + liveweight gain), assuming that N loss by volatilization was 28% of the total N excreted. Mean weight of cows was 512 ± 72.7 kg and lowland milk production was 2,430 ± 912 kg per cow. Average diet for milking cows was 7.9 ± 1.7 kg DM d^{-1} of first cut hay, 3.3 ± 1.5 of second cut hay and 3.3 ± 1.3 of concentrate feeds, with 121 ± 12 g kg^{-1} DM of Crude Protein. The mean N excretion per Livestock unit (LU) onto the valley floor of Valle d'Aosta was 37 ± 12.6 kg LU^{-1}.

Keywords. Nitrogen excretion – Dairy cattle – Indigenous breeds – Mountain farming.

Excrétion d'azote dans les déjections des bovins laitiers dans le fond de vallée en Vallée d'Aoste (Italie du Nord-Ouest)

Résumé. *L'évaluation des excrétions d'azote dans les systèmes d'élevage est fondamentale pour établir des mesures agro-environnementales appropriées. En 2013, une étude a été menée pour évaluer la quantité d'azote dans les effluents de ferme dans le fond de vallée en Vallée d'Aoste. Les données ont été récoltées par une enquête menée dans 32 exploitations, réunissant 6,5% des vaches laitières de la région, dont la plupart appartiennent aux races locales Valdôtaine Pie Rouge, Pie Noire et Châtaigne. L'excrétion d'azote par les déjections animales fut déterminée comme la différence entre les intrants (fourrages, aliments concentrés) et les sorties (lait, gain de poids vif), en faisant l'hypothèse d'une perte par émission gazeuse de 28% de l'azote excrété. Le poids moyen des vaches était de 512 ± 72,7 kg et la production de lait dans le fond de vallée de 2430 ± 912 kg par vache. Les vaches en production laitière recevaient en moyenne 7,9 ± 1,7 kg MS* d^{-1} *de foin de première coupe, 3,3 ± 1,5 de foin de deuxième coupe et 3,3±1,3 d'aliments concentrés, avec une teneur moyenne de 121 ± 12 g* kg^{-1} *MS de Matières Azotées Totales. L'excrétion moyenne dans le fond de vallée s'avéra être de 37 ± 12,6 kg* UGB^{-1}.

Mots-clés. *Excrétion d'azote – Bovins laitiers – Races locales – Agriculture de montagne.*

I – Introduction

The Nitrates Directive (91/676/EEC) limits the amount of nitrogen (N) spread onto agricultural land to a maximum of 170 kg ha^{-1} y^{-1}. Therefore, it is necessary to know the actual amount of N excreted from livestock to evaluate its environmental impact and establish suitable agro-environmental measures. In Italy, Ministerial Decree 07/04/2006 established standard values of excreted N for different species and categories of animals, stating that the N on land, deriving from dairy cow manure, is equal to 83.5 kg $head^{-1}$ y^{-1}, assuming a 28% N lost in atmosphere during waste removal and storage. This value derives from research studies in northern Italy, carried out mainly on specialized dairy breeds such as Holstein and Brown Swiss (Xiccato *et al.*, 2005).

In Valle d'Aosta, livestock is mainly made up of dairy cattle whose milk is primarily utilized for the production of Fontina PDO cheese. The production specifications for this cheese impose that the milk must come from the local cow breeds i.e. the Aosta Red Pied (ARP), Black Pied (ABP) and Chestnut (AC), whose diet must be based on local forage (hay and grass). These breeds have a low milk production, but they are able to take advantage of the rough forages offered by the permanent meadows and the mountain summer pastures which almost entirely account for the agricultural land in Valle d'Aosta. Responding to a request put forward by the regional administration, we carried out a research study aimed at determining the nitrogen production in manure from dairy cattle on the valley floor in Valle d'Aosta.

II – Materials and methods

In 2013 a sample of 32 farmers distributed throughout all over Valle d'Aosta was interviewed to collect data on input and output of the farming system, so that the following equation could be calculated:

$$N_{manure} = N_{diet} - N_{products} - N_{gaseous\ losses}$$

According to the formula proposed by ERM (2002), we considered N in forage and feed as N_{diet} and N in milk and in liveweight gain as $N_{products}$.

In spring and autumn, before and after being moved to the upper mountain pastures, many of the animals graze pastures on the valley floor, always being housed in cowsheds during the night. Since it was not possible to determine the quality and the quantity of the grazed grass on the different farms, we assumed that, during the whole period spent on the valley floor, N_{diet} was equivalent to that of a ration based on hay and concentrate feed given in the cowshed. Crude Protein (CP) contents in first and second cut hay were determined by Near Infrared Reflectance Spectroscopy, while CP in feed was recorded from the label. Only milk produced on the valley floor was taken into account to determine $N_{products}$, and as far as quantity and quality were concerned, N in meat was considered to be 24 g kg^{-1} LW (Grignani, 1996). To compare our results to the national standard values, N lost through gaseous emission was assessed as being 28% of total N in excreta, according to Xiccato *et al.* (2005). Since the heart girth circumference is quite an accurate way of determining an animal's actual weight (Wanderstock and Salisbury, 1946), we measured it in a sample of 225 cows and then converted the measurements to estimate body weight. For the transformation of animal heads into Livestock Units (LU), according to the criteria adopted by the Regional Government in the Rural Development Programme, we considered 1 LU for bovines more than 2 years old, 0.6 LU for bovines from 6 months to 2 years, 0.4 LU for calves less than 6 months old and 0.15 LU for sheep and goats.

The 32 farms were classified, using the SPSS® software, by cluster analysis based on herd size, meadow surface on the valley floor and the length of the summering period. Data were standardised using Z-scores and we used Ward's method for the clustering and the squared Euclidean distance as a measure of similarity. The variables were then submitted to the Kruskal-Wallis one-way analysis of variance and Spearman's correlation was calculated on the data set.

III – Results and discussion

The 32 sample farms raise 1,943 bovines, 1,121 of which are dairy cows, which respectively represent 5.9% and 6.5% of the total number bred in Valle d'Aosta. Herd sizes varied from 10.1 to 145.5 LU, with an average of 54.0 LU per farm; 23 farms usually send animals to subalpine pastures in summer for a period of around four months.

As expected, the cow diet differed during lactation and dry periods (Table 1). Lactating cows received 7.9 kg DM d^{-1} of first cut hay, 3.3 kg DM d^{-1} of second cut and 3.3 kg DM d^{-1} of feed, with a CP content of 121.1 g kg^{-1} DM, while dry cows received more first cut hay, little second cut hay and hardly any concentrate feed.

Since the summer production of milk from subalpine pastures was not recorded, the mean production per cow on the valley floor resulted as being about 2,400 kg of milk. This value is lower than the breed standard (Madormo *et al*., 2012), but consistent with lowland milk production in Valle d'Aosta (Bassanino *et al*, 2011). The CP content in milk was about 33.0 g kg^{-1}.

Table 1. Main features of the diet and production of dairy cows in the sample

	Lactating cows		Dry cows	
	Mean	**SD†**	**Mean**	**SD†**
First cut hay (kg DM d^{-1} cow^{-1})	7.9	1.7	9.2	2.5
Second cut hay (kg DM d^{-1} cow^{-1})	3.3	1.5	1.2	1.8
Concentrate feed (kg DM d^{-1} cow^{-1})	3.3	1.3	0.4	0.7
CP in the diet (g kg^{-1} DM)	121.1	11.9	106.0	15.4
Milk production on the valley floor (kg cow^{-1})	2,430	912.3		
CP in milk (g kg^{-1})	33.0	1.1		

† SD: standard deviation.

Mean weight of cows resulted as being 512 ± 72.7 kg, with significant difference (p = 0.002) between lighter ARP (505 ± 72.3 kg; n = 184), on the one side, and heavier AC and ABP, which are registered in the same Herd Book, on the other (542 ± 67.5 kg; n = 41).

The cluster analysis divided farms into three groups (Table 2). Cluster A groups smallest farms, with an average of about 30 LU and 9 ha of lowland grassland, sending their animals to highland pasture for 117 days in summer. Farms in cluster B are intermediate (45 LU and 19 ha of meadows) and their livestock stays on the valley floor all year long, while the biggest farms in cluster C (82 LU and 31 ha) send it to mountain summer pastures for about 130 days.

Table 2. Main features of the sample and of the three groups of farms classified by cluster analysis

	Total sample (32 farms)		Cluster			Kruskal-Wallis test *p*-values
	Mean	**SD†**	**A (11 farms)**	**B (9 farms)**	**C (12 farms)**	
Livestock Units (LU)	53.2	31.4	29.5	44.6	81.5	0.000
Dairy cows	35.0	22.6	18.6	28.7	54.8	0.000
Lowland grasslands (ha)	20.1	15.7	9.0	19.1	31.0	0.000
Summering period (d)	89.5	59.6	116.8	0.0	131.7	0.000
Nitrogen input and output on the valley floor (kg LU^{-1})						
N_{diet}	60.3	19.2	51.9	84.2	50.1	0.000
$N_{products}$	9.5	3.4	7.5	10.8	10.4	0.056
N_{manure}	36.6	12.6	32.0	52.8	28.6	0.000

† SD: standard deviation.

The mean production of N_{manure} during the period spent on the valley floor resulted to be 36.6 kg LU^{-1}, with significant differences between the three groups of farms, ranging from a minimum of 28.6 kg LU^{-1} in cluster C to a maximum of 52.8 in cluster B (Table 2).

As expected, the production of N_{manure} on the valley floor was positively correlated to the length of the period spent in lowland areas (Table 3). It was also significantly correlated to the quantity of N deriving from forage in the diet but neither to that deriving from concentrate feed nor to the proportion of CP in the diet nor to the production of milk.

Table 3. Coefficients of Spearman's correlation between N_{manure} excreted on the valley floor and some of the main variables

	N_{manure} on the valley floor (kg LU^{-1})	*p*-values
Period spent on the valley floor (d)	0.796	0.000
N in the diet of lactating cows, deriving from forage (kg d^{-1})	0.495	0.004
N in the diet of lactating cows, deriving from feed (kg d^{-1})	-0.051	0.783
CP in the diet of lactating cows (g kg^{-1} DM)	0.332	0.068
Milk production on the valley floor (kg cow^{-1})	0.349	0.051

IV – Conclusions

The weight of the cows and the quantity of N excreted in the manure on the valley floor of Valle d'Aosta by the cattle belonging to the local breeds resulted to be quite lower than those of more specialized dairy breeds (Dal Maso *et al*., 2009). This can be linked to the custom of sending cattle to highland pastures during summer but, since we also found this difference on farms which keep animals on the valley floor all year long, we deem it depends mainly on the animals diet, based on forage from permanent grasslands, with a moderate complementation of concentrate feed.

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Sustainability of sheep farming systems: the case of the northern area of Laghouat/Algeria

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Abstract. Algerian steppe rangelands are in crisis. Recurrent droughts and increasing anthropogenic pressure, on space downsizing increasingly, are exacerbating the already downgrading steppe ecosystem. This situation is obviously not without effects. Rangelands are highly degraded giving rise to a recovery rate not exceeding 50% thereby exposing the rest of the rangelands which become vulnerable to desertification. In socioeconomic terms, we are witnessing the gradual but certain disappearance of traditional pastoralism. The aim of this paper is to analyse the strategy adopted by sheep herders to deal with these changes. The results of the typology (ACM) survey carried out in the northern part of the province of Laghouat show that the traditional way of life linked to the transhumance is disappearing. In fact, the remaining farmers (about 10% of respondents) keep on practicing this way of life with more than 100 cattle head. Most farmers with herd size between 20 and 80 head tend to settle down, whereas 90% of them use tents as a permanent shelter. This settlement results in new modes of farming such as the five-fold increase in arable land.

Keywords. Algerian steppe – Agro-pastoralism – Farming system – Transhumance – Settlement.

Durabilité des systèmes d'élevage ovins : lec as de la zone nord de la wilaya de Laghouat /Algérie

Résumé. *Les parcours steppiques Algériens sont en crise. Les sécheresses récurrentes et la pression anthropique croissante sur un espace de plus en plus réduit, accentuent le déséquilibre déjà très avancé de l'écosystème steppique. Cette situation n'est évidemment pas sans effets. Les parcours sont très dégradés donnant lieu à un taux de recouvrement ne dépassant pas les 50% exposant ainsi le reste des parcours, devenus vulnérables à la désertification. Sur le plan socioéconomique, on assiste à la disparition progressive, mais certaine du pastoralisme traditionnel (Le Houérou, 1985 ; Nedjraoui et Bedrani, 2008, Daoudi* et al.*, 2013). Cette étude a pour but de déterminer et d'analyser la stratégie adoptée par les éleveurs ovins, pour faire face à ces bouleversements. Les résultats de la typologie (ACM) de l'enquête réalisée dans la zone Nord de la wilaya de Laghouat, montrent que le mode de vie traditionnel lié à la transhumance est en voie de disparition. En effet, seul 10% des enquêtés continue de le pratiquer avec un cheptel supérieur à 100 têtes. Par contre, la majorité des éleveurs, dont la taille du cheptel varie entre 20 et 80 têtes, ont tendance à se sédentariser. 90% des enquêtés ont substitué les tentes au profit des habitations en dur. Cette sédentarisation a donné lieu à de nouveaux modes d'exploitation comme l'extension des superficies labourées qui a été multipliée par cinq.*

Mots-clés. *Steppe algérienne – Agro-pastoralisme – Système d'élevage – Transhumance – Sédentarisation.*

I – Introduction

A broad consensus has emerged around the advanced state of degradation of the Algerian steppe as well as the causes (natural and anthropogenic) leading to this situation. Recurrent droughts and increasing anthropogenic pressure on little space, downsizing increasingly, are exacerbating the already downgrading steppe ecosystem. In addition, the high degree of mechanization, development land, mass imports of animal feed by government are additional artificial elements favouring large herds. The issue is related to what strategies pastoralists and agro-pastoralists can develop due to the gradual but certain disappearance of traditional pastoralism (Le Houérou, 1985; Nedjraoui et Bedrani, 2008; Daoudi *et al.,* 2013).

II – Materials and methods

The method used to determine and analyse strategies adopted by sheep herders to deal with these changes is mainly based on direct site-investigation. The investigation was carried on a sample of 600 breeders of a population of 6000 in the scattered area in the north of Laghouat Department (Wilaya).

Three variables have been considered: the plowed fields, lands under cultivation and housing system. Using the GPS and the Map Info software, we have mapped each one of these parameters. Statistical analysis of the data collected was performed using the Multiple Correspondence Analysis (MCA) and Hierarchical Ascending Classification (CHA).

III – Results and discussion

1. Characterization of respondents (typology)

This classification allowed us to distinguish two main classes (C1, C2). Class 1 (C1): In this class, we find individuals under C1a who are located in the positive part of axis 2 and C1b and C1c are located in the negative part of the first axis.

Class 2 (C2) is located in the positive side of axis 1. In addition, it consists of two sub-classes with 110 and 120 individuals, respectively.

This class distribution seems heterogeneous. Their characteristics are as follows: Class 1 (C1) - breeders formed by subclasses c1a (breeders) c1b (cow-feeders) c1c (feeders); Class 2 (C2) farmers formed by c2a subclasses (intensive) c2b (extensive). Cf Table 1.

The classes mentioned are drawn by an in-depth diagnosis of individuals' responses illustrated in the questionnaires in Table 1.

Table 1. Summary table of classes

C1 breeders			C2 farmers	
C1a	C1b	C1C	C2a	C2b
80	189	101	110	120

2. Indicators of change

To understand the impact of exploitation modes, we try to interpret the results according to the classification results of the statistical test and the influence of each variable on these classes concerned. To understand changes going on, we will first deal with farming (with its three sub-classes) and then, with crop production (with its two sub-population).

A. Farming

Almost all individuals of this class perceive that climate change impacts the livestock systems known in this region.

The first subclass (C1a) confirms that the practice of transhumance is not the same as in the past. Moreover, there is a downsizing of transhumance in distance and time. This change is due primarily to rangeland degradation transhumance areas and the disappearance of the majority of water points. The number of livestock, owned by contribution, is reduced by 60% of respondents in this class. For example, the town of Hadj Mechri does give evidence of the evolution of the type of shelter by a synchronic comparison between 1968 and 2008.

The second subclass (C1b) is considered as a transitional subclass between the first and the third: 90% of these individuals have given up transhumance and have become sedentary. They use a private space. They are supported by supplementary feeding compensates. Food shortages, resulting from these courses, provide a small part of food. This sub-population confirms that climate change imposes new conditions. It can be explained by the transition from one way of a semi-extensive livestock to ranching fashion.

The third subclass (C1c) consists of feeders who have a small number of sheep periodically renewed, with small areas for forage. This sub-population suggests that intensive breeding is currently more profitable. This is explained by the high travelling costs and the fact that the breeding system no longer bears the burden of sheep as before: 80% of them have wells for irrigation and watering.

A seasonal shift observed by farmers is confirmed by 90% of this class. It can be summarized as follows:

(i) Frost periods are from January until May and require an additional power supply and more loads.

(ii) Lack of rains: this phenomenon requires that farmers change some of their mowing practices and delay other practices (transhumance, immunization, control, etc.).

(iii) Effects on parturition in sheep.

(iv) Sheep losses (see a circle of correlation): there is a high correlation between the variables and the number of sheep lost: 80% of this class shows that the mortality rate is higher than before, despite the intervention of the State in immunizing against the MLRC, permanent presence of veterinarians, and high rates of climate hazards (flood, hail, wind and sand).

B. Agriculture (crop production)

The second class needs more understanding. It is characterized by producing crops responding to the needs of the sheep. Nearly 60% of respondents are expanding their areas. This has a high correlation with the practice of the technical rotation as it is shown in the circle of correlation (axe2. F2 - Fig. 1). Drilling and storage basins are used, which means the adoption of neo-irrigation (sprinkle, drip). These changes clearly reflect the passage of ancestral subsistence farming to modern agriculture for commercial purposes. Respondents of this class confirm that rain-fed agriculture contribution is limited and precipitation became random, even though traditional wells produce a limited amount of water. The same applied to soils that become poor which require a rest period of at least one season. Nearly 80% of individuals of this class say that climate change has a direct impact on the planting dates. Temperature instability causes harvest delay. This phenomenon might become a major threat to the quality and quantity of agricultural production. Two sub-classes are constructed.

The first subclass **(C2a)** is based on intensive agriculture. It is characterized by the establishment of monoculture (potato, onion) with extensive use of chemical inputs (insecticides, pesticides, fertilizers, soil-enhancing elements) and mechanization. Despite the means and efforts, 70% of respondents reported that the yield is still low and especially in cases where there was a preceding crop. This forces farmers to change the plots every year (extension, location). Soil loss is amplified by the various degradation factors (biotic and abiotic).

The second subclass **(C2b)** is based on extensive agriculture. The production is low: 70% of individuals are on crop. There is a lack of irrigation facilities. Rain is considered as the only means of irrigation. This eliminates the proficiency in production with an unstable output at this time: 30% of this sub-population are specialized farmers in local agriculture (lettuce, spinach, parsley, coriander, mint) in small areas using traditional means of irrigation (irrigation channel). These individuals suggest that the frozen period interrupts their activity. They are sometimes forced to repeat the sowing operation two or three times with an additional quantity of seed.

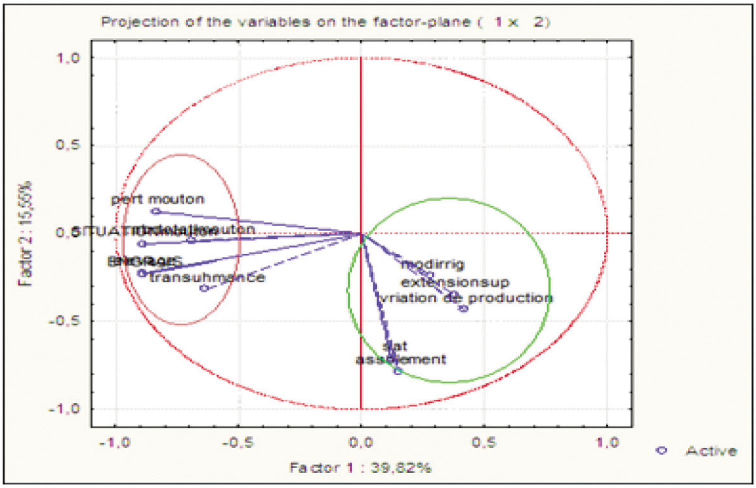

Fig. 1. Diagram components after rotation in space.

In the light of the map in the town of Hadj Mechri land, we can see that the plowed area is a fifth of the total area (12040 ha on 65270 ha) of the town. We can note also that the district of Hadj Mechri is a common steppe but clearings made by the agro-pastoralists have contributed to reduce, in the long run, the expansion of arable land. According to a study by the HCDS conducted in 2008, the town of Hajj Mechri only has an arable surface area of 1200 ha that is reflected in the alarming increase share of plowed land in the study area. To reverse the phenomenon, urgent actions are needed.

Our survey revealed a wide difference in comparison with statistics published by the DSA of Laghouat. In fact, it considers that the total area plowed covers 1100 ha while the results on the ground are about 12,040 ha, i.e a difference of 10,940 ha.

IV – Conclusions

The situation of the steppe, reflected in particular by the low forage supply, forced agro-pastoralists to change the breeding system and adopt a new system. All agro-pastoralists tried to counteract the negative effects of these changes, almost plowing (clearing), so having resort to irrigation in order to produce a feed supplement for the intensification of livestock production (fattening). Transhumance, once systematically practiced by all agro-pastoralists, is maintained actually mainly by ranchers. The decline of traditional tribal social organization resulted in the abandonment of traditional housing systems (tent) in favour of solid construction shelters.

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Quality labels: a way to support the development of pastoral resources? Methodological insights based on the monographic analysis of Hasi Region – Northern Albania

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Abstract. BiodivBalkans is a research-action project in Albanian mountains, aiming at crossing environmental injunction of biodiversity conservation with economic objectives of rural development. The main hypothesis is that the building process of an appropriate label of sustainable development could provide an effective tool for territorial development and conservation of agro-biodiversity. Our understanding of the present situation in Hasi region is based on a historical approach both of landscape and agrarian system. An analysis of both village evolutions and farm trajectories allows identifying a way of further development, based on specific niche markets. A collective action is needed to build adequate labels of origin and quality, around an endemic breed of goat (the Hasi goat) and its products: kid meat, dried meat and cheese.

Keywords. Albania – Pastoralism – Agrobiodiversity – Quality labels – Agrarian systems.

Les labels de qualité : un moyen pour développer les ressources pastorales ? Approche méthodologique basée sur l'analyse monographique de la région du Hasi – Albanie du Nord

Résumé. *BiodivBalkans est un projet de recherche-action sur les montagnes albanaises, ayant pour objectif de combiner les injonctions de conservation de la biodiversité et celles du développement rural. L'hypothèse est que la construction de signes de développement durable peut procurer un instrument efficace de développement territorial et de conservation de l'agro-biodiversité. Notre appréciation de la situation est basée sur une approche historique des paysages et des systèmes agraires. Une analyse des villages et des trajectoires des systèmes de production en relation avec les disponibilités fourragères et les pâturages, permet d'envisager un développement de ce système agropastoral via des marchés de niches identifiés. Une action collective de construction de signes de qualité et d'origine est nécessaire, autour d'une race de chèvre endémique de la région (la chèvre du Has) et de ses produits principaux : la viande de cabri, la viande séchée et le fromage.*

Mots-clés. *Albanie – Pastoralisme – Agrobiodiversité – Labels de qualité – Systèmes agraires.*

I – Introduction

BiodivBalkans is a research-action project in Albanian mountains, aiming at crossing environmental injunction of biodiversity conservation with economic objectives of rural development. A particular focus has been made on Hasi region, in the North-East part of Albania, at the border with Kosovo. In this rural region, characterized by an agro-sylvo-pastoral way of farming, the main hypothesis of BiodivBalkans project's approach is that the building process of an appropriate label of quality/origin/sustainability/equity may provide an effective tool for territorial development and conservation of agro-biodiversity (Bérard and Marchenay, 2006). However, this positive relationship between biodiversity and appropriate labels of sustainable development cannot be taken for granted (Jonhs *et al.*, 2013). Many critical reviews highlight the need of further developments in the assessment of agriculture and biodiversity conflicts and their resolution, both at farming scale as well as in a landscape perspective (Cavrois, 2009; Henle *et al.*, 2008). This paper presents a descriptive and narrative approach, that articulates an agrarian system description (pastoral resources, practises and products) with a narration of landscape evolutions, in order (i) to understand the natural resources construction process – assuming the intrinsinque link between anthropic activities and biodiversity production, particularly in Mountainous Mediterranean ecosystems (Sirami *et al.*, 2010); and (ii) to determine the range and perimeter of a possible collective action, that would promote a sustainable territorial development.

II – From agro-sylvo-pastoral to pastoral systems: a century of transformations of landscape and farming systems in Hasi region

Three main periods have been defined (Garnier, 2013; Medolli, 2013). (i) *Hasi region as a "passive territory" in pre-communist times.* Due to its harsh mountainous Mediterranean climate and its important forest cover, the Hasi region was a "poor territory", characterized by a low yields of subsistence crops (mainly wheat, barley and rye), and specialized in pastoral livestock breeding. Winter forage scarcity was a strong limiting factor for the expansion of sheep and goat flock size, except for the large patriarchal families that can drive large flocks for inverse transhumance in Kosovo plains. (ii) *Communist massive agricultural specialization*. Starting from the drastic agrarian reform of 1945 led by the Communist Party, forests, pastures and wetlands were fully nationalized whereas agriculture lands were entering into a steady but full process of collectivization (Sjöberg, 1991). The agricultural communist model was based on the *ager* intensification and expansion. These intensification trends led to strong modifications of the previous pastoral system. Cooperatives were settled on the less productive areas and specialized in livestock breeding, whereas two State farms were created on recently deforested areas and specialized in cereal and fruits productions. The Fierza hydroelectric dam building (1971-1978) intensified this process. The tiny but fertile areas and pasture lands in the Drini plain were flooded, leading to the displacement of some villages on the recently deforested uplands: around 5,300 ha of new agricultural lands were opened. These large cultivated areas were massively mechanized, systematic irrigation coupled with larger use of chemicals and fertilizers led to a rapid increase of the production. (iii) *Transition period: decrease of agricultural production and small ruminant husbandry*. Starting from 1991, the so-called "transition period" is characterized by the privatization of production means and agricultural lands. Cooperatives and State farms were dismantled and private property restored with the enactment of Law 7501, all the land was divided up among villagers on a per capita basis. Under these new political and economic conditions, the newly created small scale private farms could not maintain sufficient investments: irrigation system, agriculture machinery, inputs, etc. (Civici and Lerin, 1997). In the Hasi region, intensive fruit trees orchards on hilly slopes were abandoned as well as intensive husbandry; parts of previous large agricultural areas were turned into individual plots exploited for auto-subsistence farming, other were converted to pastures or simply abandoned to spontaneous reforestation. Livestock was reduced to mixed flocks of 10 to 50 heads (cattle and small ruminants) per farm, summer pasture practises were disused. At the same time, temporary or permanent emigration was massive, especially to England. The 1997 crisis and Kosovo conflict (1999-2000) at the border also deeply altered Hasi territory and its development.

III – A "residual pastoral system"

Therefore, the communist agro-pastoral system characterized by a dominant component of agriculture has suddenly collapsed, leading to the current situation in Hasi district that can be defined as a sort of "residual pastoral system", based on a multitude of very small mixed crop and livestock holdings. As grazing areas are not a limiting factor in this "last remaining people" situation, feeding strategies are mainly based on pasture on non-cultivated land. Nowadays, livestock farming activities are reshaping a new agrarian landscape around different evolution patterns. Different village types are identified: (i) villages from the plateau hilly area (from 500 to 700 meters), characterized by high production capacity: easy access to hilly area pastures, good agricultural and fodder production capacity; (ii) villages from the plateau hilly area, with low production capacity, defined by good access to hilly pastures and/or mountain pastures, with limited agricultural fodder production capacity; (iii) villages from the perched plateau (1,200 meters), identified by good mountain pasture access, good fodder production capacity, but a low agricultural production. From this first village scale typology, the farms are classified into three main development trajectories according to the methodology used by Biba (Biba *et al.*, 2013) :

(i) *Expanding exploitations*: middle to "large" mixed farming exploitations, characterized by livestock specialization – growing mixed or specialized flocks from 50 heads and more – with further projects of development, based on paid workforce and capital availability.

(ii) *Declining small ruminant exploitations*: small to average mixed farming exploitations, minimally exploited, characterized by small to middle size flocks (from 10 to 50 heads) and complementary agricultural production with few perspective of takeover in a near future.

(iii) *Agricultural specialization*: a rather unusual category in Hasi region, characterized by agricultural (cereal and fruits) farming specialization, based on leasing and mechanization of additional agricultural lands, whereas livestock actives remain secondary.

IV – Building appropriate labels of sustainable development

Considering this typology of farms trajectories in its context, what kind of appropriate labels might be proposed to cross agrobiodiversity conservation and local rural development? It seems that both in terms of landscape ecology and capacity of collective action, this process has to valorise the agro-sylvo-pastoral systems of farming. Different kinds of labels can be used, all widely employed in the European Union (Sans *et al.*, 2011): (i) labels of origin (mainly geographical indications), which are related with the *terroir* (Hasi region), are State guaranteed labels under the Albanian law; (ii) private collective marks can be declined into: labels of *equity* or "fair trade", which are private certification marks; labels of *environmental quality* (organic mainly); and at large, labels of *sustainability* in relation with protected areas, landscape conservation, natural parks, etc. These labels can be used alone or in combination.

Hasi goat breed is endemic to the region (Hoda *et al*., 2011). The breed and its products have been identified as the most adequate first step toward a sustainable rural development strategy (Medolli, 2013). Homogeneous flocks had been identified especially in the plateau area, characterized by its geomorphological "doline" system (Krutaj *et al.*, 1998). These systems of funnel-shaped hollows in a karst region allow higher forage production on a poor limestone soil. Moreover, Hasi meat products are nationally known for their quality. Products that could be valorised are mainly: kid meat, dried meat (*pastërma*), cheese. Even if today, most of dairy processing is homemade, market opportunities seem to appear and some small size factories are selling Hasi cheese until Tirana, the capital city of Albania. To be chosen and developed, the adequate label of sustainable development corresponding to these products needs a shared diagnosis, elaborated jointly by farmers, processors and other actors of the value chain (shareholders); and territorial authorities, national agencies, environmental NGOs, etc. (stakeholders). The aim of this process is to identify (i) appropriate actions in terms of breed selection and promotion; (ii) best pastoral practices in favor of landscape and ecology; (iii) their impact on the quality of the products, perceived by consumers; (iv) appropriate livestock farming system incentives as well as value chain; (v) possible products identification and definition – book of requirements – likely to go toward a GI related to the Hasi *terroir*; (vi) products marketing chain toward final consumers and retailers.

V – Conclusions

A comprehensive sustainable development approach – agro-biodiversity valorization and conservation – requires a reflexive and practical iterative method all along the collective action process. This process brings shareholders and stakeholders together with a common understanding of these challenges, and finds the best fit between private interests, management of the club/common good (labels), and public good (agro-biodiversity conservation). It has to be complementary to the breed identification process, environmental assessment, production system analyses and support to appropriate pastoral practices. A set of various labels can be combined in order to fit with the different challenges of natural resources conservation, livestock farming development and market opportunities. Obviously, as shown by previous GI success stories, there is no simple recipe: all cannot be done at the same time and collective dynamics may start from a very small coalition (Boutonnet *et al*., 2009).

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Brisket disease of dairy cattle and risk factors in Mantaro Valley, Peru

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Abstract. The aim of the study was to determine if the brisket disease is a limiting factor of the development of the dairy production and to identify its risk factors on the basis of farmer's perception. The work has been carried out in the provinces of Concepcion, Jauja, Huancayo, Yauli and Chupaca, belonging to the Mantaro Valley in Peru, during the period of drought of 2013. Information was compiled by survey made with 86 producers, and thanks to interviews with several veterinarians, engineers and inseminators of the valley. The impact of the problem and its factors were identified thanks to farmer's perception. Results showed that the incidence of brisket disease is decreasing these last eight years in the Mantaro valley. It concerns today about 4% of the cows. Main risks factors identified are related to cattle management (nutrition, welfare, health), genetic selection (use of insemination, selection criteria) and the environment (hypoxia, cold, solar radiation). The use of artificial insemination seems to be a major risk factor, mainly because farmers are not trained or prepared to use these types of cows. In fact, most farmers reported problems when they started a genetic specialization of the cattle for dairy production. Therefore, more complete information given to farmers and implementation of selection schemes appropriated to mountains rearing conditions would be a good alternative.

Keywords. Brisket disease – Bovines – Dairy cattle – Risk factors – Mantaro valley – Peru.

Mal d'altitude des bovins laitiers et facteurs de risques dans la Vallée du Mantaro, Pérou

Résumé. *L'objectif de cette étude était de déterminer si le mal d'altitude est un facteur limitant du développement de la production laitière et d'identifier les facteurs de risque, à partir de la perception de l'agriculteur. Le travail a été réalisé dans les provinces de Concepción, Jauja, Huancayo, Yauli et Chupaca, appartenant à la vallée du Mantaro, durant la saison sèche en 2013. L'information a été obtenue par des enquêtes réalisées chez 86 producteurs, ainsi qu'au cours d'entretiens avec plusieurs vétérinaires, ingénieurs et inséminateurs de la vallée. L'impact du problème et ses facteurs ont été identifiés à partir de la perception de l'agriculteur. Les résultats ont montré que l'incidence du mal d'altitude est en diminution durant ces huit dernières années dans la vallée de Mantaro. Il touche aujourd'hui environ 4% des vaches. Plusieurs facteurs de risques identifiés sont liés à la conduite du bétail (nutrition, bien-être, santé), la sélection génétique (utilisation de l'insémination, les critères de sélection) et l'environnement (hypoxie, froid, rayonnement solaire). L'utilisation de l'insémination artificielle semble être un facteur de risque majeur, principalement parce que les agriculteurs ne sont pas formés ni préparés à utiliser ce type de vaches. En fait, la plupart des agriculteurs ont signalé des problèmes quand ils ont commencé une amélioration génétique des bovins pour la production laitière. Par conséquent, apporter une information plus complète aux agriculteurs et mettre en œuvre des schémas de sélection appropriés aux conditions d'élevage en montagne semble être une bonne alternative.*

Mots-clés. *Mal d'altitude – Bovins – Vaches laitières – Facteurs de risques – Vallée du Mantaro – Pérou.*

I – Introduction

Brisket disease is a high altitude disease which occurs over 2000 m above sea level when oxygen partial pressure is low. The chronic exposure of one animal to these conditions can unbalance the homeostasis, mainly of the respiratory, cerebral and circulatory system (Ayón y Cueva, 1998). Today, several animal scientists and veterinarians listed this disease, and formulated the hypothesis that incidence may increase in several years. The causes are variable and mostly not revealed by scientific studies. One of the reasons is that genetic specialization, through the widespread use of artificial insemination, will increase this problem. Indeed, improved animals by their high metabolism, which can produce a lot of milk, would suffer more the oxygen shortage (Calderón, 2010).

The environment, with its low oxygen partial pressure, seems to be the main determinant of this disease. Some mammals living at high altitudes are predisposed to develop brisket disease. Susceptibility to this disease is clearly determined by genetic factors, but at present, the genes that determine chronic maladjustment to the altitude are not known (Rhode, 2005). However, there are other risk factors, as the type of management and its various components, such as feed, animal welfare or health management. The relative importance of each of these factors has also been poorly studied.

The environment complicates the development of livestock in the valleys of Colorado and New Mexico, in the Andes or in Ethiopia. In Peru, cattle are reared at different altitudes, even over 3 900 m (Brunschwig, 2001). In Peru, dairy or dual-purpose breeds that predominate are the Brown Swiss, Holstein and Creole. Creole cattle, brought by the Spanish, has adapted to these conditions. The Brown Swiss cows are reared at high altitudes (over 3800m) while the Holstein cows are more difficult to adapt to this environment. Anyway, a lot of farms have developed Holstein in the Peruvian central valley (Aubron, 2006). During the last thirty years, cattle genetics has made great progress, using artificial insemination. Thus, the animals are now more specialized in milk production.

This study aims to assess the current situation in the Mantaro Valley (Junín, Peru), where dairy farming has developed over 3000 m above sea level. We look if brisket disease is a limiting factor for the development of dairy farming in the Mantaro Valley, taking into account the experience of the farmers on this problem.

II – Materials and methods

The investigation has been done in 5 districts of Mantaro valley, in the central Andes of Peru, between 3200 and 3700 m above sea level. We carried out eighty six surveys with farmers in this area. First, general data has been asked about farm management. Then, the survey focused on the brisket disease, asking if farmers faced this problem, how the problem has been evaluated, which were the symptoms of the disease, which were risks factors and how farmers prevented this disease. The survey has been made with multiple choices and opened questions.

Farmers, who had been facing brisket disease during last 8 years in their farm, were asked to detail every situation (animal age when the problem occurred, physiologic status when it appeared, breed, reproduction method, origin of bull semen...). The survey duration took 15 to 30 minutes, depending on the farmer's knowledge of the disease, generally linked with his education level and the technical level of the farm management.

Then, ten surveys have been carried out with the farmers who had the highest technical level, to obtain a more detailed discussion. It enabled to collect the point of view of large size farm farmers, who had a general vision of the situation. This type of survey demanded one hour to one hour and a half. Eventually, 8 specialists of the agricultural sector have been interviewed: 3 veterinarians (independents, or working in dairy industry, or in slaughterhouses), 5 animal production engineers or inseminators.

We used the “snow ball” method to choose the sample of dairy farmers among 4 classes: small producers who had 2 or 3 milking cows, medium producers who had between 4 and 7 milking cows, big producers who had from 8 to 15 milking cows and biggest producers who had more than 16 milking cows.

III – Results and discussion

In our survey, small producers represent 42%, medium 29%, big 20% and biggest 9%. Considering the breeds, 47% of the cows are Brown Swiss, 37% Holstein and 16% are mixed bred or Creole.

The 62% of the farms visited have had at least one case of brisket disease in the past 8 years, with an average of 2.2 animals affected per farm and a maximum of 5 cases. This corresponds to a prevalence of this disease in about 4% of the total number of cows. The two slaughterhouses visited, reported having found cases of brisket disease at a frequency of 10 to 20 animals per year, mostly in Holstein breed but both of them reported that they worked more with Creole or mixed bred animals than with purebred animals.

Regarding the evolution of the brisket disease, 74% of farmers surveyed reported that the problem is decreasing nowadays. In addition, some coincide while reporting that, several years ago the problem was increasing, from the moment on that cattle breeders started to use artificial insemination as well as purchasing animals brought from low altitudes.

In general, farmers who never have had animals with brisket disease did not fear this problem. On the opposite, in the farms where the problem has been developed, 45% of farmers said having feared the disease, mainly because it is a disease that will not heal. The rest of the farmers reported that it was not a big problem, because the number of cases is decreasing due to the implementation of some preventive measures (providing better feeding to the animals; selecting animals according to strength rather than production). In addition, several farmers said they had now adapted cattle (other breed than Holstein).

Considering the farms where brisket disease occurred in the past eight years, the farmers reported that the symptoms of the disease were in the majority (78%) “breast oedema“, which is the most visible clinical sign of the disease. The other symptoms frequently cited are “jugular venous distension” (42%), weak animal (40%), “decreased appetite” (38%) and animal over agitated (36%). The other symptoms that were cited are diarrhoea (10%), difficult breathing (12%), and heart murmur, decreased body condition.

Four farmers reported that the sick animals had fever. This fever seems the first clinical sign, indicating the presence of an infectious disease. Then, if we take into account the classification of Andresen (2011), this would be a “secondary“ brisket disease sign, which is not caused by primary pulmonary hypertension, but by other pathological processes. Also, three farmers mentioned as an early sign of disease the fact that the animal ate earth. Some farmers did the necropsy of sick animals. In all cases, the heart was huge and bifid (with two points) with a hypertrophied right ventricle and presence of water in the body (*acitis*). Frequently, farmers said a veterinarian diagnosed the disease, but that the autopsy of the animal is essential in order to verify the authenticity of this claim. As we saw in the literature review, part of the clinical signs of the disease may be very similar to other diseases.

Cases of true altitude sickness are caused by a mismatch of animals to high altitude conditions. For this reason, breeders identify more cases in the first months of life. More incidences are also observed during times of stress, due to increased metabolic requirements: i.e. last months of pregnancy (14%), at delivery (16%), during lactation (16%) for cows with high productivity because nutrient and oxygen requirements are important. Breed also appears in this study as an important risk factor, the Holstein breed being the most sensitive (84% of cows affected).

Feeding management, particularly the mineral supplementation, is vital because satisfying nutrient requirements contributes to better animal condition. According to veterinarians interviewed, welfare is also very important, especially because a dry and warm environment at night minimizes the risk of developing pneumonia followed by cases of altitude sickness. Also, giving the cows the opportunity to stay in shaded areas when they are outside, in order to avoid heat stress, could contribute to limit brisket disease.

The problem of brisket disease in the Mantaro Valley is decreasing recently, and although several farmers said having feared it, the incidence of the problem is now very low (about 4% of the cows). This cardiovascular disease is mainly caused by hypoxia and cold. But it is clearly observed, that there is an influence with any kind of stress on the development of this disease. It could to be due to the animal itself, to the environment in which it develops or to the herd management. All farmers asked for a wider discussion on this disease, reported that changing at least one of the factors previously presented contributes to having fewer problems.

IV – Conclusions

Training of farmers is a very important aspect in order to lead them to get a better knowledge of the consequences of using artificial insemination with Holstein and the importance of selecting improved breeds for insemination. With more technical knowledge of this technology, the farmer could choose and see if using improved cattle is a good alternative and also what kind of adjustments would be needed to implement on their farms. Also, it appears that the selection criteria of the sperm bank, whose goal is to enable farmers to access to technology at a lower cost, are not adapted to the Andean conditions. Some experts proposed the idea of putting national centres for cattle selection in the three ecosystems of Peru: Andean mountains, Amazonian jungle and pacific cost, to develop selection schemes, tailored to each type of region.

With the time allowed for the study (Bes 2013) and the information obtained, this research represents a preliminary study in the area. It could be used as a basis for further studies, for example to assess precisely one of the few variables, such as the influence of selection on strength criterion. It would for example be interesting to see if the animals which effectively have more chest breadth are more resistant to brisket disease. It would also be interesting to do the same work in high pastoral areas, such as Puno (where many farms are situated above 3500 m).

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Predation impacts due to dogs on sheep herds in wolf-free areas: a synthesis based on surveys in eleven breeding territories in France

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Abstract. In order to get a better understanding of the situation in terms of predation in several French areas, the CERPAM of Provence, the SIME-SUAMME of Languedoc Roussillon, and VetAgro Sup conducted a study based on surveys in 11 territories in Southern France. These territories involved 12 departments: Monges (04), eastern Lubéron (04) and western Lubéron (84), Cévennes (30), Larzac (34), Livradois (63), Jura mountain (25 and 39), Couserans in Pyrénées (09), Ardèche mountain (07), Millevaches plateau (19 and 23) and Aix in Provence area (13). The surveys have been carried out between 1999 and 2013, during wolf-free periods of several years, in order to obtain a database on losses due to wandering dogs predation. We visited 307 farms or breeders (about 24 per territory). Two indicators have been evaluated. The attack rate is the number of attacks during a period divided by the number of farms and the number of years. The predation rate is the number of victims during a period divided by the number of grazing sheep and the number of years. We focused on adult sheep (> 4 months of age). Dog attack rate was on average 0.22 (minimum per territory 0.10, maximum 0.47) corresponding to one attack every 5 years, and dogs predation rate was 0.29%, (minimum 0,06%, maximum 0.6%) corresponding to 1 victim per year for a flock of 330 sheep. Sheep density on the whole territory had no influence on the attack rate over the level of 10 sheep per km². Each dog's attack caused an average loss of 6.3 sheep (from 1.6 to 22.9) and strongly disturbed the flocks in terms of behaviour. These attacks only occurred during the day and the visual identification of the attackers was very frequent (85%).

Keywords. Predation – Dog – Sheep herds – France – Attack rate – Predation rate.

Impact de la prédation par des chiens sur les troupeaux ovins hors zone à loups : une synthèse basée sur onze territoires d'élevage en France

Résumé. *Afin de mieux comprendre la prédation dans plusieurs régions françaises, le CERPAM, le SIME-SUAMME et VetAgro Sup ont conduit une étude basée sur la réalisation d'enquêtes dans 11 territoires répartis sur 12 départements : Monges (04), Lubéron oriental (04) et Lubéron occidental (84), Cévennes (30), Larzac (34), Livradois (63), massif du Jura (25 et 39), Couserans en Pyrénées (09), Monts d'Ardèche (07), Plateau de Millevaches (19 et 23) et pays d'Aix en Provence (13). Ces territoires ont été enquêtés entre 1999 et 2013, sur des périodes pluriannuelles sans présence de loups sur le territoire, afin d'obtenir une base de données sur les dégâts imputables aux chiens divagants. 307 unités d'exploitations, d'estive ou de transhumance ont été enquêtées. Deux indicateurs ont été pris en compte. La fréquence annuelle d'attaque correspond au nombre d'attaques sur la période enquêtée, ramené au nombre d'exploitations et au nombre d'années de cette période. Le taux de prédation est calculé en divisant le nombre total de victimes enregistrées durant la période par le nombre total d'ovins de même catégorie pâturant chaque année dans la zone, ramené au nombre d'années de la période considérée. L'étude porte sur ovins de plus de 4 mois. Les fréquences annuelles d'attaque sont de 0,22 (minimum par territoire 0,10, maximum 0,47), soit une attaque tous les 5 ans. Les taux de prédation due aux chiens sont de 0,29%, (minimum 0,06%, maximum 0,6%), soit 1 victime par an pour un troupeau de 330 têtes. La densité ovine sur le territoire n'influe pas de façon marquée sur le taux de prédation pour les bassins d'élevage ovin ayant plus de 10 ovins/km². Chaque attaque de chiens provoque en moyenne la perte de 6,3* *ovins (minimum 1,6, maximum 22,9) et perturbe de manière significative le comportement du troupeau. Ces attaques sont essentiellement diurnes et les chiens sont repérés dans près de 85% des cas.*

Mots-clés. *Prédation – Chiens – Troupeaux ovins – France – Taux d'attaque – Taux de prédation.*

I – Introduction

In order to get a better understanding of the state of predation due to wandering dogs the CERPAM, the SIME-SUAMME and VetAgro Sup have been carrying out a study, over a period of 14 years, to assess the impact and frequency of predation, in seven French regions (Provence, Alpes-Côte d'Azur, Languedoc-Roussillon, Auvergne, Franche-Comté, Midi Pyrénées, Rhône-Alpes and Limousin), four mountains (Alps, Massif Central, Jura, Pyrenees) and 12 departments (04, 07, 09, 13, 19, 23, 25, 30, 34, 39, 63, 84). This study encompasses the diversity of French breeding sheep territories. A previous bibliography (Garde, 2005) showed that no global study was previously available on this subject. The figures reported in the literature remain estimates or extrapolations from partial data and are extremely divergent (Campion-Vincent, 2002). Our surveys were therefore conducted to assess the exact losses caused by dogs, in areas without wolves or before wolf installation. The objective of the study was to produce a database on the damage caused by dogs and to better characterize their level of predation.

II – Materials and methods

Eleven territories were selected for the diversity of the situations presented. They were surveyed similarly, by direct interviews with farmers, with surveys conducted by students. Small sheep flocks (< 75 or 100 sheep) were excluded. The reference period ran on 4-5 years before the survey date. For each farm, the sheep flock and its management were characterized. Each predation event was described (date, number of victims, circumstances, place, flock management and protection, predator...) and all the informations collected were analyzed jointly (Brunschwig et al., 2007). The method applied is thus similar to investigations of "victimization" well known in sociology, to detect insecurity acts unreported or recorded systematically (Robert, 2002).

Each territory investigated takes into account a representative area of French livestock grazing systems. These territories were wolf-free areas during the years surveyed. In total 307 individual and collective flock units were surveyed, with an average of 24 units per territory. This constitutes a total of 168,000 sheep over 4 months of age, managed at grazing and a total area of 14277 km² (see Table 1).

Table 1. Characteristics of farms and territories

Departments Territories	Monges	Eastern Lubéron	Western Lubéron	Larzac	Cévennes	Livradois	Jura Mountain	Couserans Pyrénées	Ardèche Mountain	Millevaches Plateau	Aix Area
Nb of farms surveyed	29	34	43	31	26	32	24	25	21	25	17
Sheep number over > 4 months	27,682	23,673	23,387	12,995	13,630	17,599	7,829	8,480	6,830	7,320	18,617

Two main indicators were used for the analysis. The attack rate is the number of attacks during a period divided by the number of farms and the number of years. The predation rate is the number of victims (male and female sheep; animals killed, wounded or missing) during a period divided by the number of grazing sheep and the number of years. We focused on “adult” sheep (over 4 months of age).

III – Results and discussion

On the whole data the attack rates are very homogeneous, about 0.22 attacks per year over the period, representing an average attack every 5 years for a given flock unit. The attack rate ranges between 0.1 and 0.47 depending on the territory considered. Western Lubéron is an exception with a frequency of 0.36 in fact due to two neighboring herds subjected to repeated attacks in a very particular context of malevolence. When these two cases are removed from the mean, the frequency for this territory decreases to 0.1. The Jura Mountain has a high frequency of 0.41, apparently due to the low density of sheep in this region: 2.5 sheep / km ^{2} *vs* 12 to 100 for the other regions. Aix Area presents the higher frequency of 0.47 linked to the city proximity.

Predation rate averaged at 0.29% of victims per year (three victims per year for a herd of 1000 heads). The results are consistent for 7 of the 11 territories, being between 0.17 and 0.38. Cevennes and Aix Area stand out with a very low rate of 0.06%. Western Lubéron and Jura Mountain have conversely slightly higher rates with 0.55% and 0.60%, probably due either to an unusual concentration of losses in two neighboring farms, or to a very low number of sheep farms respectively.

Table 2. Main results of predation on sheep herds by dogs

Departments Territories	Grazing time (month)	Attack rates	Predation rate (%)	Dogs identification rate (% of attack)	Average number of victims per attack
Monges	5.8	0.11	0.25	92	22.8
Eastern Lubéron	8.3	0.16	0.17	78	14.2
Western Lubéron	8.2	0.35	0.55	90	4.5
Larzac	9.0	0.13	0.19	95	5.7
Cévennes	8.8	0.12	0.06	100	1.6
Livradois	6.9	0.10	0.20	88	11.7
Jura Mountain	7.1	0.41	0.60	85	3.1
Couserans Pyrénées	10.0	0.21	0.38	65	7.4
Ardèche Mountain	10.3	0.27	0.35	86	4.2
Millevaches Plateau	8.5	0.17	0.25	76	3.6
Aix Area	8.5	0.47	0.06	97	8.6
Average	8.2	0.22	0.29	86	6.3
SD	2.73	0.548	0.941	36.0	12.40

Attacks are performed by a single dog, or in a few cases by two dogs. It is important to note that the dog(s) responsible for the attack is on average identified and described in 85% of cases, the minimum value is 65%; this concerns the Couserans territory. Farms are insured for damage due to wandering dogs in 25% of cases (on average).

Nearly two-thirds of the attacks are performed by neighborhood dogs (35%) and hunting dogs (29%). Tourists’ dogs, often stigmatized, represent only a small proportion of attacks (6%). The cases attributed to “stray dogs” in the sense of an animal without owner (Charmettant and Dimanche, 2006) are very rare (0.4%).

Each dog attack causes an average loss of 6.3 animals. However, this mean figure includes large disparities per territory (1.6 in Cevennes, from 3.1 to 4.5 in Jura Mountain, Millevaches Plateau, Ardèche Mountain and western Lubéron, 5.7 to 7.4 in Larzac and Couserans, from 11.7 to 14.2 in Livradois and Eastern Lubéron; 22.9 in Monges) and per type of dog involved (from 4.4 per hunting dogs to 6 or 10 for tourists dogs or neighborhood dogs).

Finally half of dog attacks occur during autumn (51%), associated with the hunting season, while the rest of the attacks are distributed quite evenly between spring (16%), summer (20%) and winter (13%).

These surveys, conducted on various territories and combined into a single database, enable for the first time in France a precise analysis of predation due to wandering dogs. The first achievement of this study is the establishment of a predation rate obtained from direct surveys of farmers: the annual average for the eleven territories is 0.29% victims of dog attacks per year and the figure never exceeds 0.60%. These observations remain far below the figures reported in the references where the order of magnitude is from 2 to 5% of animals killed (Wick, 1998; Chevallier, 1999; Moutou, 1999; Sales, 2001; Pfeffer, 2000; Bobbé, 2002). A doubt on the validity of these various ungrounded references had already been mentioned by Cousse and Matter (2002). This doubt was confirmed by an audit work which shows that none of the figures came from a field study (Garde, 2005). So the question of the scientific status of these data and their engagement in the debate on large size predators is raised.

IV – Conclusions

This study, based on 11 territories, and carried out over a period of 14 years, was the first one in France to present field based results about dog predation. The diversity of territories surveyed and the homogeneity of the results enabled to consider the figures of the predation rate and attack rate as representative of the French situation. The results, which keep between 0.1 and 0.6% losses, are comparable to the international literature, which offers a range from 0.1 to 0.9% of loss (Solari and Maddalena, 2002; Taylor *et al*., 2005; USDA, 2007; Massucci, 2009).

In order to get a better knowledge of the whole predation impact, it could be of interest to complete this study by surveys or analysis considering predations due to various wild animals. Some preliminary results attest that sheep were attacked by wolfs, bears and lynx, but also by foxes, crows and boars. If data of predation due to one predator is available, it seems we haven't data about predation due to various predators in France.

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Diversity of efficient dairy farming systems in the PDO Saint-Nectaire cheese area

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Abstract. The abolition of the milk quota system in 2015 raises issues for the future of mountain dairy farms if they do not improve their economic efficiency. The interbranch organization of Saint-Nectaire cheese (PDO) wishes to support farmers in improving the food self-sufficiency of their farms. The aim of the study was to describe the diversity of production conditions of 33 efficient dairy farms. Farms were chosen according to their technical and economic results. A multivariate analysis identified four production systems. They are mainly characterized by the management of the dairy herd and grassland and by the product sold (milk or cheese). C1 and C2 groups included farms with high milk yield, a large amount of homegrown harvested feed and high stocking rates. They are mainly distinguished by the herd breed and their farm product. C3 and C4 included mainly dairy farms with less productive herds. They differed among themselves mainly by the contribution of dairy cattle to the total livestock unit, the stocking rate on the fodder area, the place of milking during the grazing period, and the winter cows' basic diet. This work has confirmed the wide variability of production means, management and technical performance of the dairy herds. In particular, some farms maximize the use of local resources (grassland) while reducing inputs. For others, the high value of the cheese compensates for the high feeding cost.

Keywords. Farming system – PDO cheese – Saint-Nectaire – Milk cost of production.

Diversité des systèmes d'élevage laitiers dans la zone AOP Saint-Nectaire

Résumé. *La suppression prochaine des quotas laitiers pourrait remettre en cause la pérennité des exploitations laitières de montagne si elles n'améliorent pas leur efficacité économique. L'interprofession de l'AOP Saint-Nectaire souhaite donc accompagner les éleveurs dans l'amélioration de l'autonomie alimentaire des exploitations. Le but de cette étude était de décrire la diversité des conduites de 33 exploitations laitières d'avenir selon des critères de performances techniques et économiques. Une analyse multivariée a permis d'identifier 4 groupes d'exploitations. Ils se différencient principalement sur la conduite du troupeau laitier et des surfaces en herbe ainsi que sur le type de produit vendu (lait ou fromage). Les groupes C1 et C2 rassemblaient les exploitations avec un niveau de production laitière par vache élevé, une surface récoltée importante et le plus fort niveau de chargement. C1 et C2 se distinguaient par la race du troupeau et le type de produit (lait ou fromage). Les groupes C3 et C4 rassemblaient principalement les producteurs de lait avec des troupeaux moins productifs. C3 et C4 différaient principalement par leur degré de spécialisation laitière, le chargement de la surface fourragère, le mode de traite en été et la nature de la ration de base hivernale. Ce travail a confirmé la grande variabilité des moyens de production, des modes de conduite et des performances techniques du troupeau laitier. En particulier, certaines exploitations maximisent l'utilisation des ressources herbagères locales tout en réduisant les intrants. Pour d'autres, la bonne valorisation du fromage compense des charges alimentaires élevées.*

Mots-clés. *Système de production – Fromage AOP – Saint-Nectaire – Coût de production du lait.*

I – Introduction

The abolition of the milk quota system raises issues for the future of mountain dairy farms if they do not improve their economic efficiency. The strength of the link between dairy products and their area of origin provides a lever for adapting to this new situation (Farruggia *et al.*, 2009). The PDO Saint-Nectaire cheese area is one of the smallest in Europe (1,900 km^2), with a variety of soils and micro-climates. The farm fields are distributed at altitudes from 800 to 1886 m a.s.l, with fertile volcanic or, to a lesser extent, granitic soils. The average annual rainfall is abundant, with more than 1,200 mm per year on 70% of the territory; the lower altitudes receive less rain. In 2012, 690 dairy farms were involved in the supply chain: **MP** farms produce milk which was then transformed into "Factory cheese" by dairies located in the PDO area; **CP** farms produce milk and transforme it (wholly or partly) into "Green cheese", twice a day, directly after milking. "Green cheese" is either matured on farm or sold to industries for ripening. This diversity leads to different types of managements and contrasted economic results which can be amplified by climatic events and extreme input prices. In 2007, the interbranch organization (IO) modified its specifications in order to strengthen the exploitation of the available local resources while reducing production inputs in farming practices (Ministère de l'Agriculture et de la Pêche, 2007). In order to provide tools to support farmers to achieve food self-sufficiency on their farms, an inventory of the diversity of production conditions and technical/economic performance of the dairy units was carried out on farms considered to be efficient according to farm advisors.

II – Materials and methods

1. Study design

Thirty three dairy farms spread out over the area of the Saint-Nectaire cheese PDO and involved in the supply chain were selected by farm advisors. Among farms belonging to accounting and milk recording organisations, the advisors chose farms considered to be efficient. Technical and economical criteria were used: annual milk yield, gross operating income per 1000 L of milk produced or amount of the investment. MP and CP farms were equally represented. The dairy cows are mainly fed with local permanent grassland forage and concentrates. Of the 15 MP farms, 8 fed haylage or silage together with hay (FF) and 7 fed just hay (DF). Of the 18 CP farms, 8 used FF and 10 farms only DF.

2. Data collection

The milk recording organization provided data on the technical performance of the dairy herds in 2010 and 2011. The accounts recording organization provided the economic performance of the dairy units for 2011. Information related to the description of the farm practices was collected by on-farm surveys in autumn 2012. The information collected was mainly related to dairy herd characteristics and management, forage supply management, type of livestock farming and workforce.

3. Data analysis

To identify relationships between the conditions of milk production, a multicomponent analysis (MCA) was carried out (Spad 7.4.56 software for Data Analysis). It was based on 14 quantitative variables and the 8 qualitative variables describing the management and operating costs of the dairy herd, the forage area and workforce (table 1). A hierarchical cluster analysis (HCA) was performed on the farms coordinates on the first six factors of the MCA, which explained 53 % of the data variability. The HCA separated the farms into 4 production systems (C1 to C4). The system's characteristics were compared using the ANOVA procedure; multiple comparisons were performed by Fisher's least-significant-difference test on quantitative data. The Fisher's exact test was used in the analysis of contingency tables for qualitative data.

III – Results

1. General description

The farms were managed by 1-4 associates. On average the youngest was 35. The labour productivity varied from 18 - 77 LU per annual work unit. The useable agricultural area was 115 ha on average and varied from 42 to 195 ha. The number of dairy cows per farm varied from 20 to 92.

2. Production systems

The production systems differed mainly in their milk yield level, stocking rate, relative area cut for conservation or grazing, winter cows‘ basic diet and feed costs. C1 and C2 included farms with the highest milk yields (table 1). A large portion of the meadow area was reserved for harvested feeds. The home-grown harvested feed cost and the stocking rate were high. The size of the building for forage storage was often too small. These two classes distinguished themselves by the type of milk product, the cow breed and the winter basic diet. Therefore, in C1, MP and CP farms fed Holstein herds with hay and fermented grass in winter. In C2, CP farms fed Montbeliarde herds mainly with hay during winter and had high purchased feed costs. They employed a large farm workforce and paid salaries.

Table 1. Characteristics of dairy farms according to their production system (indicators used in the MCA: quantitative data in normal font; *qualitative data in italic*)

	C1 n=11	C2 n=12	C3 n=4	C4 n=6	*P* [1]
Milk yield (kg/cow/305 days of lactation)	7,310 ^{a}	6,807 ^{a}	5,539 ^{b}	5,374 ^{b}	***
Contribution of dairy cattle to total livestock unit (%)	93 ^{a}	88 ^{a}	56 ^{b}	91 ^{a}	**
Age at first calving (months)	32	32	34	33	NS
Proportion of primiparous births for the herd (%)	99	96	99	97	NS
Winter cows diet only based on hay (DF) (nb of farms)	0	10	2	6	***
Calves born within a 3-month period (nb of farms)	4	4	0	4	NS
Outdoor milking (nb of farms)	1	3	0	6	***
Animal given into agistment (nb of farms)	4	2	1	1	NS
Stocking rate on forage area (LU/ fodder area)	1.0 ^{a}	1.0 ^{a}	0.9 ^{a}	0.5 ^{b}	***
Proportion of permanent grassland (% usable agricultural area)	92 ^{b}	100 ^{a}	98 ^{ab}	100 ^{a}	*
Areas cut for conservation / main fodder area (%)					
- First cut areas	51 ^{a}	51 ^{a}	34 ^{b}	31 ^{b}	***
- Second cut areas	40 ^{a}	36 ^{a}	8 ^{b}	5 ^{b}	***
Storage of forage: too small building size (nb of farms)	8	6	1	3	*
Fraction of hay in total stock (%)	67	84	72	88	NS
Length of grazing without supplementation (days)	54 ^{b}	90 ^{ab}	103 ^{ab}	152 ^{a}	*
Feed costs for milk production (€/1,000 L)					
- Purchased feeds (concentrates and/or forage)	118	151	128	133	NS
- Homegrown harvested feed	22 ^{a}	29 ^{a}	12 ^{b}	7 ^{b}	***
Other operating costs (veterinary, custom services...) (€/1,000 L)	63	66	60	50	NS
Labour productivity (nb LU/annual work unit)	43	40	41	39	NS
Employment of paid or voluntary labour (nb of farms)	1	10	2	4	*
Type of farm product (nb of farms)					+
- MP (only milk produced)	6	2	3	4	
- CP (milk transformed into farmhouse cheese)	5	10	1	2	

[1] + P < 0.10; *P < 0.05; ** P <0.01; *** P < 0.001.

Data within the same row and season and not sharing a common superscript are different (p < 0.05).

C3 and C4 included farms with the less productive herds. Most were MP farms. The area of harvested grasslands and the home-grown harvested feed cost was lower than in C1 and C2. C3 and C4 differed mainly in the contribution of dairy cattle to the total livestock unit (reflecting the presence or absence of a suckling herd), the stocking rate on the fodder area, the place of milking during the grazing period, and the winter cows‘ basic diet. Therefore, in C3, all dairy herds were associated with suckling herds. In C4, all the winter diets were based only on hay and the stocking rate was the lowest. Most of calves were born over a 3-month period; all cows were milked outdoors during the 5-month grazing season without supplementation.

III – Discussion and conclusion

This work has allowed us to quantify and evaluate the very large variations in technical performance of these mountain grassland farms, members of an AOP. The differences turn out to be considerable between the most productive farms using a lot of inputs and more grazing-orientated ones, and also between the products sold. Certain farms maximise the use of local herbage resources whilst reducing inputs. For others, the profitability of cheese makes up for the high feeding costs.

The changes to the specification (stopping of the feeding with fermented forages) will have different consequences according to the production system and the current farm management. There will be no impact for producers who comply with current specifications. However, the abandonment of wet forage could require heavy investment in new building for stocking dry forage. Farmers could increase the proportion of milk produced during the grazing season by making more use of grazing. In some cases, complying with the specification will not result in a reduction of inputs. The abandonment of wet forage could be associated with an increase in the amount of purchased feed because the diet could contain 30% of concentrates over a year. One of the missions of the IO would be to support breeders in bringing back grazing to the heart of their AOP farm.

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Agri-environmental measures for the conservation of semi-natural grasslands: a case study in Natura 2000 sites in Marche region (Italy)

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Abstract. Agri-environmental measures (AEM) are increasingly seen as essential tools for land conservation and management. Typically, Rural Development Programmes (RDP) are implemented on a farm level while most of the biophysical processes in agriculture occur on a larger scale. In 2011, Marche Region RDP 2007-2013 enabled Agri-Environmental Agreements (AEA) for biodiversity conservation. An AEA is defined as an agreement between public and private stakeholders (SHs) of a limited territory in order to improve its environmental conditions. We did a stakeholder analysis (SA) in a case study of AEA launched on a Natura 2000 site. We analysed the results in the light of a well-experienced conceptual diagnostic framework and its variables. The AEMs were first defined between regional services and some experts which also included a researcher who made experimentations with farmers in the area. After defining the AEMs, farmers were encouraged to get involved in meetings only to choose which of the proposed AEMs could be adopted in their AEA. SA results showed that the lack of involvement of the farmers after the defining of AEMs, limited the local knowledge inclusion which was only partially compensated by experts who participated. Moreover, involvement of other SHs also turned out to be indispensable since the first steps to take into account bureaucratic issues that could slow down the process of implementation. Based on AEA analysis, we propose guidelines for defining AEMs in order to guarantee a landscape approach to better address the conservation issues regarding semi-natural grasslands.

Keywords. Agri-Environmental Measures – Biodiversity – Participatory processes – Stakeholders.

Mesures agro-environnementales pour la conservation des prairies semi-naturelles : une étude de cas dans des sites Natura 2000 de la région des Marches (Italie)

Résumé. *Les mesures agro-environnementales (MAE) des Programmes de Développement Rural (PDR) sont considérées de plus en plus comme des instruments essentiels pour la conservation et la gestion du territoire. Dans la plupart des cas les PDR sont mis en œuvre à l'échelle de la ferme alors que la plupart des phénomènes biophysiques qui interviennent dans l'agriculture le font à une échelle plus vaste. En 2011 le PDR 2000-2013 de l'Administration Régionale des Marches a mis en œuvre des Accords Agro-environnementaux (AAE) pour la conservation de la biodiversité. Un AAE est défini comme un accord entre « stakeholders » (SHs) publics et privés d'un territoire limité afin d'améliorer ses caractéristiques environnementales. Nous avons conduit une « Stakeholder Analysis » (SA) dans une zone Natura 200 où un AAE a été mis en œuvre. Nous avons analysé les résultats sur la base d'un cadre de diagnostic et de ses variables. Les mesures agro-environnementales ont d'abord été définies par les services régionaux et quelques experts parmi lesquels un chercheur qui avait fait des recherches dans la même zone. Après avoir défini les MAEs, les agriculteurs ont été invités à participer à des rencontres pour choisir les MAEs à adopter dans l'AAE. Les résultats de la SA ont montré que le manque d'intérêt de la part des agriculteurs dans les premières phases de définition des MAEs a limité l'inclusion des connaissances locales, ce qui a été en partie comblé par la participation des experts intéressés. En outre, l'implication d'autres SHs s'est très vite révélée indispensable pour les questions bureaucratiques qui pourraient ralentir le processus de mise en œuvre. Sur la base de l'analyse de l'AAE nous proposons des lignes directrices pour la définition des MAEs garantissant une approche territoriale pouvant traiter les questions liées à la conservation de prairies semi-naturelles.*

Mots-clés. *Mesures agro-environnementales – Biodiversité – Approches participatives – Stakeholders.*

I – Introduction

Biodiversity conservation depends directly on traditional types of agricultural land use and farming systems. Agri-Environmental Measures (AEM) represent the most used tool for improving or maintaining biodiversity in agriculture even if their successful implementation varies across Europe (Henle *et al*., 2008). AEMs are voluntary agreements that give compensation payments to farmers for the adoption of management practices (e.g., landscape and habitat conservation).

AEMs included in Rural Development Programme (RDP) are designed at farm level, although most of the agriculture biophysical and ecological processes, like soil erosion, biodiversity or nitrate leaching, occur at different scales (e.g., watershed or hillslope) (Prager *et al*., 2012). This can lead to a spatial scale mismatch between ecological processes and agricultural management (Armitage *et al*., 2008; Cumming *et al*., 2006; Pelosi *et al*., 2010). For this reason, a need has come up for stakeholder (SH) collaboration and coordinated actions at landscape scale to define AEMs (Prager *et al*., 2012). The EU encourages its Member States to design participatory AEMs involving SHs in a bottom-up process. Some authors have observed that different levels of power between SHs (Prager and Nagel, 2008) or lack of trust among them (Schneider *et al*., 2009) can constrain the participatory process.

In 2011, the authority responsible for RDP coordination of Marche region (central Italy) launched a set of AEMs at landscape scale for biodiversity conservation in Natura 2000 sites. From the analysis of the implementation process in 'Montagna di Torricchio' Nature Reserve, we discuss how a participatory approach can lead to shared and more accepted AEMs.

II – Materials and methods

In 2011, the Marche regional authority launched Agri-Environmental Agreement (AEA) for conserving biodiversity in Natura 2000 sites. An AEA is defined as an agreement between public and private SHs of a limited territory in order to improve its environmental conditions. An AEA is composed of AEMs already included in the RDP but allows SHs to propose changes to the original characteristics of AEMs through their participatory approach.

The managing authorities of Natura 2000 sites were identified as 'AEA potential lead partners' by Marche Region. The AEA implementation path was divided into two subsequent sessions of participatory meetings. The first one was between the regional authorities (Agriculture and Environment Services) and some external expertise advisors. In this phase, AEMs were defined. The second was between local SHs and the lead partners that discussed those AEMs to be adopted in their area. After approximately one year, 6 managing authorities launched an AEA in their areas mostly for the conservative management of Habitat 6210* – Semi-natural dry grasslands and scrubland *facies* on calcareous substrates (*Festuco-Brometalia*) (EU Habitat Directive 92/43/EEC). We analysed the AEA implementation path in the 'Montagna di Torricchio' (820-1575 m a.s.l.) located in the southern Marche region (lat 42.962868, long 13.018124) where pasturelands are often common lands under customary grazing rights.

We did a Stakeholder Analysis (SA) by carrying out semi-structured interviews in order to obtain the greatest flexibility in terms of discussion, and we arranged a list of 'subjects for discussion' for each class of SH (Reed *et al*., 2009). In particular, we investigated: (i) the origin of scientific knowledge, (ii) the SHs' involvement level and the facilitation process, and (iii) the procedure constrains in the changes in RDP. We recorded each interview by a voice recorder and transcribed the conversations on a spreadsheet. Then we compared each sentence within the SLIM Diagnostic Framework (DF) and its variables: (i) Stakeholder and Stakeholding (understood as the process in which SHs become aware of their role in the system); (ii) Policy and Institutions; (iii) Ecological Constraints and (iv) Facilitation. In social learning processes, the improvement in understanding an issue triggers a change in SHs' practices. SLIM DF is a dynamic model that evolves in the course of time to a further better situation through concerted actions (Steyaert and Jiggins, 2007).

III – Results and discussion

We interviewed 14 SHs and obtained 1196 sentences: 1033 were clustered according to the four DF variables and 163 were not allocated because they went off the subject. The results of the analysis of the variables are discussed below.

Stakeholder and Stakeholding: SA underlined the synergy between the two regional services due to the possibility of launching AEMs in Natura 2000 sites. One Marche Region officer stated that: *'...in the past there were some conflicts between us, but AEA is a good example of collaboration between regional services and a starting point for future collaborations...'*.

The building process of AEA not only enhanced collaborations between regional authorities but also favoured the inclusion of new SHs, such as unions, farmers, researchers and managing authorities of protected areas, which generally act disconnected or in conflict,.

The SA highlighted the crucial role played by the Torricchio manager who was also a university researcher. The interviews confirmed the close relationship between the researcher and the farmers due to *'…past and cooperative scientific activities…'*. Shared experimentations fostered trust among SHs and triggered the facilitation process through local knowledge inclusion. Most of the AEMs proposed to the farmers arose from a combination of trust and local knowledge.

To this day Torricchio AEA covers around 11,000 ha involving 40 farmers and has the biggest membership of farmers compared to the other 5 AEAs, where *'...farmers did not have any experience concerning the effects of the AEMs on the their activities...*' (Farmers Unions).

Ecological Constrains: No specific constrains emerged from the SA linked to the chosen AEMs. Other ecological constrains were not overcome due to the impossibility to change the AEMs proposed by Marche Region. In particular, some SHs stated that some different grazing options could have been identified taking into account the grazing behaviour of different animals *'…for example horses could graze the pasture at the end of the grazing period to preserve forage quality and the environment...'* (Farmer).

Policy and Institutions: The main reason behind AEA implementation was the conservation of pasturelands from invasive species (mainly *Juniperus communis* and *J. oxycedrus, Rosa canina, Brachypodium* sp.) threatening 6210 Habitat. Despite the high level of AEM acceptance, some constrains emerged from SA. Firstly, Marche region authority did not take into account that most of pasturelands of Torricchio' were common lands under customary grazing rights. This led to a 2-year delay of compensation payment as the farmers had to prove the exclusive use of the fields as required by EU. Secondly, the AEM implementation process was constrained by the choice of the regional managers to prevent farmers from changing the AEMs. This choice is a consequence of the long time required for defining AEA and negotiations with EU regarding changes in RDP. Regional officers could be discouraged to adopt a bottom-up and participatory process in the implementation of AEMs. For this reason, a simplification of bureaucratic procedures is required.

Facilitation: As can be observed from the previous analysis of variables, the facilitation and involvement of SHs are some of the main components in the AEM building process. The only involvement of a researcher in the definition of AEMs was not sufficient to include all the local knowledge even if he was very active in sharing research activities with farmers. The missing participation of the payment authority in defining AEMs generated bureaucratic issues and delay in payments which were solved only after long negotiations. In each step toward defining AEMs, all the SHs, including other institutions like payment authorities or EU, should be involved in integrating their knowledge in order to hasten the process.

IV – Conclusions

Existing incentive programmes such as EU agri-environmental schemes, usually neither require nor encourage large-scale coordination but favour a farm scale approach leading to individual and disconnected actions (Prager *et al*., 2012). Although RDPs are generally strict tools, Torricchio AEA showed that modifications are allowed by EU, and that the inclusion of local knowledge could lead to the implementation of landscape measures.

AEA analysis highlighted how facilitation and SHs involvement issues constrained the flow of local knowledge in the implementation process. Based on Torricchio AEA, an alternative approach to define AEM can be identified. The authorities responsible for coordinating the programme should (i) involve local SHs from the first discussion phase to ensure their empowerment (Reed, 2008), and (ii) act as a bridge between local SHs and EU. RDP could be seen as an 'empty box' which defines only strategic targets (e.g., grassland, biodiversity or landscape conservation) to be filled with bottom-up AEMs. In the 'empty box' model, the involvement of SHs could lead to new site specific AEMs not considered by Region authority on RDP but with a high level of acceptance by the farmers. EU should improve RDP procedure to reduce the negotiation time for AEMs, which actually emerged as one the main constrains for spending available funds on RDP.

These co-management measures would guarantee a landscape approach to better address the management of semi-natural grasslands and biodiversity issues for their conservation in Natura 2000 sites.

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Diversity of goat livestock systems in Livradois-Forez (France) and forms of ecological intensification

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Abstract. The Livradois-Forez (LF) is a small region of fairly low mountains in France where grazing livestock, mainly cattle, is largely based on grass. In this territory, goat farms are a minority but an attractive way to produce on small areas (fragmented and heterogeneous land) and use ecosystems with limited potential. The objective of this study was to analyse the diversity of goat farming systems (GFS) and assess their ecological intensification position. Semi-structured interviews were conducted with 18 farmers, a sample selected to cover the diversity of livestock forms in this territory. Our approach is constructed on three concepts: the farming system, the framework of the farming activity and agro-ecology for animal production. We identified four types of GFS operations discriminated by the place of goat livestock in the farm and the mobilization of available resources. We present and explain the correspondence between types of operations and ecologically-intensive practice profiles. We show the interest of the approach to identify what promotes or limits the development of these systems into more ecologically-intensive forms.

Keywords. Agro-ecology – Farmer practice – Livestock farming systems – Sustainability.

Diversité des fonctionnements d'élevages caprins en Livradois-Forez et formes d'intensification écologique

Résumé. *Le Livradois-Forez est une région de moyenne montagne où l'élevage d'herbivores, principalement bovin et largement basé sur l'herbe, prédomine. Dans ce territoire, les élevages caprins sont minoritaires mais apparaissent comme une voie intéressante pour produire sur de faibles surfaces (foncier éclaté et hétérogène) et utiliser des écosystèmes aux potentialités limitées. L'objectif de cette étude est d'analyser la diversité des fonctionnements de ces systèmes en cherchant à les positionner par rapport à une direction plus « écologiquement intensive ». Des enquêtes semi-directives ont été réalisées auprès de 18 éleveurs choisis pour couvrir au mieux la diversité des formes d'élevage dans ce territoire. Notre cadre d'analyse est basé sur trois concepts : le système d'élevage, le cadre d'exercice de l'activité d'élevage et l'agro-écologie en élevage. Nous identifions 4 types de fonctionnement discriminés par la place de l'atelier caprin dans l'exploitation et la mobilisation des ressources disponibles. Nous montrons la correspondance entre types de fonctionnement et profils de pratiques « intensives écologiquement » et l'explicitons. Nous discutons de l'intérêt du cadre d'analyse proposé pour comprendre ce qui favorise ou contraint l'évolution des systèmes d'élevage vers des formes écologiquement plus intensives.*

Mots-clés. *Agro-écologie – Durabilité – Pratiques de conduite – Système d'élevage.*

I – Introduction

The study was conducted with goat farmers in Livradois-Forez, a rural territory of low mountains, to the east of the Massif Central in France. The goat farms are scattered and form a minority in the territory, but because of this and the ecological intensification of the livestock activity they are of interest. In fact, this type of livestock farming often makes good use of marginal areas with limited potential, of little interest to the cattle farms that form the majority in this region. These systems do not require much land and offer opportunities for low-volume production with high added value because processing can take place on the farm and sales on local markets.

Nowadays the ecological intensification (EI) concept is highlighted to suggest possible answers to the dual challenge of mitigating environmental impacts and increasing livestock production at global level, whilst at the same time incorporating the local dimension (Griffon, 2006; Steinfeld *et al.,* 2010). Ecological intensification is an evolution of agriculture that aims to produce without harming the environment and to make better use of ecosystem functions (Bonny, 2011; Griffon, 2013). The development of these new forms of farming systems needs to improve the integration of ecological processes into the operation of livestock systems. Thus, this paper describes and understands the diversity of goat systems in Livradois-Forez and identifies their position into more ecologically-intensive forms.

II – Method

Surveys were conducted with eighteen goat farms, selected to cover as large a diversity of systems as possible in terms of dimension (surface area and herd), goat grazing, production orientation (milk or cheese) and association with other animal units. Semi-structured interviews addressed the trajectory of farmers and farms, the management practices of herds and lands and their justification, marketing and valorisation of products, and farmer perspectives.

These data were used to build variables according to three concepts: the farming system (Gibon *et al*., 1999), the framework of the farming activity (Terrier, 2013) and agroecology for animal production (Dumont *et al*., 2013). We define the operation of a livestock system as an association between family and farm system configurations (available dimensions and structures, labour force), the chosen production project (animal production type, investment for processing and marketing the products, and combination of economic activities) and the combination of management practices (crops, herds and valorisation of products), and the trajectory of the farmer (who manages the goat herd) and of the farm has been introduced to take into account the dynamic aspect of this. We used the five major agroecology principles for the design of sustainable livestock systems proposed by (Dumont *et al*., 2013) to describe the practices implemented on the farms and build an ecological intensification (EI) profile for each of them; they are: (i) Health, adopting management practices aimed at improving animal health; (ii) Inputs, reducing the inputs needed for production; (iii) Pollution, decreasing pollution by optimizing the metabolic functioning of farming systems; (iv) Diversity, enhancing diversity within animal production systems to strengthen their resilience; and (v) Biodiversity, preserving biological diversity in agro-ecosystems by adapting management practices.

A typology was carried out on the operation active variables by Bertin's graphical method (Bertin, 1977) and each type of systems reflecting specific logics of operation that are characterized as prototypes (Girard, 2006).To characterize the EI profile of each system, five variables were built, one for each principle (Health, Inputs, Pollution, Diversity and Biodiversity). The system typology was then cross-referenced with the characterisation of the EI profile. Thus for each type of system we built an EI profile, retaining for each variable (principle) the modality which was the most represented among the farms of the type.

III – Results

The typology in 18 goat farms identified four types of operation systems, which are discriminated by the importance of the goat activity in the farms and the mobilization of available resources and corresponding to different ecological intensification profiles (Fig. 1).

In the first type called "resource-centred" the farmers settled on the family farm when a parent took retirement. They aim for production quantity and deliver all of their goat's milk to a dairy unit. Farms that have expanded since the farmer's installation are relatively large for the sample and in addition to the goat unit, they include another beef cattle or sheep activity of the same importance in terms of income and labour. The interaction between these herds is thought to be the best way to manage the territory of the farm (nearby fields for the goats). The logic of the operation is centred on plant resource management and the assignment of the best feed to the goats. Diversity of surface area (temporary and permanent meadows, cereals) achieves forage self-sufficiency and covers part of the production of concentrates for the animals. The ecological intensification profile of "resource-centred" farms is out of balance. It is characterized by the importance of "ecologically-intensive" practices linked to the management of surface areas including those that can reduce inputs (rotations, choice of plant species, grass-legume integration, organic fertilization, organization of fields to reduce movement of stock). On the other hand, animal management favours quantity of milk production over the integrated management of goat health; there is no diet transition, drying-off is sudden, pesticides are used systematically, and animal housing is poorly adapted.

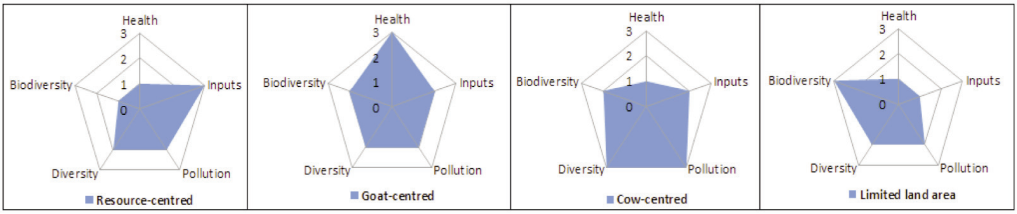

Fig. 1. Ecological intensification profile of each type of operation of goat livestock systems (Degree of ecological intensification: high = 3, medium = 2, low = 1).

The "goat-centred" type occurs in smaller farms managed by couples who became established outside the family framework more than 15 years ago because of their passion for the work. The system was built around the goat herd and the processing and marketing of goat cheese; it has gradually changed, without expanding, to include other activities (educational farm, farm accommodation, bed and breakfast, cottages) and other animal units. It has gradually improved the management of forage resources. In these systems, the diversity of resources, whether animal, vegetable or labour force, is thought to foster system flexibility and efficiency. The "goat-centred" farms are those which have the most balanced ecological intensification profile. Practices that can be described as "dense" from the EI point of view concern the whole system. Particular attention is given to the integrated management of animal health: the females do not suckle their kids, so as to prevent the transmission from goat to kid of the Caprine Arthritis Encephalitis Virus (CAEV); goats are returned to the building during rainy days to prevent lung problems; feed transitions are reflected, grazing is organized to reduce parasitism, trees in pasture and buildings provide goats with thermal comfort. Farmers have gradually changed their strategy for using animal and plant resources, minimizing inputs and playing on complementarities among animals (remote field for sheep or horse grazing, whey used for pigs).

The "cow-centred" type of farming is found in large family-based systems managed by a collective formed progressively by the arrival of new members (family members and employees). The system is designed around the main herd composed of dairy cows, following logic consistent with the dominant model in Livradois-Forez, i.e. intensified production with a forage system based on corn silage and with high use of feed concentrates and chemical fertilizers. The ambition of these farmers is to continue to extend their farms. The goats are secondary, providing added value for the cow's milk via the processing of mixed cheeses. In the 1950s, the majority of farms in the Livradois-Forez had dairy cows and a few goats to make “Brique du Forez”, a mixed cheese typical of this territory. The “cow-centred” farms have an EI profile that reflects their ability to promote synergies and recycling via the interaction between plant crops and two different animal herds, dairy cows and goats. The processing of mixed milk cheese enhances the value of the two dairy productions. The possibility of processing cow’s cheese when goats are dry also allows the farmers to keep their place on the market all year round. On the other hand, this type of farm is relatively intensive on land use and on animals, with the use of inputs (mineral fertilizers, phytosanitary, and health products).

In the last type called “limited land area”, the farmers set up their business outside the family framework, because it was their passion, challenge and desire to change their lifestyle. The project revolves around the processing and marketing of cheeses. The farmers have only recently set up their business; their land area is limited, and their fields do not allow them to produce enough forage to feed their animals, so they resort to purchasing forage and concentrates in varying proportions. They are still building up systems that have not yet found a balance between livestock production and the management of farm plant resources: at this stage the farmers focus more on the development of cheese processing and marketing. For the “limited land area” farms, land management is not or poorly implemented by farmers and food purchases are considerable. The priority of farmers who are starting up their system is to process cheese and develop a marketing network. One hundred percent of the utilized agricultural area is composed of permanent grass grazed or harvested in late mowing to make hay, but without seeking a high production, which promotes biodiversity (Dumont *et al.,* 2013).

IV – Discussion – Conclusion

The application of the approach has enabled us to describe the diversity of goat systems in Livradois-Forez. The absence of a specific goat technical model in this territory partly explains the high diversity of operations observed, within a framework of the livestock exercise: (i) combining this activity with other herbivores; (ii) managed by a couple or by wider forms of association. The approach showed that each type of livestock system operation was associated with a different ecological intensification profile. It also highlighted the impact of available land, the farm and farmer history, on the livestock system operation and the EI profile. This confirms the need to understand and analyse the farming system, taking into account the trajectory of these systems (Milestad and Darnhofer, 2003; Schiere *et al*., 2012): the systems with the most agro-ecological practices are those developed gradually within the trajectories of couples who were seeking self-sufficiency in food and reduction in inputs rather than farm expansion.

Acknowledgments

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Rangeland degradation and adaptation of livestock farming in the Algerian steppe: The case of Hadj Mechri (Wilaya of Laghouat)

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Abstract. The Algerian steppe used to be one of the most important regions of North Africa where farming was mainly based on rangeland grazing. Since the 70s, it has faced many socio-economic and biophysical changes in part caused by recurring droughts. Ecologists and farmers concur that rangeland forage productivity and surface areas have decreased. Our analysis focuses on production systems and the adaptation of their feeding practices bearing in mind the following question: to what extent does grazing still contribute to animal feed? Our research was conducted in the town of Hadj Mechri (Laghouat Wilaya) in the heart of the Algerian steppe. Our hypothesis was that the livestock in the study area required between a quarter and a third of supplementary feed (including barley grain). Results suggest that in this area (65,270 ha), rangelands can cover the needs of animals 0.33 eq. sheep ha^{-1} yr^{-1}. As the total number of sheep is 55,940, the stocking rate of the rangeland should be 0.85 eq. sheep ha^{-1} yr^{-1}. Therefore, to release grazing pressure, farmers implement two strategies and practices: (i) they regularly adjust the size of their herds; and (ii) they provide high levels of supplementation, i.e. >60% of the herd feed needs.

Keywords. Grasslands – Carrying capacity – Desertification – Agro-pastoralism – Livestock herding system.

Régression des parcours et adaptation des élevages en zone steppique algérienne

Résumé. *La steppe algérienne était une des plus importantes régions d'Afrique du nord où l'élevage reposait essentiellement sur la pâture de parcours naturels. Depuis 1970, elle connaît de nombreux changements d'ordre socioéconomiques et biophysiques notamment des sécheresses récurrentes. Les écologues comme les éleveurs s'accordent sur la baisse de productivité des parcours et la diminution de leurs surfaces. Ces parcours régressent, tant en surface qu'en productivité fourragère. D'où notre questionnement qui a porté sur les élevages et l'adaptation de leurs systèmes d'alimentation, avec une première question: Quel est la contribution de la pâture à l'alimentation des animaux ? Notre recherche a été menée dans la commune de Hadj Mechri (Wilaya de Laghouat). Nous avons mené nos recherches avec comme hypothèse que le cheptel en place dans notre commune d'étude devait recourir à un quart voire un tiers d'aliments complémentaires. Nos résultats tendent à montrer que dans la commune étudiée (65270 ha), les parcours peuvent en moyenne satisfaire les besoins des animaux pour 0,33 eq. ov. ha^{-1} an^{-1} Compte-tenu que l'effectif total est de 55940 équivalents ovins le chargement sur les parcours devrait être de 0,85 eq. ov. ha^{-1} an^{-1}. En conséquence, pour soulager la pression pastorale les éleveurs ont recours à deux stratégies et pratiques : (i) ajuster régulièrement la taille de leur troupeau ; et (ii) apporter de forts niveaux de complémentation, supérieurs à 60% des besoins alimentaires de leurs troupeaux.*

Mots-clés. *Parcours steppique – Charge pastorale – Agropastoralisme– Système d'élevage.*

I – Introduction

The Algerian steppe, with about 20 million ha, remains an important area for grazing (16.8 million sheep and 1.6 million goats in 2011). Over the past four decades, it has faced many socio-economic and biophysical changes (more severe recurring droughts, desertification and erosion). Scientists and farmers report that grassland surface areas and productivity have been decreasing (Aidoud *et al.*, 2006; Nedjraoui and Bedrani, 2008; Saidi and Gintzburger, 2013; Daoudi *et al.*, 2013).

These overgrazed lands have been shrinking both in terms of surface area (crops replace pastures, land-use planning, urban development) and forage productivity. Hence, the question is how farmers adapt their feeding system to changes and what the current proportion of pasture is in the feed. This study aims at answering these questions in the context of the central steppe of Southern Algeria, in Hadj Mechri town, Laghouat Wilaya (District).

II – Materials and methods

The vegetation survey was carried out in spring 2007, in the steppe of Hadj Mechri (33°51' N, 01°20' E, altitude 1200 m) at the foothills of djebels Amours (Saharan Atlas) (Fig. 1). It covers 65,270 ha and has about 6,700 inhabitants, 80% of which live in scattered areas. The arid climate, with cold variations (in the sense given by Emberger) of the study area is characterized by an average annual rainfall of 315 mm (El Bayadh station from 1971 to 2008), with high interannual variability of rainfall (variation coefficient of 31%). The ombrothermic diagram shows a lengthening by one month and a half of the dry period between the beginning and the end of the 20th century.

Seventy-four phytoecological samples were collected according to the "quadrat points" method (Daget and Poissonet, 1971), to obtain specific frequencies of species. These frequencies were similar to recoveries. Vegetation groups were determined by a factorial correspondence analysis and a hierarchical cluster analysis using ANAPHYTO software developed by Briane (1992). Productivity and capacity were obtained by calculating the pastoral value, taking into account the specific contributions and the specific quality index (Daget, 1995). Livestock numbers were obtained by crossing administrative census data with data from our investigation.

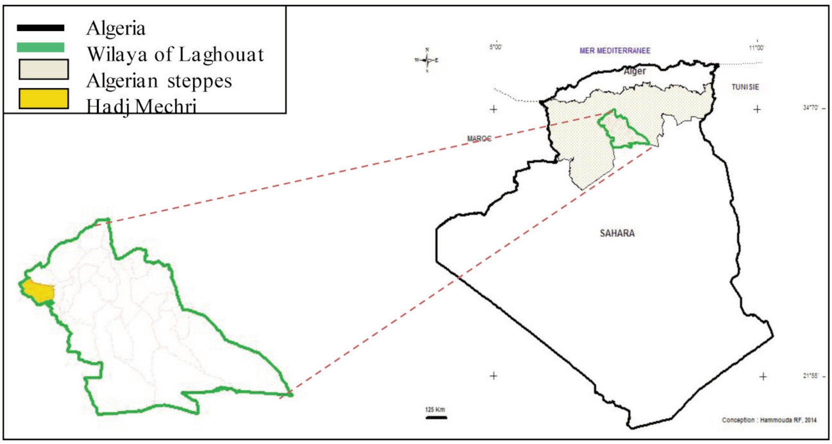

Fig. 1. Location of the study area.

III – Results

1. Definition of plant communities and rangeland condition

The statistical treatment of floristic data helped to characterize four types of rangelands dominated by:

(i) Alfa grass (*Stipa tenacissima*), which is under high anthropogenic pressure;

(ii) Sparte grass (*Lygeum spartum*), because of its high ecological plasticity it can colonize a wide range of soils; the process of alfa steppe degradation is accompanied by eolian sand deposits and a change towards the establishment of a Sparte steppe (Aidoud and Aidoud-Lounis, 1992);

(iii) Drinn (*Stipagrostis pungens*) on sandy soils. Rangelands tend to expand a great deal because of the high anthropic pressure, such as plowing which promotes wind erosion.

(iv) A mix of Alfa, Sparte, and Chih (*Artemisia herba-alba*), as well as *Noaea mucronata* which exemplifies steppe degradation.

The analysis of the state of the rangelands, based on pastoral productivity (Table 1) shows that three quarters of them are undergoing severe to very severe degradation, to the point that any attempt to restore them would be to no effect (Aidoud *et al.*, 2011).

Table 1. Evaluation of the rangeland pasture condition

Rangeland condition	%
Fairly good	27
Moderately degraded	39
Degraded	9
Severely degraded	25

2. Pasture potential of rangelands

The estimation of the carrying capacity shows that grasslands can meet the needs of the livestock in the conditions of 0.33 eq. sheep ha^{-1} yr^{-1}. However, the total number of eq. sheep in the town is 55,942 (Table 2), which translates into 0.85 eq. sheep ha^{-1} yr^{-1}. The difference between the feed supply of the steppe and the livestock feed demand shows that the grazed pastures only cover one third of the needs of the animals, a result similar to that reported by Kanoun *et al.* (2013) in Djelfa region.

Table 2. Livestock distribution and their equivalent sheep

Animal species	Size herds in the study area	Eq. sh.	Equivalent number of sheep
Ovine	45,330	x 1	45,330
Goat	4,640	x 0.8	3,712
Cattle	1,380	x 5	6,900
Total			55,942

IV – Discussion

The study of the vegetation showed pasture degradation caused by anthropogenic actions. This degradation has been amplified by the adverse climatic conditions of the past decades, and by the increase in livestock, land fragmentation and changes in rangeland use (Bessaoud and Tounsi, 1995).

The portions of pasture to the animals (30-40%) keep decreasing compared to the 80s (50-60%) (Le Houérou, 1985). This highlights the ability of farmers to shift from a pastoral system to a system more and more based on grains and other purchased feed. Feed supplementation has become a major practice in as much as farmers have to adapt to both the decline of grasslands and productivity. In 2003, Bensouiah reported that 82% of the farmers in Djebels Amours area used concentrates.

Assessing the contribution of pastures should also include the levels of self-adjustments by farmers through the purchase or sale of livestock based on the season. During droughts and tied-over periods, farmers are under pressure to sell some of their animals so as to have enough feed for the rest of the herd. The state of total decapitalization is easily reached by small farmers in the event of persistent drought (Daoudi *et al.*, 2013). Mobility should also be included in the analysis to understand the seasonal contribution of rangelands. Indeed, movements to search for new forage resources is a strategic option that grants both more flexibility in feed risk management and a rest period to ensure grassland regeneration.

V – Conclusion

This study shows that steppe-type rangelands are still much used even if they are less productive. However their contribution to the animal feed has been decreasing steadily (< 30-40%). Farmers have been adapting their farming systems, but they are vulnerable to drought and even more so to variations in the price of concentrates. In the wake of this work, further functional analyses will be conducted on the use of rangelands in relation to the seasons and within the overall framework of the feeding methods currently applied. Future research will aim to identify methods that enhance steppe resources while ensuring its renewal within a more efficient integration of the feeding systems still in the making.

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Conflict of goals? Animal welfare and greenhouse gas emissions in Swiss beef production systems of different intensity

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Abstract. The case study analysed and discussed the trade-offs between reduction of greenhouse gas emissions and animal welfare in Swiss beef production. The aim was to find out whether there are significant differences in the levels of animal welfare between single farms and different production systems and to which extent animal welfare can be improved under the given circumstances. Therefore, an On-farm Welfare Assessment scheme was designed and applied. Furthermore differences in the climate impact of beef production on the single farms and production systems were calculated and evaluated with a Life Cycle Assessment approach. The comparison of the production systems showed huge differences in animal welfare, but only small differences in the climate impact, which was up to 50% due to methane emissions from enteric fermentation. Farms of the same production system hardly differ in these issues. Some factors like the cattle's movement area and free roaming on pastures achieve bigger improvements in animal welfare than negative impacts on the GHG emissions. For these reasons and for further ecological, economical and physiological aspects beef production should base on high quality forage and pasture.

Keywords. Animal welfare – Greenhouse gas emissions – Beef production – Pasture – On-farm Welfare Assessment – Product Carbon Footprint.

Conflit d'objectifs ? Bien-être animal et émissions de gaz à effets de serre dans différents systèmes de production de bœufs en Suisse

Résumé. *Dans cette étude de cas, les possibilités d'optimisation entre la réduction des émissions de gaz à effet de serre et le bien-être animal dans la production de bœuf en Suisse ont été analysées et discutées. Le but était de vérifier s'il existe des différences significatives de niveaux de bien-être des animaux entre les fermes individuelles et les différents systèmes de production et jusqu'à quel point il est possible d'améliorer le bien-être des animaux dans les conditions données. Un plan d'évaluation du bien-être dans les fermes a été développé et appliqué à cet effet. Les différences au niveau des impacts environnementaux de la production de bœuf dans les fermes individuelles et avec les différents systèmes de production ont été calculées et évaluées avec un modèle d'analyse du bilan écologique. La comparaison des systèmes de production a fait ressortir de grandes différences au niveau du bien-être des animaux, mais seulement de petites différences concernant l'impact sur le climat pour lequel le méthane contribue à 50%. Quasi aucune différence d'émissions n'est constatée entre les fermes qui ont le même système de production. Certains facteurs, comme la surface de mouvement ou le déplacement du bétail en pâturage libre, obtiennent d'avantage d'améliorations du bien-être des animaux que d'impacts négatifs sur les émissions de gaz à effet de serre. Pour ces raisons et pour d'autres aspects environnementaux, économiques et physiologiques, la production de bœuf devrait être basée sur du fourrage ainsi que de la pâture de haute qualité.*

Mots-clés. *Bien-être animal – Gaz à effet de serre – Production de bœuf. – Patures – Evaluation – Empreinte de carbonne.*

I – Introduction

Climate change has become an important issue in agriculture and concerning politics. Avoiding greenhouse gas (GHG) emissions and the reduction of emissions per produced unit are main topics (Alig *et al.*, 2012; BLW, 2011). Aspects of animal welfare are often neglected in this context. The case study analysed and discussed the trade-offs between reduction of GHG emissions and animal welfare in Swiss beef production systems of different intensity. The aim was to find out whether there were differences in the levels of animal welfare between the single farms and the different production systems and to which extend animal welfare could be improved under the given circumstances. Furthermore differences in the climate impact of beef production on the single farms and production systems were evaluated. Conflicts of goals and synergies between climate protection and animal welfare were pointed out. Relevant measures were discussed with regard to their implementation in agricultural practices.

II – Methods

Investigations and discussions of different definitions of animal welfare lead to an own appropriate On-farm Welfare Assessment scheme to collect and to evaluate data on chosen farms. Three beef production systems of different intensity were examined: “Qualitätsmanagement Schweizer Fleisch” (QM) is characterized by a short and intensive fattening period of bulls based on concentrate feeding and indoor housing. “TerraSuisse” (TS) practices short and intensive fattening of bulls also based on concentrate feed, but offers more space and different areas in the indoor housing and an additional outdoor yard. “Bio-Weide-Beef” (BWB) typically practices long and extensive fattening of steers and heifers raised on a forage based diet on pastures, at least in summer. Three Swiss farms of each production system were evaluated using specifically defined and weighted indicators of the following welfare parameters: moving behaviour, social behaviour, resting and sleeping behaviour, feeding behaviour, animal comfort, health and hygiene (Sambraus, 1978; Bartussek, 1996; Sundrum, 2007; Welfare Quality®, 2009; Rütz, 2010).

Global warming potential (GWP) was calculated per kilogram of beef yield at farm gate using a farm model based on a Life Cycle (LCA) Assessment approach (Schader *et al.*, 2012). The farm model consists of a plant model and a livestock model which both allow implementation of farm specific data. Soil-born nitrous oxide emissions were calculated using a model that differentiates between nitrogen from organic and mineral fertilizers (Meier *et al.*, 2012). Thereby the climate impact of the dung of browsing cattle could be modelled more precisely. Animal welfare and climate impact were specifically assessed and modelled for nine farms.

III – Results

The comparison of production systems showed huge differences in animal welfare, but only small differences in the climate impact. Farms of the same production system hardly differed in these issues. The low number of farms assessed within this case study did not allow for a statistical testing. Distinct differences are indicated by not overlapping double standard deviations (Alig *et al.*, 2012).

Related to an optimal farm with 100% animal welfare, QM farms offered 16%, TS farms 53% and BWB farms 76% overall animal welfare, calculated by the mean of single welfare criteria. Thereby distinct differences in animal welfare between the three production systems were shown, although mainly slight differences between the single welfare criteria occurred. This can be seen in Fig. 1.

The GWP of QM beef was 9.5, TS beef 10.8 and BWB 11.5 kg CO_2-eq kg per live weight at the end of fattening. No distinct differences existed as shown in Fig. 2. In all production systems methane

(CH_4) from enteric fermentation accounted for about 50% of the total GHG emissions. Furthermore the duration of the fattening period accounted most for the climate impact of beef production. An analysis of the climate impact of one fattening unit per year revealed 30% less emissions by the extensive farms compared with the intensive systems: For QM farms we calculated on average 4,976, for TS farms 5,412 and for BWB farms 3,673 kg CO_2-eq per fattening unit and year.

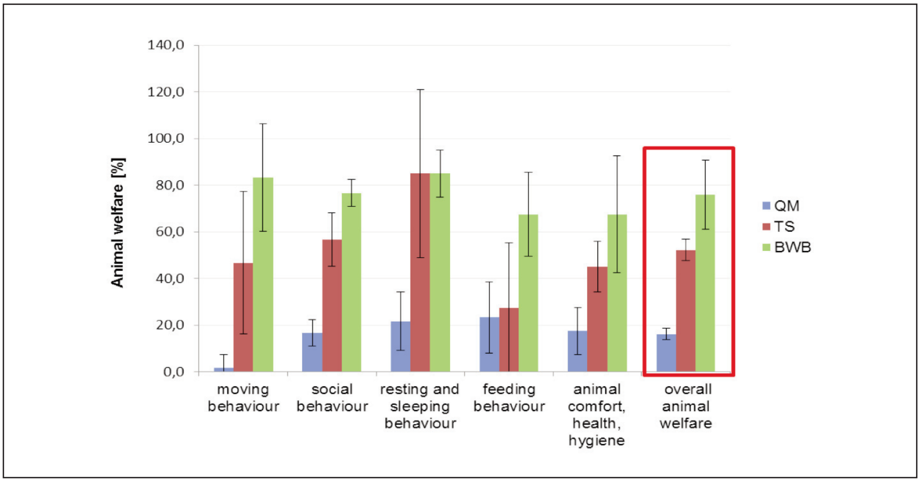

Fig. 1. Animal Welfare related to optimal farm divided in welfare criteria and production systems. The double standard deviation implied significant differences in the overall animal welfare between the three production systems.

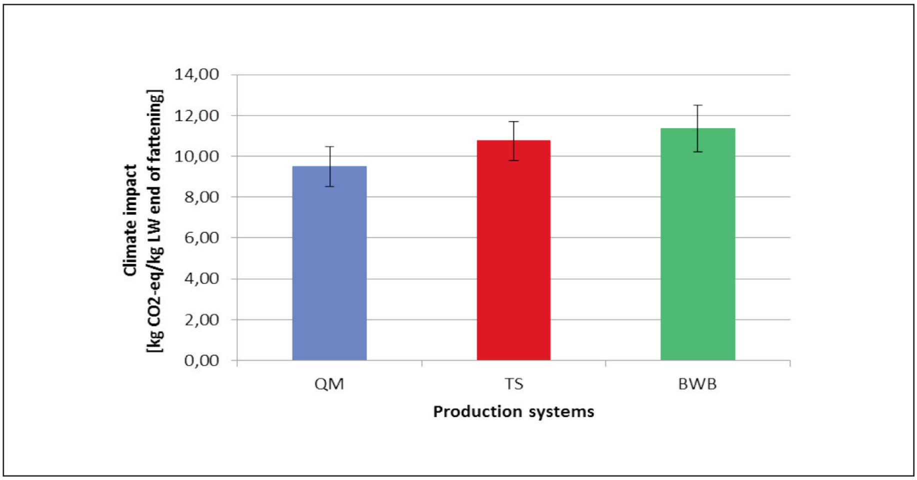

Fig. 2. Global warming potential of the three beef production systems. The double standard deviation did not imply distinct differences.

IV – Discussion

Based on the current findings it appears important and possible to establish and support synergies between animal welfare and GHG reduction measures. Some factors like the size of the cattle's exercise area, pasture and litter achieved large improvements in animal welfare but only small negative impacts on the GHG emissions. Furthermore, pastures provide important synergies like carbon sequestration, mitigation of N_2O emissions, use of grassland and animal welfare (Bartussek, 1996; Bischofberger and Battinger, 2011; BLW, 2011).

A shorter fattening period with high daily weight gains of animals fed on a concentrate-based diet results apparently in the lowest GWP per kg live weight. However, the forage based fattening system resulted in only slightly higher GWP per kg live weight showing no clear trade-off between animal welfare and GHG emissions. In addition, for different ecological, economical and physiological reasons the use of concentrates in livestock feeding shall be reduced and replaced by forage. This measure has gained importance because the assumption of higher CH_4 emissions as a result of roughage feeding had been disproven (Hindrichsen *et al*., 2006 – Klevenhusen *et al*., 2010).

V – Conclusions

The case study revealed potential synergies between animal welfare and climate protection. These synergies should be established and supported. Extensive pasture-based systems as practiced on BWB farms offer best requirements for synergies. Often mentioned conflicts of goals got relativised considering the distinct differences in animal welfare and the slight differences in climate impact between the three production systems. Housing systems which don't offer outdoor yards, litter and pasture can only be supported for economic, but not necessarily for ecological reasons. According to the high percentage of CH_4 in total GHG emissions and its limited reduction potential the most efficient way to mitigate the climate impact of beef production is a short fattening period with high daily weight gains based on forage. In order to support these goals pasture management, roughage production and conservation, nutritive requirements and values and breeding schemes have to be focused on (Spengler Neff, 2011).

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Agricultural added value and its evolution in the Entlebuch UNESCO Biosphere Reserve (Switzerland)

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Abstract. The Entlebuch UNESCO Biosphere Reserve (UBE) is situated in the northern foothills of the Swiss Alps. It consists mainly of grazed grassland and designated nature or landscape conservation areas. In 2004, the Cantonal Government and the Agricultural Credit Bank funded the "Entlebucher Milk" project, an advisory programme initiated with the objective of keeping jobs and agricultural added value within the UBE. In 2012 the project included 914 mountain farms with an average area of 18.2 ha; 504 dairy farms produced 47.8 million kg of milk. Of that, 31.5 million kg of milk was processed by eight cheese factories located in the Entlebuch region. The factories produced an Emmentaler "big-whole" cheese from ensiled feed milk, a traditional Emmentaler AOC-certified (Appellation d'Origine Contrôlée), and Sbrinz AOC. Only 7% of the produced milk was processed into milk specialities. In 2008, the participating farms produced 32.5 million kg of farm animal carcasses. Six local slaughterhouses butchered a share of the animals. In 2013, various processing enterprises established a common marketing company. The production of milk and meat specialities, as well as the merchandising of the brand "Origin Entlebuch," are promising prospects. Bottom-up approaches and participatory decision making are raising stakeholder awareness of how economic benefits can be optimised while considering ecological conditions for sustainable development. Targeted subsidies, such as those for the Entlebucher Milk project, can be an important tool to maintain added value in fringe regions such as the UBE.

Keywords. Swiss mountains – Agricultural added value – Dairy and meat industry jobs – Targeted subsidies.

Développement rural et création de valeur agricole dans la Biosphère UNESCO d'Entlebuch en Suisse

Résumé. *La Réserve de Biosphère UNESCO d'Entlebuch (BUE) est située sur le versant nord des Alpes suisses. Elle est principalement constituée de prairies pâturées et de zones de réserves naturelles. En 2004, l'Etat Cantonal et la Banque d`Agricole ont financé le projet public "Lait d'Entlebuch". Ce programme de vulgarisation a été initié dans le but de maintenir des emplois et de créer de la valeur agricole dans cette région. En 2012, le projet comprenait 914 fermes de montagnes avec une surface moyenne de 18.2 ha. Les 504 fermes laitières ont produit une quantité de 47.8 million de kilo de lait, dont 31.5 million de kilo ont été affinés en fromage par les huit fromageries artisanales de la BUE. Les fromageries ont produit de l'Emmenthal AOC, célèbre pour ses "gros trous", de l'Emmenthal à base de lait d'ensilage et du Sbrinz AOC. Seul 7% du lait produit fut transformé en spécialités laitières. En 2008, les fermes de la BUE ont produit 32.5 million kilo de carcasse et six boucheries artisanales découpaient la viande dans la BUE. En 2013, plusieurs entreprises de transformation artisanale ont fondé une coopérative de commercialisation. La production de spécialités de viande et de lait, ainsi que la vente ses produits sous l'appellation "Appellation d'Origine d'Entlebuch", semblent prometteuses. Les approches de bas-en-haut et participatives augmentent la conscience des participants sur la manière d'optimiser leurs bénéfices économiques, tout en considérant les conditions écologiques de leur développement durable. Les subventions ciblées, comme le projet "Lait d'Entlebuch", peuvent jouer un rôle important pour le maintien de l'emploi et pour la création de valeur agricole dans des régions éloignées, comme la BUE.*

Mots-clés. *Montagnes suisses – Création de valeur agricole – Filière laitière et viande – Emploi – Subventions ciblées.*

I – Introduction

Peripheral regions are particularly challenged (Hofstetter *et al*., 2007) by factors such as economic weakness, and the adoption of agricultural policies (Lanz, 2012; FOAG, 2014) such as the Swiss Agriculture Policy 2014-2017, the free trade agreement with the EU, and WTO negotiations. Subsidies play an important role in the agricultural income of farmers (Hofstetter, 2010).

The Entlebuch UNESCO Biosphere Reserve (UBE) is a fringe region situated in the northern foothills of the Swiss Alps. In 2008, 31.1% of the 9,245 employees in the UBE worked in the primary sector, 29.6% in the secondary sector, and 39.3% in the tertiary sector, compared with 4.2%, 25.3%, and 70.5%, respectively, among the working Swiss population (Lustat, 2012).

Over the past 10 years, farmers in the UBE have increasingly changed their livestock systems from dairy to beef production and shifted their conservation system from hay to silage. Therefore, small cheese factories that mainly produced silage-free cheese lacked a sufficient supply of milk. Consequently, their efficiency was lower and they were not able to generate a competitive milk price. Some businesses closed, jobs were lost in the region, and more milk was processed in larger, more remote creameries outside the UBE. In 2004, the Agricultural Credit Bank and the Cantonal Government of Lucerne funded the "Entlebucher Milk" project (2005) with the objective of retaining agricultural added value within the UBE. Based on market analysis, the study advised small cheese factory co-operatives to merge; optimise their milk logistics; produce softer, semi-hard goat and sheep cheeses or organic products; and to merchandise these as branded products. The inevitable questions arise of: (i) whether the recommendations of that study have been implemented; and (ii) whether this state-funded targeted project helped to retain added value in the UBE.

II – Material and methods

The UBE comprises an area of 394 km^2 situated in the foothills of the Northern Swiss Alps, a Pre-Alpine region. Its agricultural (30.2%) and alpine (18%) zones consist mainly of grazed grassland, or designated nature or landscape conservation areas with high biodiversity (Coch *et al*., 2009). The main production systems are dairy farms, summer fattening and cattle-rearing farms are increasing in number.

During the vegetation period from April to November, grazing systems, in combination with housing, are predominant on lowland farms. In the main valley, most cheese factories produce traditional hard cheeses from raw bovine milk. Some of the farms are moving their young cattle to Alpine farms for summer grazing. Data and trends were taken from Lustat (2012), Central Milk Producer` association (FOA, 2013), Gottlieb Duttweiler Institute (GDI, 2013), and Federal Statistical Office (FSO, 2013).

III – Results and discussion

1. Development of the agriculture farm structure

The numbers of agricultural employees, operational farms, and the gross value added (*i.e.* production value minus preparatory efforts) decreased from 2000 to 2012 (Table 1). In 2012, 93% of farms in the UBE kept cattle, and 36% produced pigs; mostly in addition to dairy farming. In 2000 and well in 2012 within the UBE, there were fewer organic farms compared to the Swiss average, partly due to the high levels of stock in the main valley of Entlebuch and the existence of only two organic cheese factories.

Therefore, most organic milk is sold outside the region. In 2011 and 2012, the UBE included 504 dairy farms with milk production capacity of 42.4 million kg. The average annual milk production per regional dairy farm was low compared to the Swiss average of 135,308 kg.

Table 1. Agricultural facts for the UBE and Switzerland in 2000 and 2012

Year	UBE		Switzerland	
	2000	2012	2000	2012
Persons employed (>75%)†	1,301	900	95,595	72,633
Number of farms	1,096	914	70,537	56,575
Of which full-time farms, %	73	70	70	71
Of which organic farms, %	3	5	7	10
Dairy farms††	632	504	38,082	24,972
Dairy farm size, ha†††	14.8	16.9	19.1	23.8
Merchandised milk, kg/farm††,†††	79,030	84,851	81,691	135,308
Merchandised milk, kg/ha†††	5,340	5,111	4,278	5,696
Merchandised milk, kg/cow†††	4,939	5,110	4,994	6,161
Gross value added, EUR Mio.††††	86	58	452	312

† Full-time labour; part-time job is less than 25%. †† Dairy farms within the UBE in 2007/08; ††† Data in 2012 for the whole mountain region in the Canton of Lucerne; †††† UBE data were calculated from those for the Canton of Lucerne.

2. Development of the processing companies

In 2004, 23.1 million kg of milk was processed in the UBE and 15.1 million kg was sold outside the region. Although the number of cheese-producing co-operatives decreased from 14 in 2004 to 8 in 2012, the average amount of milk processed per factory and the total amount increased (Table 2), mostly because of the consolidation, whereby smaller co-operatives had combined to form fewer factories in larger scale ones. In order to retain added value within the region and reduce transport costs, a new dairy factory was built in a remote part of the region, which has processed about 16 million kg of ensiled feed milk for an Emmentaler "big-hole" cheese. Only about 7% of the produced milk was processed into milk specialities. In 2012, twelve companies marketed certified milk and cheese specialties under the label "Origin Entlebuch."

Table 2. Facts of the dairy industry in the UBE from 2004 to 2012

	Cheese factories [nos.]	Former milk quota, new average supply with contract per annum [kg]	Total milk processed per enterprise [kg]
Cheese factory co-operatives, 04/05	14	23,100,000	1,650,000
– producing other cheese specialities	8	1,850,000	231,250
Cheese factories, 2007/08	11	28,052,143	2,550,195
– producing milk specialities	12	~ 3,000,000	Partially certified
Cheese factories, 2001/12	8	34,250,306	4,281,289
– producing milk specialities	6	~ 3,500,000	Partially certified

Farms within the UBE produced about 3.3 million kg of animal carcasses, consisting of 1.9 million t cattle, 1.3 million t pig, and 0.1 million t of small cattle, wild animals and chicken etc. (Vogel, 2010). The small slaughterhouses butchered animals and treated the meat to produce specialties for selling over the counter and offered party services. Three slaughterhouses were processing an increased quantity of meat. A high share of the carcasses was processed elsewhere. In 2013, a new trading company was established by 15 enterprises (Echt Entlebuch, 2014) in order to boost marketing by offering an attractive aggregate supply of food specialties from the UBE.

3. Impact of the study

Structural reforms in the cheese factories were carried out as proposed in the Entlebuch Milk study. Milk logistics have been optimised by building a new cheese factory in a remote part of the valley, and through an increase in branded specialities. These specialities generate higher added value even though they require more labour input than traditional food production. It is a great challenge to develop and merchandise food specialities through new marketing channels, and is essentially dependent on dynamic entrepreneurship. For small- and medium-sized companies, well-educated and constructive cheese and meat manufacturers play a key role.

Contrary to the study's proposition, there was no increase in organic farming and its products. In summary, this targeted, state-funded program helped to retain greater added value within the UBE.

IV – Conclusions

As a result of measures to promote entrepreneurship, the new cheese dairies seem able to generate competitive milk prices and to effectively market their specialities. Although jobs and added value declined in the primary sector, new jobs were created in manufacturing and added value was retained within the region. In an environment of rising public debt, government spending and its outcomes should be monitored. In this study, we have shown that targeted subsidies can be an important tool to maintain added value in fringe regions such as the UBE. However, the main entrepreneurial initiative has to arise from the stakeholders.

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Designing a multicriteria index to assess on-farm working conditions to maintain farms in mountain areas

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Abstract. Grass-based dairy farming systems located in mountain areas and complying with Protected Designation of Origin specifications provide multiple services to these territories. However, the number of dairy farms has decreased since the 80s. Consequently, there is a need to assess the sustainability of these farms. As on-farm working conditions are a major issue of the sustainability of farms, this study aims to develop a tool to assess on-farm working condition (FWC) on a farm scale to detect possible leeway to improve sustainability of dairy farms and to maintain milk production in the mountains. To design a relevant and meaningful tool for the target users –the farmers– relying on a pertinent and exhaustive overview of working conditions of the PDO dairy systems, a participatory approach has been chosen. First, a focus-group, including farmers, advisors and researchers, defined criteria covering the different aspects of working conditions. Then, they selected or created appropriate indicators out of a list of possible existing indicators. Afterwards, the index was built by weighting indicators and criteria. This process results in an index made up of 5 criteria described by 40 indicators with original criteria compared to former index such as mental dimension of work. The index will be further tested on dairy farms. This index, designed by and for the farmers will be implemented on a large number of PDO dairy farms to obtain more insight on their FWC and to help advisors to support farmers to improve their FWC and their sustainability.

Keywords. Working conditions – Multicriteria assessment – Participatory approach – Grass-based dairy systems – PDO cheese systems – Mountain area.

Co-construction d'un index multicritère sur les conditions de travail de l'exploitation agricole pour améliorer l'évaluation de la durabilité : cas des systèmes laitiers de montagne adhérant à une AOP fromagère

Résumé. *Malgré les services rendus par les systèmes laitiers situés en montagne et adhérant à une AOP, ces derniers tendent à diminuer. Il y a donc un besoin d'évaluer leur durabilité, et plus particulièrement leur durabilité liée aux conditions de travail, considérée comme étant un point critique de ces systèmes. Dans le but de construire un index le plus exhaustif et le plus pertinent possible pour les futurs utilisateurs, que sont les éleveurs, une démarche participative a été choisie. Un focus-group a été ainsi constitué comprenant des éleveurs, des conseillers et des chercheurs afin de sélectionner et/ou créer des indicateurs pertinents. Les focus-group ont permis d'aboutir à un index comprenant 5 critères regroupant 40 indicateurs.*

Mots-clés. *Condition de travail – Évaluation multicritère – Approche participative – Système laitier herbager – Système AOP fromager – Montagne.*

I – Introduction

Since the 1950s, mountain areas have to cope with a continuous reduction or abandonment of agriculture (García-Martínez *et al.*, 2009), even higher than the general decrease in the number of dairy farms in France. Grass-based dairy farms located in mountain areas complying with Protected Designation of Origin (PDO) specifications have not been spared from this drastic trend (Sturaro *et al*., 2013). On-farm working conditions (FWC) play a crucial role in dropping number of farms in pasture-based livestock farming systems (Bernuès *et al*., 2011).

Many tools to assess FWC on a farm scale exist. These tools are either specifically related to FWC or include some FWC aspects within a more global tool to assess sustainability, such as IDEA tool (Zahm *et al*., 2008). But these tools do not take into account special features of those systems such as geographical and pedoclimatic constraints due to mountain location and the special link between farming practices. But those constraints affect FWC, such as a long in-door period implying tasks dedicated to in-door feeding and manure scraping. Moreover, the IDEA tool assesses FWC with only 6 indicators such as social involvement, life quality, workload intensity, training programmes, isolation and visits on farm, hygiene and security conditions on the farm. Considering that on-farm working conditions deals with many disciplinary fields such as sociology, economics, ergonomics and medicine (Madelrieux and Dedieu, 2008),this IDEA index does not cover all the dimensions of FWC. So there is a need to build a relevant and complete tool to assess FWC. Thus, it has been decided to build, *de novo*, an index to assess FWC, by a participatory approach, in order to: (i) consider system specifications; (ii) tend to cover all the dimensions of working conditions; and (iii) being pertinent for helping farmers to improve their FWC. So this study will focus on working condition assessment in order to develop a tool built by the farmers and for them. Indeed, this tool will be directly used by the stakeholders of the PDO network in order to establish on-farm diagnosis and supply advice supports.

II – Material and methods

The aim of this study is to build a relevant and appropriate multicriteria index to assess on-farm working conditions for the target users, the farmers. By building an index, we mean to describe on-farm working conditions by its dimensions, to select or to create indicators, to scale, to rate and rank them.

The building process of multicriteria index relies on a strong bill of specifications referring to the project’s aim. Selection of indicators relies on the strong premise that they have to be relevant and operational. In this way, firstly, to be selected, indicators have to be adapted to local context and PDO system specificities. But, they also need to be generic for all the different dairy systems within the geographical PDO area, and relevant to on-farm working condition assessment. Secondly, data collection of indicators has to be carried out easily and quickly to perform on-farm working condition assessment on a large panel of farms. Secondly, index building process relies on a participatory approach. Indeed, to design a relevant, meaningful and useful tool for the target users, the farmers, a participatory approach, is appropriate (Reed *et al*., 2006).

The multicriteria index has been built based on a four-step process: (1) defining criteria covering the different dimensions of working conditions and then, selecting, or creating if necessary, appropriate indicators from a list of possible existing indicators from literature review; (2) establishing a scale for each defined indicators; (3) setting up a score corresponding to indicators’ scales; and (4) ranking and weighting indicators within and between working condition criteria. The two first steps, which require comprehensiveness and creativity, have been conducted with an extended focus-group. It was made by three categories of stakeholders: (i) production sector with farmers and representatives of the institution defensing and promoting the PDO; (ii) advisors; and (iii) researchers. This composition has been decided to diversify points of views on on-farm working conditions. Advisors and researchers have been selected by their expertise and their interest. As step 3 and step 4 depend on the desired directions for PDO systems, they have been carried out with a restricted focus-group of farmers and PDO representative.

III – Results and discussion

The building process has resulted in an index assessing on-farm working conditions with 5 criteria described by 40 indicators (Table 1). The criteria are: (i) Work duration and work organization; (ii) Life quality; (iii) Physical dimensions; (iv) Mental dimensions; and (v) Isolation and relationships with others. The building process by focus-group leads to a large number of indicators. They cover diversified aspects of on-farm working condition dimensions comparing to existing tools assessing on-farm working conditions. Indeed, few general indexes at farm-scale integrate few social indicators related to working conditions (van Calker *et al*., 2007) and are mainly on one particular aspect of social sustainability, such as (van Calker *et al.*, 2007) centered on worker physical health, (Reig-Martínez *et al.*, 2011) on workforce description. Working conditions are not only physical health conditions or workload but also quality of life, relationships between the farmer and his close environment: family, professional, territory, etc.

Table 1. description of index to assess on-farm working conditions

Criteria number	Name of criteria (dimensions of working condition)	Weight indicators	Number of indicators	Type of indicators		
				quantitative	qualitative	mixed
1	Work duration and work organization	28	6	5	1	–
2	Quality life	25	11	3	7	1
3	Physical dimension of work	18	9	–	1	8
4	Mental dimension of work	16	3	–	3	–
5	Isolation and relationships with others	14	11	–	11	–

Our index is made by diversified indicators with mainly qualitative ones, but also quantitative and mixed ones (Table 1). For instance, to assess life quality, there are quantitative indicators such as number of week-end per year without any farm activity, qualitative indicators like “presence or not of regular time slot for farm activities” and mixed indicators with “presence of a working organization change between weekdays and weekends” coupled with a quantification of the extend of working organization changes (the whole week-end, only Sunday or Sunday evening). Other general tools exclusively rely on quantitative and qualitative indicators without mixing them. For instance, van Calker *et al.* (2007) have chosen to restrict working condition to physical and psychological health linked to farm characteristic variables and to exclude psychosocial and personal dimensions due to their non-measurable dimension. On the contrary, Ripoll-Bosch *et al*. (2012) and Zahm *et al.* (2008) assess qualitative and subjective indicators based on farmer’s perceptions.

Thereby, index designing process relying on participative approach mixing different actors enables to generate certain creativity. Indeed, the focus group members worked on a list of possible existing indicators. Some indicators have been selected in their original format; some have been simplified due to the constraint of collecting data easily on the farm. For instance, the well-established Quaework method developed by Hostiou and Dedieu (2012) to assess workload requires time to collect and to process data (1.5 day per farm). As a consequence, the focus-group decided to simplify the method by subdividing it into easier indicators. Thus, in order to estimate workload, it has been decided to use two steps: (i) a quantification of daily routine work on a typical day basis during winter-time and pasture-time; and (ii) a quantification of overloaded working days on total time needed to achieve a list of predefined tasks.

Furthermore, some indicators have been created. Unlike Ripoll-Bosch *et al.* (2012) or Zahm *et al.* (2008), the focus group members did not only want to base the assessment on farmer’s perceptions concerning their stress or satisfactory level. So they designed an indicator which objectively estimates farmer’s perceptions. To assess factor stress, the farmer declares three main factors from a predefined list of factors which can lead to stress. Each factor on this list has been previously judged by the focus-group members as a significant factor or as a less important factor with a different score.

In spite of certain creativity due to the participative approach, some features of work assessment on a farm scale have not been included in the index such as indicators related to labour productivity or labour input. These indicators are currently used to assess work or labour from an economic perspectie. These aspects of FWC have not been judged as relevant by the focus-group members. At this step of index building process and with this ranking method, compensation is possible between criteria or indicators. There is no threshold of exclusion.

IV – Conclusions

The participative approach based on focus-group meetings enabled to design a rich and diversified multicriteria index to assess on-farm working conditions with 40 indicators covering different dimensions. However, this index still needs to be tested on farm to verify that: (i) indicators are relevant and operational; (ii) data are easy to collect and process. Performing the index on a large number of PDO dairy farms will enable to get more insight on FWC and help advisors to support farmers to improve it.

This index to assess FWC is a part of an extended index to assess sustainability of dairy farms. This extended index is made up of 5 other dimensions or objectives: (i) respecting and highlighting natural resources and local heritage; (ii) improving and securing the farmer's incomes, (iii) being able to pass on the farm, (iv) guaranteeing the quality of milk product, (v) contributing and promoting the link between the farm and the territory and PDO food-chain. In the future, it would be interesting to investigate how this index could fit to other dairy systems.

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Red meat production in south-east Tunisia: typological outline of producers

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Abstract. In Tunisia, the livestock production systems with all their components are still inadequately regulated, weakly organized and suffer from lack of statistical data. This makes the red meat chain profoundly affected by many problems. To face these problems, a thorough analysis of chain components is crucial for better regional integration. This work is based socioeconomic data collected in 2012-2013 from surveys of sixty small ruminant breeders in Medenine province (South east Tunisia). The objective is to develop a typology of small ruminant breeders. All the elements of livestock activities have been considered such as breeders (socio -economics, income, assets, inputs and outputs), livestock (composition and herd management practices) and resources used in the production process. The typology shows five groups of breeders with different practices and strategies. Three groups, representing 56% of the sample are mainly specialized in breeding for red meat production. The other two groups are considered more as family breeders which are encountered in all regions of the study area. Nevertheless, livestock for red meat production is localized in large farms and it's correlated rather to the space (area) and also to the size of the flock.

Keywords. Meat sector – Typology – Producers – Small ruminants – Tunisia.

La production de viandes rouges au sud-est de la Tunisie : esquisse de typologie des producteurs

Résumé. *En Tunisie, les systèmes de production animale avec toutes leurs composantes sont aujourd'hui encore mal réglementés, mal organisés et manquent de données fiables et chiffrées. Ceci génère un grand nombre de problèmes dans la filière des viandes rouges. Face à cette situation une analyse approfondie des maillons de la filière est indispensable pour une meilleure intégration régionale. Cet article s'appuie sur un travail d'enquêtes socio-économiques, réalisé fin 2012-début 2013, auprès d'une soixantaine d'éleveurs de petits ruminants dans le gouvernorat de Médenine (Sud-est de la Tunisie). L'objectif est de mettre au point une typologie des producteurs (éleveurs) de viandes rouges ayant des petits ruminants. Tous les éléments définissant l'activité d'élevage ont été considérés, tels les éleveurs (socio-économie, revenus, patrimoine, recettes et dépenses), le cheptel (composition et gestion des effectifs) et les ressources mobilisées dans le processus productif. La typologie montre cinq groupes d'élevages avec des dynamiques de production différentes. Ainsi, trois groupes, représentant 56% de l'échantillon, sont principalement spécialisés dans l'élevage pour la production de viandes rouges. Les deux autres groupes relèvent, plutôt de l'élevage de type familial. Cet élevage de type familial est localisé dans toutes les délégations du gouvernorat. L'élevage pour la production de viandes rouges est lié plutôt à l'espace (superficie) mais aussi à la taille du troupeau.*

Mots-clés. *Filière viande – Typologie – Producteurs – Petits ruminants – Tunisie.*

I – Introduction

Despite the organization and structuring of livestock sector and commercialization chain, the animal products are important source of income especially for rural population in Tunisia. The Tunisian meat production in terms of the national agriculture gross domestic product (GDP) is around 16%. Nevertheless, Tunisia is not yet self-sufficient for the meat production and the import of meat represents one of the main factor of the agricultural deficit of the country. Small ruminant breeding plays a socioeconomic role for the pastoral populations (Snoussi *et al*., 2008). The market and the productive systems of the red meat remained dominated by the informal sector (uncontrolled and illegal slaughtering of animals), the multiplicity of actors and their roles (Faye *et al.,* 2001) which makes difficult the intervention of government authority and their actions to structuring red meat and livestock sector. To deal with this problematic, a complete analysis seems indispensable along the production chain with special reference to the meat from sheep and goats in southeast of the country. The main objective is to understand firstly the organization of the meat sector and secondly to make recommendations allowing optimize, viability and sustainability of this sector (Petit, 1985). The present study analyses the main important component of red meat sector, which is the small ruminant livestock breeders in the region of Medenine southeast of Tunisia. Thus, the typological characterization of the main groups of the breeders in the study zone will be analysed in order to understand the diversity of existing breeding practices.

II – Materials and methods

The data were collected from socioeconomic surveys covering different delegations (counties) in the governorate of Médenine. 67 farmers' sample has been selected from the sampling frame. This sampling frame is an update list of small ruminant farmers in the whole governorate provided by the regional Office of Livestock and Pasture (OLP) of Médenine. The sample was identified and selected in a simple random 1.5% sample of the total population (4470 breeders) on the basis of a computer-generated random sampling frame. The aim of multivariate analysis in to treat the data for the typological analysis which would clarify the characteristics of the different types of existing farms. Variables used in this typology concern (Gibon *et al.*, 1999) land ownership, animal ownership, sheep and goats' flocks, flock management, numbers of entries and exits within the previous 12 months of the survey, production costs and sales returns for sheep and goats. A principal component analysis (PCA) was made using 17 variables (Table 1). This analysis synthesizes data which can be dispersed and heterogeneous for some variables and factors; this explains most of the total variability of the sample (Daniel *et al.,* 1994). The interpretation of the factors it was eased by the use of a hierarchical analysis (cluster analysis) that was performed on the coordinates of the farms (Hair *et al*., 1987) against the first three factors. This analysis differentiates and groups farms according to their homogeneity using Ward Criteria. Five groups were obtained from the cluster analysis. All calculations were made using the XLSTAT (7.5.2 version).

Table 1. Variables used for the principal components analysis (PCA)

Producer characteristics	Codes of Variables	Averages	Standard
Surface area ownership (hectare)	SURF_AREA	17	43,7
Small ruminant herd (head)	RUMINANTS	85	129
Sheep herd (head)	SHEEP	63	109
Goats herd (head)	GOATS	22	36
Returns for sheep (dinars)	RETURN_SHEEP	3069	5230
Returns for goats (dinars)	RETURN_GOATS	8609	15840
Livestock product in one year (head)	PDT_LIVEST	32	60
Fertility rate (%)	FERTILITY	88%	14%
Renewal rate of males (%)	MALE_RVL	43%	37%
Renewal rate of females (%)	FEMALE_RVL	55%	28%
Sales of animal in bad annual rainfall (head)	SALES_ AS	29	57
Purchase of animals in bad annual rainfall (head)	PURCHASE_ AS	4	24
Sales of animals in good annual rainfall (head)	SALES_ AP	29	57
Purchases animal in good annual rainfall (head)	PURCHASE_ AP	4	24
Labour cost (dinars)	COST_MO	1807	2140
Feed cost (dinars)	COST_ALM	1534	2028
Others cost (dinars)	COST_OTHERS	628	563

III – Results and discussion

Five groups were obtained from the cluster analysis. Two groups of 17 and 12 breeders belonging to family or domestic breeding (G_1, $G_{5)}$. The other three groups were composed of 16; 7 and 15 breeders considered as the most important because they represent the core of red meat breeding (G_2, G_3, G_4). The mean structural, technical and economic indicators that define each group were calculated to describe typological groups (Table 2).

The group of farmers rearing goats breeding (G_1): It is composed of 17 farms (about 25% of the sample) had an average total surface area of 7 ha. Mean age of owners was about fifty years, and the average family size was 5.4 persons. The flocks were small sized (42 heads) compared with the mean of sample (85 heads). On these farms sheep were not usually bred together with other livestock. Total mean labour employed was 2 persons, without salaried workers involved. In this group, owner and his wife usually work full time on the farm. With respect to flock management, in this group traditional heard management and livestock was the normal practice and there was not a specific performed production of kids over the year since the product was sold directly to local butchers. This was the group of farms which had existed in the entire southeast region and especially in mountainous areas. However, income from goats was 72% of the total income, due to the fact that a large proportion of other agricultural production was barely enough for their family and subsidies came mainly from goat's livestock. We note that this type of farming was both extensive and intensive farming system because both types are located in almost everywhere in these regions, even in Djerba Island).

The group of agro pastoralist and ranchers (G2): It is composed of 16 farms, representing 24% of the sample. Farms of this group had a mean total surface area of 33 ha. Mean age of owners was about 51 years, and the average family size was 5.6 persons. The mean size of flocks was high (147 heads) compared with others groups and with the sample mean (85 heads). However, the portion of sheep was 81% of the total flock. The mean total labour force was between 3 and 4 persons, most of them are family members (sons and daughters). Most of these types of farmers practice, or most of them alternate grazing (Bourbouze, 2000). This group had the highest mean livestock expenditure per head. They had to resort to buying livestock products more than the other groups. Mean sheep expenditure was more than 74 % of total expenditure, and income from livestock activities was 71% of total income. Finally, these farms had the highest economic productivity of farming and livestock activities.

The investing farmers (G3): this group was composed of only 7 farms or 10% of the sample, it represented a type of farm which was clearly differentiated from the rest of the sample surveyed. It's a group of farms with large sizes, positive and high level of profitability. This profitability is generally due to high performance of both sheep and goats. The mean size of flocks was high (120 heads) compared with the sample mean (85 heads). However, the portion of sheep and goat was respectively 53% and 47% of the total flock. The mean total labour force was between 4 and 5 persons, three of them are salaried workers. Most of these farmers practice, most often alternate grazing. This group corresponds to a core investor or who are in most cases owners of restaurants ("machwa") at the age of the main asphalt road and they had their own stock of cattle for immediate slaughter. These kinds of breeders were located particularly not far from cities.

The group of farmers keeping mixed herds of goats and sheep (G4): Composed of 15 farms or 22% of the sample had a mean total surface area of 10 ha. Mean age of owners was about forty-nine years, and the average family membership was 5.7 persons. The flocks were medium sized (82 heads) compared with the mean of sample (85 heads). On these farms sheep and goats were usually farmed together. Total mean labour employed was 2 persons, without salaried workers involved. In this group, owner and his wife usually worked on the farm. However, income from sheep was not equal to this from goats, due to the fact that sheep farming costs per sheep were low compared to thus for goats, and were only 35% of total farm costs. All farms had installations for separating sheep into lots and the practice of traditional heard management. As the same of group 1 livestock product was sold directly to local butchers.

The group of farmers rearing sheep (G5): Composed of 12 farms or 18% of the sample, had the lower mean total surface area of 5 ha. The average age of owners was about sixty-one years, and the average family membership was 6.2 persons. The flocks were small sized (48 heads) compared with the mean of sample (85 heads). Most of the flock was composed of sheep, or 82%. This group had a high mean livestock expenditure per heard. As the surface area was low, they had to resort to buying feed products more than the other groups. Mean sheep expenditure was more than 92% of total expenditure, and income from sheep was 88% of total income.

Table 2. Summary of main defining characteristics (mean values for the farm groups)

Farmer's groups	Sample Size	Household Size	Area (ha)	Flock (head)	Sheep (head)	Goats (head)	Sheeps return (dinars)	Goats return (dinars)	Global costs (dinars)	Global result (dinars)
Sample	67	5,8	17	85	63	30	7766	3985	9100	2578
(G1)	17	5,4	7	42	18	30	3576	1491	7163	-2096
(G2)	16	5,6	33	147	119	33	17163	3966	10841	10288
(G3)	7	7,1	30	120	64	56	10343	6150	13362	3131
(G4)	15	5,7	10	82	59	23	6000	3330	7672	1658
(G5)	12	6,2	5	48	39	9	1750	4988	6488	250

IV – Conclusion

In short, we may say that some types of farmers (G_2, G_3, $G_{4)}$ representing 56% of the sample, are very different from the rest. They are mainly specialized in breeding for the production of red meat and constitute the core of red meat industry. The other two types G_1, G_5, represent farming family type. They can be located in all regions of the study zone. Finally, it can be concluded that despite the low productivity of the farming systems identified by the typology, many advantages could be pointed out, particularly: First, the breeder is able to adapt his strategy to the climate and unusual conditions and has a very strong know how for using available resources and overcome in most of the cases the problems of livestock feed. Second, local breeds are well adapted to harsh conditions of the dry areas. However, the breeders are still obliged to cope with many other imposed constraints and, therefore, there is a serious need for the intervention of the government especially in terms of livestock sector organization.

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Horses and rangelands: Mutual contributions and perspectives

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Abstract. Horses are increasingly present in pastoral areas but little is known about their potential contribution to rangeland utilization. In order to investigate this question in the context of Southern France, a specific research project was undertaken, with: (i) a farm-scale analysis to determine the importance of rangelands for horse feeding in agro-pastoral farming systems; and (ii) a territorial analysis to identify the role and importance of horses for pastoral areas, based on inventories, spatial analysis with GIS and interviews with local stakeholders. Among the "professional" horse farms we studied, only a few feeding systems relied mainly on rangelands. On the other farms, rangeland utilization was limited due to the lack of land, equipment or pastoral knowledge. On a territorial scale, horses were rarely accepted as proper rangeland users and access of horse owners to land depended on the evolution of local ruminant farms. For a number of stakeholders, horses can help reducing land abandonment and show interesting complementarities with ruminants. Further research is needed on the interest of associating horses with ruminants for rangeland utilization on farm and landscape scales.

Keywords. Equids – Pastoralism – Feeding system – Territorial analysis.

Chevaux et parcours: apports mutuels et perspectives

Résumé. *Les chevaux sont de plus en plus présents dans les territoires pastoraux, mais leur contribution à la valorisation des parcours a été très peu étudiée. Pour apporter des éléments de réponse à cette question dans le contexte du Sud de la France, un projet de recherche-développement spécifique a été mené, comportant : (i) une analyse à l'échelle de l'exploitation pour établir la place des parcours dans l'alimentation des chevaux au sein des systèmes d'élevage agro-pastoraux ; et (ii) une analyse territoriale visant à identifier le rôle et l'importance des chevaux pour les espaces pastoraux, à partir d'inventaires, d'analyses spatiales avec outils SIG et d'enquêtes auprès des acteurs du territoire. Parmi les exploitations équines « professionnelles » enquêtées, seuls quelques systèmes d'alimentation étaient principalement basés sur les parcours. Dans les autres exploitations, l'utilisation des parcours était limitée par le manque de terres, d'équipements ou de compétences pastorales. A l'échelle territoriale, les chevaux étaient rarement acceptés comme acteurs du pastoralisme et l'accès à la terre des propriétaires équins dépendait des évolutions des élevages de ruminants locaux. Pour certains acteurs, les chevaux pourraient contribuer à limiter la déprise agricole et présentent des complémentarités intéressantes avec les ruminants. A l'avenir, il s'agira d'analyser les opportunités offertes par l'association de chevaux et ruminants pour l'utilisation des parcours aux échelles de l'exploitation et du territoire.*

Mots-clés. *Equins – Pastoralisme – Système d'alimentation – Analyse territoriale.*

I – Introduction

In the last 30 years, with the development of horse-based leisure activities, the equine sector has soared. In France, the 1 million estimated equids (REFErences, 2012) would use 5% of the permanent grasslands (REFErences, 2009) and up to 6% of the total surface area in certain rural districts (Vial *et al.,* 2011). Besides, horses are increasingly present in pastoral areas, but little is known about their potential contribution to rangeland utilization. Rangelands are lands bearing "heterogeneous natural vegetation communities with high conservation value, growing in harsh environments and characterized by high heterogeneity in the spatial and temporal distribution of the forage resource" (Jouven *et al*., 2010).

In order to investigate the mutual contributions between horses and rangelands, a specific research project was undertaken, associating research and development institutes, pastoral services and professional stakeholders. Two complementary approaches were developed: a farm-scale analysis aimed at determining the importance of rangelands in horse feeding systems, and a territorial analysis aimed at identifying the role and importance of equids for the pastoral areas, as seen by the various territorial players. This article presents the major results of these two studies and puts them into perspective.

II – Rangelands can feed horses … if the system is designed for it

In Southern France, grazing rangelands is altogether a tradition, a means to produce hardy animals and a low-cost feeding system. We investigated two contrasted systems: (i) the Camargue farms, where horse breeding is traditionally practiced in association with cattle; (ii) the Endurance farms in the Causses. Endurance farms in this area have been introduced recently (end of the 20th century), with the development of endurance as a sport, in pastoral areas traditionally exploited by sheep farms.

1. Material and methods

In 2011, a dozen farms per system were investigated, following the method "functional analysis of feeding system" developed in the 1980s by the Institut de l'Elevage (Moulin, 2005). We selected farms with 5 or more mares, including a pastoral component (rangelands and grazing). The 12 Camargue farms investigated exploited on average 350 ha of land of which 74% rangelands (mainly marshes and salted pasture) with 59 horses. The 11 Endurance farms investigated used on average 240 ha, of which 79% rangelands (mainly dry open pasture) with 43 horses. Farms widely differed in terms of total surface area (25 to >1500 ha) and, to a minor extend, herd size (20 to >100 horses). Farms usually diversified their sources of income, mainly with equestrian activities.

For each animal group, we estimated the contribution of grazed forage (grazing ratio) and more specifically of rangelands (pastoral ratio) to the feeding system. With reference to a whole year, we calculated the percentage of days where animals were fed on such resources. This percentage was corrected as a function of supplementation. The ratios at farm scale were obtained by averaging the ratios for animal groups, weighed by their size and time of presence.

2. Rangelands can provide up to 85% of horse feed requirements

Based on grazing and pastoral ratios (Table 1), the farms of each system were divided into three groups: (P+) included farms with large areas of rangelands and the highest pastoral ratios (≥60% of feed grazed on rangeland at farm scale); (P) included farms with high grazing ratios (40-98%) but lower pastoral ratios (25-60%) due to a significant contribution of either grazed grasslands or forage and concentrate supplementation to the feeding system; (P-) included the least pastoral farms, which made little or no use of their rangelands.

Within the farms, the highest pastoral ratios were for the young and the mares (Table 1), while in (P) and (P-) farms the mounted horses were fed almost exclusively on conserved feed and kept close at hand to be easy to catch. The high pastoral ratio of (P+) farms seemed to be due both to the secured access to a large surface area of rangelands and to the deliberate low-cost and rangeland-based feeding strategy of the farmer. In (P) farms, the lower pastoral ratio could be explained by a precarious access to rangeland associated with a lack of pastoral equipment and/or the belief that rangelands (compared to grasslands) were no decent forage resource. Grazing in (P) farms was mainly limited by land availability and disputes between neighbors.

Table 1. Grazing and pastoral ratios, with basic information about farm structure, for the three farm types (P+: very pastoral, P: with pastoral component; P-: almost no pastoral component) and the two types of farming systems (C: Camargue; E: endurance)

Type of farm	P +		P		P-	
Type of system (nb farms)	**C** (5)	**E** (3)	**C** (5)	**E** (5)	**C** (2)	**E** (3)
Total surface area	311	373	521	221	35	131
Rangelands/total surface area	83%	90%	84%	84%	23%	58%
Herd size (nb horses)	77	55	51	33	36	47
Mares and young† / herd size	65%	45%	47%	58%	47%	46%
Grazing ratio (whole farm)	82%	71%	70%	51%	50%	27%
Pastoral ratio (whole farm)	**68%**	**69%**	**46%**	**38%**	**0%**	**12%**
Pastoral ratio (mares)	83%	60%	62%	35%	0%	11%
Pastoral ratio (young†)	85%	81%	64%	57%	0%	23%

† Young: weaned young horses before breaking in (from 6 months to 3-4 years old).

III – Horses against agricultural abandonment in pastoral areas

The territorial impact of horses was studied in the Cevennes National Park, which has a strong pastoral tradition in dairy and meat sheep farming. Equine activities in the Park were introduced at the end of the 20th century, and occupied the areas abandoned with the decline of ruminant farms.

Our investigations aimed at characterizing equine activities in the Park, with their territorial impact, and the perception of such activities by local stakeholders.

1. Material and methods

Information was gathered from existing databases about equine activities, and expert knowledge of Park guards. Such data were completed with a postal survey, then analyzed with GIS software to determine the type of equine activities in the Park and the factors explaining their spatial distribution (results not presented in this paper).

Fifty-seven interviews were carried out during the spring and summer 2013, with: equine farmers and equestrian structure owners (33 persons interviewed); non-equine farmers (7); elected representatives of equine activities (3); people of pastoral and agricultural technical services (3); employees of the Cevennes National Park (3); employees of tourist information centers (3); others (5). The interviews consisted in a discussion about: a) the perception of rangelands, b) the local impact and evolution of equine activities, c) the interactions between equine activities and local stakeholders and d) the opportunities and drawbacks of equine activities for the area.

2. Equine activities suffer from a negative image

Most local stakeholders consider that equine activities bring little or no contribution to the local agricultural, ecological, and economic dynamics. This opinion is probably a result of the poor integration of equine farmers into the social and technical agricultural environment and of the image of luxury associated with horse owners and the cost of horse riding (especially for Endurance horses, which attract each year visitors from the Arabian Emirates). Moreover, equine activities have mostly been set up by newcomers and are mainly practiced by the urban population. Although most equine farms in the Park use large areas of rangeland, many stakeholders associate horses with land degradation, based on the image of amateurs keeping their animal all year round on the same small paddock. As a consequence, landowners prefer to work with ruminant farmers and access to land is particularly difficult for equine farmers. Though, most equine farmers develop a good relationship with the neighboring farmers.

3. Actual contribution of horse-based activities to pastoral areas

Most equine structures in the Park are diversified (farming +/- tourism +/- equestrian activity) in order to cope with the unpredictability of horse sales, the short touristic season, and the low population density. The spatial distribution of equine activities can be explained by the recent evolution of ruminant farms, and suggests that horses can help fighting land encroachment by using the rangelands abandoned by ruminant farms. For example, endurance farms have developed in the Causses on the land abandoned by sheep farms.

The stakeholders with the broadest territorial views cited a number of positive impacts of equine activities. Horses can be a means to create social links between rural and urban populations. They can also contribute to the touristic and economic dynamism, provided that they are well organized at large scale (ex. asine tourism in the Cevennes). Finally, pastoral services and a number of equine and non-equine farmers recognize the contribution of horses to the ecological preservation of open rangelands and their complementarities with ruminant species in terms of feeding behavior and preferences.

IV – Conclusion and perspectives

Horse numbers grow, and equine activities increasingly take part to the agricultural, socio-economic and ecological dynamics in rural and peri-urban areas. This work has contributed to the establishment of references about equine activities in pastoral areas of Southern France. Our results suggest that horses and horse-based activities can contribute significantly to the provision of ecological and socio-economic services in pastoral areas. In order to achieve this, equine farmers should be: (i) better integrated into the agricultural sector; (ii) considered as proper rangeland users; and (iii) provided with technical support in order to encourage rangeland-based feeding systems. Further research is needed to investigate the interest of associating horses with ruminants for rangeland utilization at farm and landscape scales.

Acknowledgments

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Milking and reproduction management practices of transhumant sheep and goat farms

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Abstract. Transhumance is the seasonal movement of livestock and people between regions of different climate conditions aiming at a better development of grazed areas. Transhumant people move towards summer pastures in spring and spend 5 to 6 months in the uplands, where animals are kept outdoors or in makeshift facilities. The transhumant farming system in Greece is still practiced in many regions of the country. The purpose of this paper is to examine the prevailing management practices of this specific sheep and goat production system, especially concerning milking and reproduction. For this purpose data from a representative sample of transhumant farms from the Region of Thessaly were collected. Then, frequency analysis was used in order to reveal the main practices characterizing the system. The results highlight the persistence of traditional milking practices, with the domination of hand milking. At the same time a proportion of the farmers adapt improved ways of milking, such as the introduction of various types of milking machines, which are used during winter and sometimes during summer. This development illustrates that the intensification trend of animal production has also affected this predominantly extensive system. Concerning the reproduction management of the herds, farmers tend to introduce foreign dairy breeds in order to increase their farm outputs. Also, the majority of the farmers apply natural mating and only a few incorporate modern management practices such as oestrus synchronization.

Keywords. Transhumance – Sheep – Milk production – Reproduction – Herd management.

Les pratiques de gestion dans des élevages ovins et caprins transhumants

Résumé. *La transhumance des troupeaux entre les régions de différentes conditions climatiques vise à un meilleur développement des zones pâturées. Les troupeaux transhumants se déplacent au mois de mai vers les prairies d'été où ils passent 5 à 6 mois. Les animaux restent à l'extérieur ou dans des installations simples. Le but de cette étude est d'examiner les pratiques de gestion des systèmes de production ovine et caprine, en particulier concernant la traite et la reproduction. Les données d'un échantillon représentatif des exploitations transhumantes de Thessalie ont été recueillies. Ensuite, une analyse de fréquence a été utilisée pour révéler les pratiques principales caractérisant le système. Les résultats mettent en évidence la persistance de pratiques de traite traditionnelles, avec la domination de la traite à la main. Mais, une partie des agriculteurs adopte des méthodes de traite améliorées, telles que l'introduction de divers types de machines à traire, qui sont utilisés au cours de l'hiver et parfois durant l'été. Cette évolution montre que la tendance de l'intensification de la production animale a également affecté ces systèmes. En ce qui concerne la gestion de la reproduction, les éleveurs utilisent des races laitières afin d'augmenter leur production laitière. En outre, la majorité des agriculteurs utilise la reproduction par monte naturelle et seuls quelques-uns intègrent des pratiques modernes de reproduction telles que la synchronisation de l'œstrus.*

Mots-clés. *Transhumance – Moutons – Production laitière – Reproduction – Gestion du troupeau.*

I – Introduction

Transhumance, the annual movement of livestock between winter and summer rangelands, is still practiced nowadays in most parts of Greece and maintains its traditional character linked to certain ethnic groups (Ispikoudis *et al.,* 2002; Constantin, 2003) and the survival of rather traditional practices such as grazing, milking by hand and non-selective natural mating. The sheep and goat farming sector in the country has been developed during the past decades as many producers adopted modern management practices in order to satisfy the increasing market demand mainly for dairy products but also for meat. Specifically, the reproduction schedule of sheep and goat farms is usually designed so that the offspring are born and weaned in time to meet the increased market demand (McKenzie-Jakes, 2008) during Christmas and Easter holidays, when Greek consumers demand whole lamb and kid carcasses.

In order to achieve such goals, improvements in the reproduction management of farms have been proposed. A common one includes the preparation of ewes and dams by providing additional feed for two months during the breeding season, which improves the reproductive performance of the animals (increase of ovulation rate), and the simultaneous estimation of the body condition rate (McKenzie-Jakes, 2008; Martin and Karadowa, 2004). A method used to adjust the timing of mating is the "male effect", referring to the sudden introduction of males in the herd in order to induce ovulation to reproductive quiescent females –for instance out of season or lactating– and it also advances the first cycle in young ewes and dams (Martin *et al.*, 2004). In the past few decades important improvements have been made in altering the reproductive process of the animals, of which oestrus synchronization allows for shortening of the breeding season by bringing all dams and ewes in oestrus at the same time. The synchronization is performed using vaginal progesterone pessaries, progesterone implants or prostaglandin injections (Freitas and Melo, 2010). Another method that alters the reproductive performance of the animals and is also suitable for the genetic improvement of the herd is artificial insemination (AI) combined with oestrus synchronization so that superior genetic material can be introduced in the flock (Martin and Karadowa, 2004; McKenzie-Jakes, 2008). While AI focuses on the performance of males, multiple ovulation and embryo transfer (MOET) intend to maximize the performance of genetically superior females (Freitas and Melo, 2010).

Apart from reproduction, milking is one of the most important aspects of sheep farm management and transhumant systems constitute no exception. During the past few years crossbreeding among local and foreign improved breeds has increased productivity, although threating local genetic diversity (Salazar *et al*., 2012). Better milk yields induced the introduction of milking machines in the production process, as they offer better working conditions to producers, improve milk quality and facilitate the monitoring of the health condition of the udder as well as the productivity of each animal.

The aim of this paper is to present the management practices of transhumant herds in Greece, especially concerning milking and reproduction, and to explore whether and to which extent its traditional character still remains. The prefecture of Thessaly, where the survey was conducted, has been used for centuries as winter domicile for transhumant herds. According to Syrakis (1925), in 1925 there were more than 600,000 transhumant animals in Thessaly, while in 2002, the transhumant sheep and goat population was almost reduced by half, reaching 320,000 animals (Laga *et al*., 2003).

II – Materials and methods

Based on a questionnaire which included questions about the reproductive scheduling of the herds, the potential use of techniques such as oestrous synchronization and artificial insemination, the use of milking machines (both during winter and summer) and the productive performance of transhumant sheep and goat herds, a survey was conducted in the Region of Thessaly, where the majority of transhumant producers maintain their herds during winter (744 transhumant farms – 37.6% of transhumant farms in the country) (Laga *et al.,*2012) and the survey was administered to 121 producers, 16.3% of the total cohort.

III – Results and discussion

Among the 121 surveyed producers, 23.1% maintain only goats, 56.7% only sheep and the remaining 20.2% keep both sheep and goats in various proportions. Rams and bucks are kept separately and are introduced in the herd in late spring, usually when flocks arrive to summer rangelands. Commonly males are kept in the herd until November/December, after the return of flocks to the lowlands. The main kidding/lambing period is on November/ December, while late births occur mostly on February and March.

The mean age of admittance in reproduction is calculated at 14.35 months for young bucks and at 13.80 months for young rams. The same results for young ewes and dams vary and are presented in Table 1. The first mating for most of the females, either ewes or dams, occurs between the age of 9 and 12 months; nonetheless, females are introduced in reproduction after the age of 18 months in a considerable percentage of goat herds (32%). The average prolificacy is 1.35 lambs per lambing for sheep (standard deviation 0.23) and 1.40 kids per kidding for goats (standard deviation 0.30). These results reflect the influence of crossbreeding on both traits, age on reproduction and prolificacy. In particular, 62.50% of young ewes enter reproduction at the age of 9-12 months and the prolificacy is considerably improved, compared to the expected 1.0-1.3 of mountainous Greek breeds of sheep and goats (Lagka, 2005).

Table 1. Mating age of ewes and dams

Age	% Ewes	% Dams
9-12 months	62.50%	43.00%
12-15 months	30.10%	12.50%
15-18 months	2.40%	12.50%
>18 months	5.00%	32.00%

Crossbreeding between local and foreign breeds is very common in the extensive transhumant system. More than three out of four (76.5%) producers have tried to improve the productivity of their farms through crossbreeding, their main goals being the improvement of milk production followed by meat production and endurance to the harsh environment of mountainous pasturelands. On the other hand, only 23.5% maintain sheep and goats of Greek indigenous breeds, especially mountainous, either purebred or crossbreeds. It should be noted that the genetic improvement of herds through crossbreeding is mainly done with the introduction of males from improved breeds, either bucks or rams, in the reproductive procedure, while transhumant farmers rarely resort to the use of females (ewes and/or dams), which they buy from markets. The main Greek sheep breeds used for the improvement of transhumant flocks are Karagouniko and Chios (see Lagka (2005) for details), while Lacaune, Friesland and recently the Spanish Assaf sheep are the most popular foreign breeds. When it comes to goats, foreign breeds (Alpine, Zaanen and Damascus) are preferred by transhumant farms.

Transhumant farmers commonly prepare ewes and dams for the mating season by providing additional feed (74.4% of the questioned producers), while for the remaining 25.6% preparation is based only on grazing. When it comes to modern reproduction practices, only 3 out of the 121 transhumant producers of the sample had practiced oestrous synchronization in the past, with the use of intravaginal progesterone pessaries, but none of them is willing to retry this procedure or to test other improvements, such as artificial insemination (AI). Possible reasons for this reluctance are the increased prolificacy rates (more than two lambs/kids per birth) resulting from AI, which decreases the quantity of marketed milk –the most important product of these farms– and the low price of meat.

When it comes to milking, the mean annual goat milk yield is calculated at 96.00 litres/dam (standard deviation 50.80 litres) and the mean annual sheep milk yield at 93.00 litres/ewe (standard deviation 39.10 litres) (Table 2). The high standard deviations and the broad difference between highest and lowest yields in both sheep and goat farms can be attributed to several reasons. Indeed, yields differ substantially because of the varying degree of crossbreeding in the herds. Furthermore, the application of a third milking per day, especially during the first milking period, commonly from Christmas until early March, increases yields up to 20%. Another parameter is the nutritional management of transhumant herds, as the nutritional requirements of the animals in the various stages of their production cycle are not always covered properly.

Table 2. Milk production of transhumant sheep and goat

Traits	Goat	Sheep
Mean milk yield (l)	96.00 ± 50.80	93.00 ± 39.10
Max milk yield (l)	224.00	180.00
Min milk yield (l)	24.00	32.00

The majority of the producers (85.5%) apply milking by hands and only 14.5% use milking machines; of the latter producers, only one uses a mobile milking machine, which can be transferred from winter to summer domiciles. The main causes for this are the low productivity of transhumant flocks as well as the cost of this improvement, both of which do not generally justify the use of milking machines.

IV – Conclusions

The results of this survey among transhumant farmers in Thessaly revealed that the higher market demand for dairy and meat products has affected the transhumant system, being one the main causes for the introduction, although slow, of modern management practices. The main improvement is the use of genetically improved animals, while mechanization of production, especially the use of milking machines, as well as use of techniques for reproductive improvement activity is limited.

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Rangeland Rummy to support adaptive management of rangeland systems

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Abstract. To support the development of adaptive management strategies in rangeland-based livestock systems, we developed a game called "Rangeland Rummy". It is intended to stimulate farmers' discussion and knowledge exchange around the collective design and evaluation of rangeland-based livestock systems. We present the game and its various components.

Keywords. Farm model – Rangeland system – Adaptation – Simulation – Learning.

Le Rami Pastoral : un jeu pour favoriser la gestion adaptative des systèmes d'élevage pastoraux

Résumé. *Pour favoriser le développement de stratégies de gestion adaptatives des systèmes d'élevage pastoraux, nous avons développé un jeu appelé le Rami Pastoral. Il vise à stimuler les discussions entre éleveurs et le partage de connaissances autour d'un exercice collectif de conception et d'évaluation de systèmes d'élevage pastoraux. Nous présentons ce jeu et ses différents éléments.*

Mots-clés. *Modèle de système d'élevage – Système pastoral – Adaptation – Simulation – Apprentissage.*

I – Introduction

Rangeland-based livestock systems have to deal with the significant instability and uncertainty of the agricultural context (climate change, volatility of input prices, etc.). To support the development of adaptive management strategies in grassland-based livestock systems, we had previously developed a board game including a computer model called *Forage Rummy* (Martin *et al*., 2011). It proved successful in stimulating farmers' learning about their livestock systems and the scope for their adaptation. *Forage Rummy* was unsuited to address the specific features of rangeland-based livestock systems such as heterogeneous vegetation on paddocks or the practice of delayed grazing. Then, we developed a new game called *Rangeland Rummy* intended to stimulate farmers' discussion and knowledge exchange around the collective design and evaluation of rangeland-based livestock systems.

II – Overview of *Rangeland Rummy*

1. Conceptual model of a rangeland-based livestock system

Our conceptual model of a rangeland-based livestock system represents the interactions between four system components: rangeland (divided into types of paddocks), feed stocks (conserved forage and concentrate), herd or flock (divided into animal groups) and farmer (represented by its management strategy and practices). The farmer organizes the herd or flock into animal groups and allocates rangeland use by deciding upon grazing and feeding management. To feed his grazing animals, the farmer builds up on each paddock a type of grazable feed resource which results of previous utilizations. Over the short term, this feed resource depends on the actual state of the vegetation when it is grazed; over the long term, it depends on the vegetation type. The farmer also decides about the use of feed stocks that are allocated to animal groups.

2. Objects included in *Rangeland Rummy*

In *Rangeland Rummy*, manipulated objects are of two types (Fig. 1): (i) material objects (e.g. cards) enabling modelling, i.e. design of rangeland-based livestock systems on a board game; and (ii) a computer object, i.e. a computer model enabling simulation in order to evaluate these systems. Material objects are intended to create a connection between players. Farmers and/or agricultural consultants manipulate these material objects and the information they encapsulate to design rangeland-based livestock systems. Throughout this process, they share knowledge, opinions and discuss the pros and cons of different options. Computer objects are intended to provide integrated evaluation of rangeland-based livestock systems designed by players in order to stimulate their reflections and discussions. Such evaluation is based on relevant and objective up-to-date knowledge encapsulated in the simulation model.

A. The game board

The game board (a whiteboard marked with information; Fig. 1) was designed to address the key challenge faced by rangeland farmers, i.e. managing the feeding system in compliance with desired, attainable and accessible feed resources. Along the x-axis, the board is divided into 24 15-day periods, i.e. one year, whose starting date is not fixed. Along the ordinate, the upper part is an area axis expressed in hectares and is used to represent the rangeland and grassland paddocks (or paddock types) and the corresponding feed resources. The lower part offers space to build until four animal groups and the feeding regime allocated to each of these groups. Therefore, the game board enables to organize the system components, their dynamics and their interactions.

B. The calendar stick

The starting date of the game board corresponds to the transition between the end of winter and early spring. At this time occurs a breakpoint in biomass production kinetics on rangelands. Then, a calendar stick (Fig. 1) specifies this date and the dates of the following 15-day periods for each regional application of *Rangeland Rummy*. These dates can be defined using a France-wide database on rangeland production and use (Institut de l'Elevage, 1999) or based on expertise.

C. The feed resource sticks

Rangeland Rummy contains flattened sticks (that we call feed resource sticks, Fig. 1) referring to combinations between a vegetation type (e.g. broom moorland) and a management type (e.g. full grazing at full spring and incomplete grazing in autumn) on a paddock. Sticks are marked with the corresponding feed resources available per hectare and for given seasons (early spring, full spring, end of spring, summer, autumn, end of autumn, winter), or with the available yield (in tons of dry matter per hectare) through mechanized harvests. Colors are used to represent feed quality (low, medium, high) of the feed resources. For each new application of the game, feed resource sticks corresponding to the application situation are developed based on different sources. The main one is the France-wide database on rangeland production (Institut de l'Elevage, 1999). In order to represent climatic hazards, rangeland sticks can be produced based on expertise or using crop and grassland models.

Playing *Rangeland Rummy*, farmers can represent their rangeland and grassland paddocks and the management practices they implement on these paddocks on the game board using the feed resource sticks. They first have to select the corresponding feed resource sticks among the whole set of sticks. Then, they have to place the sticks on the upper part of the game board and decide on the area to allocate to each stick corresponding to the paddock area.

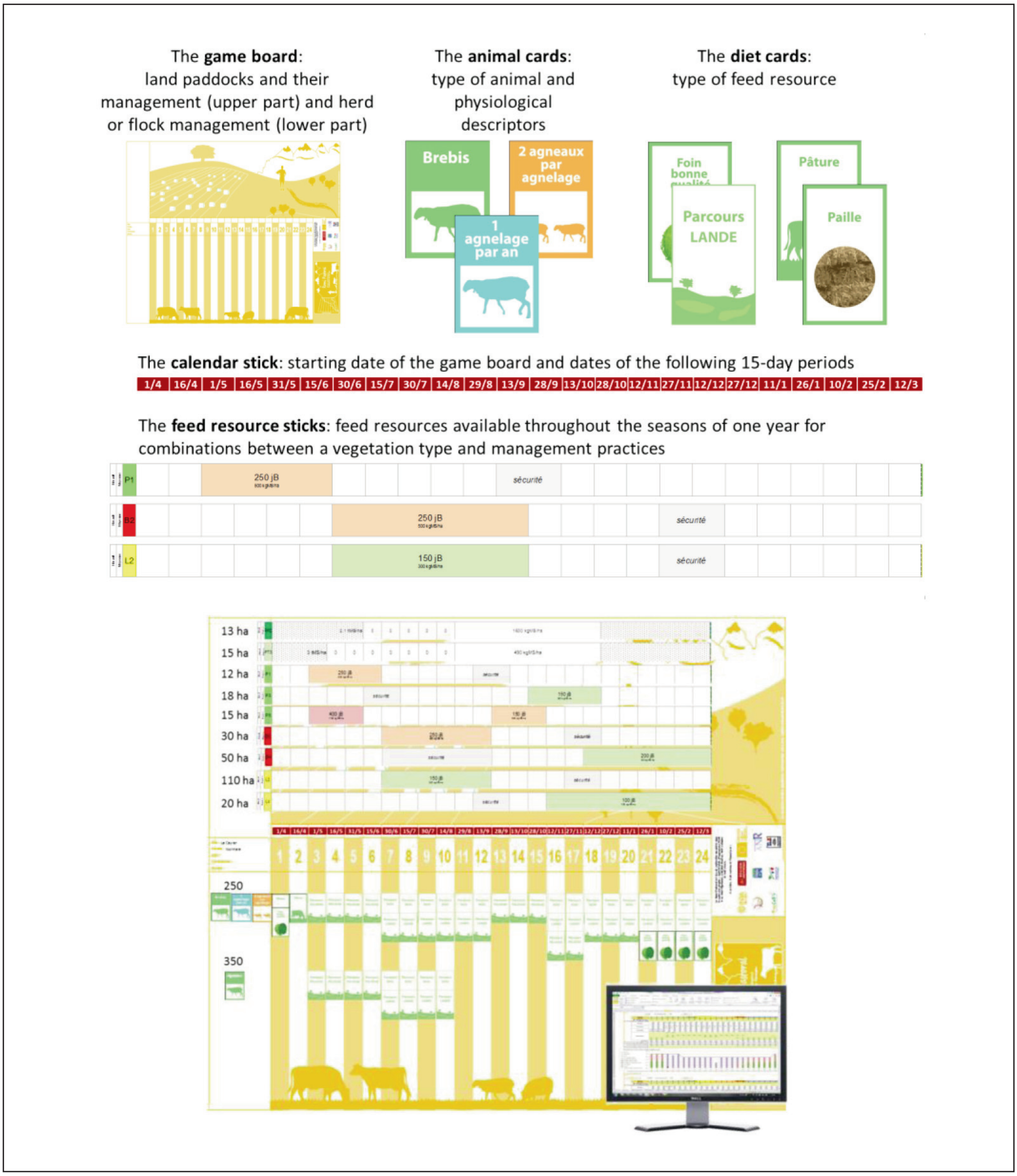

Fig. 1. Separate view of the material objects manipulated when using *Rangeland Rummy* (upper part) and aggregate view of the same objects placed on the game board together with a screen displaying inputs and outputs of the computer spreadsheet (lower part).

D. The animal cards

Herd or flock management in rangeland-based livestock systems consists of organizing the herd or flock into one to several animal groups and deciding upon animal species, breed, body condition and reproduction. Then, *Rangeland Rummy* contains animal cards displaying a type of animal (e.g. beef cow, meat sheep) and a physiological state (e.g. a calving period) descriptor (Fig. 1). Combining animal cards amounts to describe the target animal of a group. To represent herd or flock management, farmers have to combine animal cards and specify a headcount to each combination on the game board, thereby creating animal groups (at most 4). In this way, farmers explain their strategy for herd or flock management. It is not visible on the game board (only in the spreadsheet), but each combination is given a pattern of daily dry matter (in kg) and feed quality (low, medium, high) requirements of the animal across the 24 15-day periods of the year. Such patterns are developed using animal intake simulation models.

F. The diet cards

Each diet card represents a type of feed: forage (e.g. grazed woodland, grazed grassland, hay, silage) or concentrate (e.g. soya meal). Diet cards have to be combined by farmers in order to build the feeding regime of each animal group across each of the thirteen four-week periods of the calendar year (Fig. 1). While defining these regimes, farmers have to connect each card has with a given feed resource stick. This way, diet cards make a link between such a stick and the animal group grazing the corresponding feed resource(s).

G. The spreadsheet

Throughout the game, farmers' choices regarding the feed resource sticks and their area allocation, the animal groups and their size as well as their diets are entered into a computer spreadsheet (Fig. 1). The spreadsheet integrates this input information and automates the calculations of indicators and graph building used for evaluation of the rangeland-based livestock system designed. For instance, graphs illustrate the extent to which quantitative and qualitative animal feeding requirements are covered over each 15-day period. It also holds data, among other things, about residual standing biomass after grazing on the different vegetation types (e.g. shrubland, woodland) as well as self-sufficiency for forage, concentrates and straw. The spreadsheet thereby hastens the process whereby players visualize whether feed resources adequately match animal feeding requirements across seasons and eventually decide whether to continue with additional design and evaluation loops.

3. Workshop content

Rangeland Rummy is intended to be used by agricultural consultants and/or researchers with small groups of 2 to 4 farmers during workshops lasting from 2 to 4 hours. The problem situation is defined with farmers prior to the workshops or at their very beginning. Workshops include collectively and iteratively designing and evaluating rangeland-based livestock systems, while confronting them to new contextual challenges (e.g. climate change, volatility of input prices) or new farmers' objectives (e.g. being self-sufficient for animal feeding).

IV – Conclusion

Rangeland Rummy has been tested with agricultural consultants and farmers in two regions of France. It tended to stimulate farmers' discussion (e.g. about how to prevent shrub encroachment with grazing), reflective and interactive analysis and learning about rangeland-based livestock systems, their management and the scope for their adaptation. For instance, a farmer was proposed by his colleagues a way to modify the timing of grazing on moorland and woodland to increase grazing pressure on insufficiently grazed paddocks. *Rangeland Rummy* is currently being tweaked to prepare its transfer into the activity of agricultural consultants.

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The contribution of livestock to farm income in different agro-ecological zones of Egypt

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Abstract. This study was conducted to explore the economic importance of livestock enterprises in different agro-ecological zones of Egypt. Based on soil characteristics and water resources, four different agro-ecological zones were identified: (i) Rainfed area; (ii) Old land; (iii) Reclaimed desert; and (iv) Oases. Structured surveys were conducted, with 162 households to elicit information on income-expense details of each farm enterprises. The profitability of farm enterprises was estimated using the whole farm budgetary analytical method. Livestock herds differed in size and composition among different agro-ecological zones. Although irrigated zones have a similar farming system, they form a marked contrast. The areas cultivated with animal fodder around the year ranged from 26.5 to 47%. On the other hand, the main animal feed resources are natural rangelands in rainfed areas. Livestock makes a substantial contribution to the economy of farmers. Livestock contribution ranges from 32.3% in the oases to 66.76% in the new land. The study concludes that livestock enterprises are economically viable. They provide returns on investment ranging from 17.64 to 28.33%. These findings have important implications for the improvement of livestock enterprises. Making farmers aware of the financial benefits of livestock may convince them to consider it as a better alternative to crop production in the study areas in terms of income generation. This will probably influence their decision on the allocation of their limited resources to competing alternatives.

Keywords. Farm income – Household surveys – Cropping – Agro-ecological zones.

La contribution de l'élevage au revenu agricole dans les différentes zones agro-écologiques de l'Egypte

Résumé. *Cette étude a été menée afin de déterminer l'importance économique des entreprises d'élevage dans les différentes zones agro-écologiques de l'Egypte. Sur la base des caractéristiques du sol et des ressources en eau, quatre zones agro-écologiques différentes ont été identifiées : (i) Pluviale ; (ii) Vielle terre ; (iii) Désert récupéré ; et (iv) Oasis. Des enquêtes structurées ont été menées, avec 162 ménages pour obtenir des informations sur les détails de revenus dépensent de chaque entreprise agricole. La rentabilité des entreprises agricoles a été estimée en utilisant toute la méthode d'analyse budgétaire agricole. Les troupeaux de bétail diffèrent en taille et en composition entre les différentes zones agro-écologiques. Bien que les zones irriguées aient un système d'exploitation similaire, ils forment un contraste marqué. Les surfaces cultivées avec du fourrage autour de l'année variait de 26,5 à 47%. D'autre part, les principales ressources de l'alimentation animale sont des aires naturelles dans la pluie zone nourris. Élevage apporte une contribution substantielle à l'économie des agriculteurs. L'élevage contribue variait de 32,3% à l'oasis de 66,76% à la nouvelle terre. L'étude conclut que les entreprises d'élevage sont économiquement viables. Il a fourni de retour varie de 17,64 à 28,33% du capital investi. Ces résultats ont des implications importantes pour l'amélioration des exploitations d'élevage de ménages. Faire agriculteurs conscients des avantages financiers de l'élevage peut les convaincre de le considérer comme une meilleure alternative à la production agricole dans les zones d'étude en termes de génération de revenus. Ce sera probablement influencer leur décision sur l'allocation de leurs ressources limitées pour les alternatives concurrentes.*

Mots-clés. *Revenu agricole – Suivi d'exploitation – Culture – Zones agro-écologiques.*

I – Introduction

The suitability of an area for either animal or crop production, and the type of animal or crop to be produced in the area depends on the agro-ecological conditions of the area (Tolera and Abebe, 2007). The extent of cropping and the type of crop, in turn, determine the quantity, quality and distribution of animal feed resources throughout the year. On the other hand, the feed resource bases determine the animal production system of the area. Egyptian farming systems vary with agro-ecological zones. Based on soil characteristics and water resources, four agro-ecological zones can be identified in Egypt:

(i) Old land is located in the Nile Valley and Delta Regions. It covers a total area of 2.25 million ha and is characterized by good quality soils (silt-clay mixtures), deposited during thousands of years of Nile flooding. The land is intensively cropped and yields are relatively high. The Nile is the main source of water for irrigation;

(ii) New land is located mainly on both East and West of the Delta and scattered over various areas in the country. It covers 1.05 million ha. Reclamation of this land was started in the early 50s and is continuing. Nile water is the main source of irrigation water but in some desert areas underground water is the only source of irrigation water. Sprinkler and drip irrigation regimes are practiced;

(iii) Rain fed areas are more common in the north-western coastal zone (NWCZ) and Sinai where rainfall fluctuates between 100-200 mm annually; and

(iv) Oases are characterized by alluvial, sandy and calcareous soils. In geography, an oasis is an isolated area of vegetation in a desert. They cover a total area of 40,000 ha. Underground water is the main source for irrigation.

Seré and Seinfeld (1996) stated that a livestock production system is considered as a subset of the farming system, which has different impacts under differing locations and managerial conditions. In Egypt, livestock forms an important component of the agricultural sector, representing about 24.5% of the agricultural gross domestic product (SADS, 2009). Sheep and goat population represent around 50% of the total ruminant population (Alary, 2010). Their contribution to the total red meat produced in Egypt is about 12%, shared equally between the two species (Galal *et al*., 2002). This study was initiated to identify the general features of the agro-ecological zones studied and to investigate the role of livestock in the generation of farm income in each zone. Sainfoin (*Onobrychis viciifolia* Scop.) is a forage legume much appreciated by farmers due to its high palatability, high nutritional value and non bloating properties (Delgado *et al.*, 2002).

II – Materials and methods

This study was conducted to explore the economic importance of livestock enterprises in four agro-ecological zones of Egypt. Three of the four zones are located in NWCZ which extends from Alexandria East to the Libyan west border for about 500 km. The western area is a rainfed area with low erratic rainfall (<150mm/yr). Raining seasons start from mid October to mid March. Average farm size (with the exclusion of rangelands) is 51.3 acres (Table 1). Green fodders are not grown in this region. The main animal feed resources are natural rangelands, which show marked variation in availability and quality based on variability of rainfall. Lately, natural ranges have deteriorated due to overstocking and repeatable drought incidence. Cropping is limited to barley, beside cultivation of some fruits such as olives and figs. Mean livestock holdings are larger than in the other zones with limited cattle population (Table 1).The eastern area is a new reclaimed land. Wheat, maize and groundnuts are the dominant cereal crop in this farming system. The main fruits are citrus fruits and grapes. The average livestock holding consists of 22.76

large ruminants and 100.25 small ruminants. The areas between west and east are mainly mine fields from World War II, with limited livestock activities. Siwa Oasis is located in the Western Desert near the Libyan border, 550 km west of Cairo and 350 km from Matrouh city. In Siwa oasis, farmers depend for their water resources on springs and groundwater. The lack of drainage system there results in soil salinity problems. Due to scarcity of water, about 47% of the total farm size is left fallow in summer. Wheat is the main cash winter field crop besides the cultivation of the date palm tree. Cattle comprises around 53% of the herd. The forth studied zone located in Sharkie governorate, east of the Nile Delta, representes the old lands agro-ecological zone. The average farm size is 2.8 acres. The main crops are wheat, corn and rice. On average, a household owns 3.4 large ruminants and 4.9 small ruminants. However, Egyptian irrigated zones can have two crops per year, usually planted in winter and harvested in the spring and again planted in the spring and harvested in late summer. The areas cultivated with animal fodder around the year ranged from 26.5 to 47% (Table 1).

Table 1. General features of the agro-ecological zones studied

General features	Agro-ecological zones			
	Old land	New land	Rain fed	Oasis
Average land holdings/Farm, acre	2.80	12.70	51.3	7.55
Land holding distribution:				
Green fodder	0.74 (26.5)	5.96 (47.0)	0.0 (0.0)	2.26 (29.93)
Field crops	1.89 (67.5)	4.52 (35.6)	33.35 (65.0)	3.25 (43.04)
Vegetable	0.17 (6.0)	0.44 (3.44)	1.39 (2.7)	0.26 (3.44)
Fruit, %	0.00 (0.0)	1.77 (13.96)	16.57 (32.3)	1.05 (13.90)
Mean livestock holdings/farm, head	8.30	123	149.7	7.8
Livestock type, head:				
Cattle	1.36 (16.38)	18.0 (14.63)	3.80 (2.7)	4.18 (53.12)
Buffalo	2.04 (24.57)	2.77 (2.25)	0.0 (0.0)	0.07 (1.25)
Camel	0.00 (0.0)	1.99 (1.62)	6.75 (4.8)	0.05 (0.62)
Total large ruminants	3.40 (40.96)	22.76 (18.5)	10.55 (7.5)	4.3 (54.99)
Sheep	2.39 (28.79)	75.18 (61.12)	113.4 (74.2)	1.74 (22.44)
Goats	2.51 (30.24)	25.07 (20.38)	25.75 (18.3)	1.76 (22.57)
Total small ruminants	4.90 (59.03)	100.25 (81.5)	130.15 (92.5)	3.5 (45.01)

Figures within parentheses indicate percentage contribution.

Egyptian clover (*Trifoluim alexandrinum*) is the major winter fodder, while green maize or sordan grass fodders are important sources of animal feed in summer. Crop residues and farm by-products contribute feeding animals especially in the autumn months. 59.44, 23.5, 19.74 and 32.1% of the households interviewed utilize it in autumn, winter, spring and summer seasons, respectively. This study was implemented in 2011 based on household interviews and secondary data from published and unpublished resources. Eight villages were selected for each zone and a total of 162 households were interviewed.

A questionnaire was designed and submitted to the above-mentioned households. It provided information on current and past crops and income-expense details of each farm enterprise. The profitability of farm enterprises was estimated using the whole farm budgetary analytical method. Total costs were obtained by estimating both the operating cost and fixed cost. The fixed cost was obtained by valuing the family labour. The returns were obtained by estimating the total value of production which included each product sold and consumed. Farm gate prices for a unit of each product were used.

III – Results and discussion

Table 2 shows that livestock enterprises are economically viable. They provide returns on investment ranging from 17.64 to 28.33%. Thus, livestock production remains to be the main means of livelihood. Hence, more emphasis should be given to improving livestock productivity and proper utilization of farm resources. The net income per farm per year averaged LE 12387.2 in old lands and LE 15780.2 in the oases, of which 38.38% and 32.2%, respectively, were contributed by livestock production. Despite the low contribution of livestock under these zones, this investment is sound; the annual rate of return on investment for livestock production is estimated at 28.33% and 25.81, respectively. The herds are integrated with cropping systems. Integration of livestock into cropping systems plays an important role for the efficient utilization of farm input resources where fodder crops and agriculture residues provide the feed for animals and animal manure makes the soil more productive (Metawi, 2011; Singh *et al.,* 2006). In Oases, there is a wide utilization of non-conventional feed sources such as palm dates leftovers. According to the households interviewed, 73.5% fed their animals with palm dates leftovers. Within the livestock sector; cattle contributes the highest (53.1%) in this zone. Devendra (2000) showed that the contribution of cattle to gross income ranged from 21% to 41% on natural pastures, and from 42% to 71% with cattle on improved pastures. Old lands are more productive and intensively cultivated than the other irrigated zones. The annual rate of return on investment for crop production is estimated at 24.05%. The contribution of livestock to farm income ranged from 41.63 % in the new land and 66.76% in rainfed area (Table 2). Animals are purchased and sold according to cash flow needs. Farm cash incomes should therefore not necessarily be considered as a proxy for wealth accumulation. As crop yields fail, farmers are forced to sell animals to purchase agricultural inputs. In view of the importance of livestock as a source of security and investment, there is some evidence that farmers with larger livestock holdings derive a relatively smaller proportion of their cash income from livestock production.

Table 2. Farm household income analysis

Income source	Agro-ecological zone							
	Old land		New land		Rain fed		Oases	
	LE†††	RCI%††	LE	RCI %	LE	RCI%	LE	RCI%
Net income†:								
From crops	8423.3	24.05	19263.2	19.08	34315.5	13.37	10685.0	18.34
From livestock	4755.2	28.33	38690.9	23.46	24483.6	17.64	5095.2	25.81
Total	12387.2	57954.1	58799.1	15780.2				
% from livestock	38.38	66.76	41.63	32.2				

† Green fodder was not included in the analysis as it was not considered in most cases as a cash crop.
†† The annual rate of return on investment. ††† US$ = LE5.8.

IV – Conclusions

Although irrigated zones have a similar farming system, they form a marked contrast. Old land is more productive and intensively cultivated than the other irrigated zones. It provides returns on investment of 24.05%.

Livestock makes a substantial contribution to the economy of farmers. Livestock contribution ranges from 32.3% in the oases to 66.76% in the new land. The study concludes that livestock enterprises are economically viable. It provides returns on investment ranging from 17.64 to 28.33%. These findings have important implications for the improvement of livestock enterprises of households. Making farmers aware of the financial benefits of livestock may convince them to consider it as a better alternative to crop production in the study areas in terms of income generation. This will probably influence their decision on the allocation of their limited resources to the competing alternatives.

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Feeding strategies and main expenses in sheep breeding in mountainous area of Tizi-Ouzou, Algeria

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Abstract. With the aim to identify the feeding strategies of sheep breeders in relation with expenses of sheep and the role of pasture in the feeding of the herd, a regular follow-up of 16 sheep farms in mountain area of Tizi-Ouzou (Algeria) was adopted during one year. The first results show that these strategies are related to climate and to period of strong complementation such as the complementation in periods of lambing or fattening in order to sale. For 37% of the farmers, sheep breeding is considered as the main activity of which herd size varies from 7 to 75 heads. The average time spent by animals in pasture is 6 hours/day. The Rangelands and natural grasslands are used throughout the year. The animals receive an average of 54 g/head/day of feed complement. The complement is often wheat bran, concentrates, corn and barley. For this purpose, the feed cost reaches 240 DA[1]/head/month; this represents 24% of total operating expenses. The use of mountain pasture seems secure sustainability strategies adopted by farmers.

Keywords. Pastures – Food strategies – Operating expenses – Mountain area – Mediterranean – Sheep.

Stratégies d'alimentation et principales dépenses dans les élevages ovins en zone montagneuse de Tizi-Ouzou (Algérie)

Résumé. *16 exploitations ovines situées en zones de montagne de Tizi-Ouzou (Kabylie) ont été suivies pendant une année. L'objectif était d'identifier les stratégies d'alimentation des éleveurs ovins en relation avec les dépenses des ovins, et la place des pâturages dans cette alimentation. Les résultats montrent que ces stratégies sont liées au climat et aux périodes de forte complémentation comme celles des périodes d'agnelage ou de l'engraissement en vue d'une vente. Pour 37% des éleveurs l'élevage ovin, dont la taille des cheptels varie de 7 à 75 têtes, est considéré comme activité principale. Le temps moyen passé par les animaux sur les pâturages est de 6 heures/jour. Les parcours et les prairies naturelles sont utilisés durant toute l'année. Les animaux reçoivent en moyenne 54 g/tête/jour de complément. Ce dernier se constitue souvent de son, de concentré, de maïs et d'orge. A cet effet, le coût alimentaire atteint 240 DA/tête/mois soit 24% des dépenses totales de l'exploitation.*

Mots-clés. *Pâturages – Stratégies d'alimentation – Dépenses de l'exploitation – Méditeranéen – Ovins.*

I – Introduction

In the mountainous area of Tizi-Ouzou (Algeria), sheep farming presents some particularities due to the topography of this region and the availability of the means of production in the farms. The study area covers a surface of 2976 km² with a human density of 400 hab/km^2 (http://www.tiziouzou-dz.com/). It consists of five distinct physical homogeneous groups, including mountainous area

[1] DA : Dinar Algérien.

which culminates at more than 700 m, representing 52% of the total area study.The size of the ovine livestock is about 184,101 heads (DSA, 2011). The extensive system is used in mountain pastures in order to reduce feed costs. In these conditions, what are the feeding strategies related to the use of pasture and feed complement? What are the costs inherent to these strategies? This study aims to answer to those questions.

II – Methodology of conducting the survey

Sixteen farms were followed in the mountainous region of Tizi-Ouzou during 12 months (from March 2012 to February 2013). The choice of the breeders was based on their agreement to participate to this survey. Monthly visits to farms were planned and a survey questionnaire was completed after an interview with the breeders. The questionnaire items are mainly related to herd feeding. Variables concerning the use of mountain pastures and distribution of feed complement are the only ones presented in this paper.

III – Results and Discussion

The sizes of the ovine herds are not important in this study area. They vary from 7 to 75 heads per herd with an average of 32 heads/herd. In 37% of the exploitations the ovine raising represents the main activity. While for the majority (63%) it's a secondary activity. In some African countries, these small ruminants contributed considerably to cash income (Legesse *et al.* 2010).

The forage calendar (Fig. 1) shows how animal feed is diversified during the year. The feeding of sheep in this mountainous region is mainly based on pastures which are forest grazing and natural grasslands. Their use is daily and throughout the year. The same situation was reported in Portugal by Pacheco (2002).

Feed complement and pastures (natural grassland and forest grazing) are used throughout the year, while the hay is used from September to March with the derisory quantities. In mountain areas, the surfaces devoted to the fodder crops are very low, so the forage on offer is insignificant. The use of stubble is limited to 4 months (from Jun to September)(from July to September).

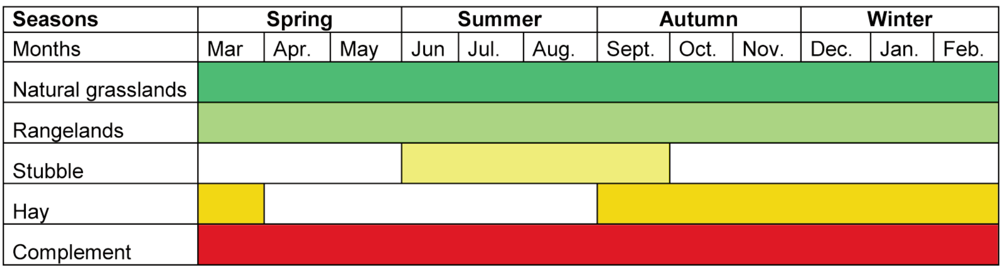

Fig. 1. Forage calendar used in ovine exploitation in the study area.

Furthermore, animal feed ration is complemented by an average of 54 g/head/day. This quantity increases to 200 g/head/day during the fattening period, the lambing and winter season (September-February). The same situation is reported in Morocco by Ibn El Bachyr and Mounsef (2011). The complement used was constituted of a mixture of wheat bran, barley and commercial concentrate for cattle. The proportions of these complements are different according to the breeder and period.

According to the level of complementation, breeders followed were grouped into three distinct groups (Table 1). The first group of farmers does not use complement. The average herd size is 38 ± 29 head/farm, and sheepwere fed exclusively on pasture. Animals spend more time on pastures (average 7 hours/day).

Table 1. Feeding characteristics and expenditure structure

	Group 1	Group 2	Group 3
Head size and feeding characteristics			
Heard size (head)	38 (± 29)	40 (± 23)	15 (± 9)
amount of feed distributed (g/head/day)	0	26 (± 8)	81 (± 22)
grazing time (hour/day)	7 (± 1)	6 (± 1)	4 (± 1)
Average expenditure(DA/head/month)			
Labour cost	73 (± 73)	32 (± 45)	134 (± 271)
Animal purchase	159 (± 138)	443 (± 491)	1336 (± 1785)
Feedcost	96 (± 69)	147 (± 94)	476 (± 228)
Healthcost	1 (± 1)	7 (± 5)	19 (± 8)
Total cost	330 (± 203)	629 (± 549)	1966 (± 1961)

The second group whose average herd size is a little higher (40 ± 23 heads/exploitation) distributes few complement (26 g/head/day), and animals spend on average 6 hours/day on pastures. The third group, had the smallest herd size (15 ± 9) and the animals received more than 80 g/head/day of feed complement and spend less time on pasture (5 hours)compared to the other groups.

There is a strong negative correlation (- 0.7)between these two parameters (Fig. 2). These strategies are implemented to reduce the costs involved to the feeding.

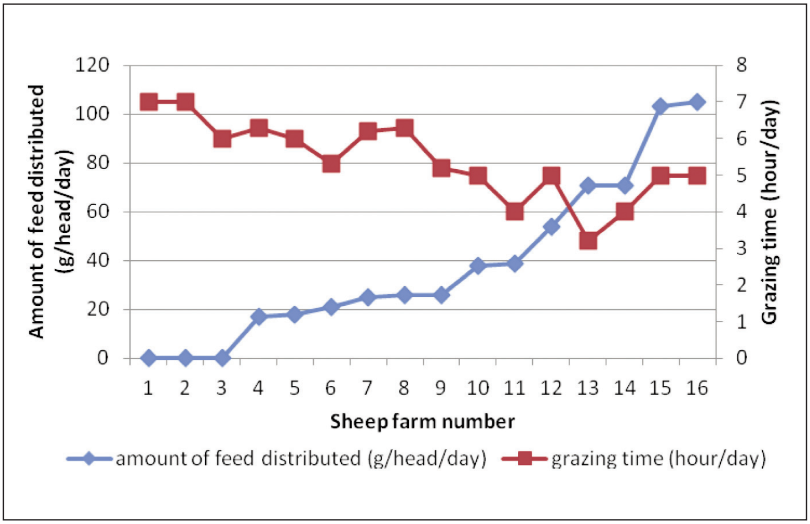

Fig. 2. Amount of feed distributed and grazing time in the sheep farms studied.

The different spending strategies for the three different groups of farmers are summarized in Table 1. Globally, the average of total spending on sheep amounted to 990.00 DA/head/ month (€ 9.64 / head / month). Contrarily to that find in Spain by Perez et al. (2007), feed in our region represents only 24% of total expenses. The post of animals purchasing is the most important and represents 68% of total out-farm expenses. Conversely, structural expenses related to the manpower represent only 7% of total expenses. This charge is lower compared to that reported by Tchakerian *et al.* (2001) in French meat sheep farms which are nearly 15%.

The group 1 had the lowest cost. Except for manpower, it ranked in second position. Two farmers used a temporary workforce for forage harvesting. This group spent less but purchased less animals. Low feed cost (for hay) explained the high use of pastures. The group's strategy was to minimize the costs to the detriment of the shortfall in sales animals without fattening. These breeders have a very weak dependence overlooked the feed market.

The group (the largest in number of animals) distributes small amounts of feed complement and also recorded low feed costs (146.5 DA/head/month). Feed costs are similar to those of the first group. We denote the lowest workforce cost. Workforce is essentially family even for forage harvesting. The group's strategy is to use in addition to pasture, the distribution of feed complements (concentrate mixture for the cattle, barley, wheat bran and sometimes corn) with small quantities. The goal is to have animals with a good weight at marketing.

The third group records the most important costs even with low numbers of livestock. Feed costs are 476 DA/head/month that are the largest among the three groups. The strategy of these breeders is to increase the feed from the pasture by a distribution of feed complement that may average 81 g/head/day. It is a business strategy that dictates them to spend more to have fattened animals for sale. Farmers of this group buy monthly animals to fatten them and then return them to the market. They are more contractors than other groups.

IV – Conclusion

The mountain pastures which are essentially forest grazing and natural grasslands are the main source of feed for sheep raised in such regions. Sheep farms with small heard size use these pastures daily and throughout the year. Some breeders distribute a supplement at a low level. According to the use of feed supplement, three strategies driving feed emerge. Farmers who use the first strategy does not distribute complement, they are not related to the market. Breeders who use the second strategy distribute low amounts of complement. Link of these farmers with the market is average. Finally breeders who use the third strategy are part of a marketing strategy by improving animal rations by complement.

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“Alpine Pasture-Farms System”: A concept to analyse the management of alpine pastures

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Abstract. Adapting to climate change on alpine pastures requires finding flexibility at different levels. The articulation between the alpine pasture and the farms is where potential solutions might be activated. Yet research focusing on alpine pasture management usually considers the farm as a black box. The use of an alpine pasture –which is sometimes collective– nevertheless lends a number of specific characteristics to livestock farming systems. The distance between the alpine pasture and the farmsteads, the mixing up of herds/flocks, the necessary collective organisation, as well as the challenges stemming from the multiple use of these collective spaces, must be taken into account in an analysis of these systems. We propose the concept of the Alpine Pasture-Farms System to analyse the consequences of these specific characteristics in analyses at farm level and to gain a better understanding of interactions between the alpine pasture and farms.

Keywords. Agropastoral system – Alpine pasture – Adaptation to climate change – Flexibility.

Le système Alpage-Exploitations : un concept intégrateur pour analyser la gestion des alpages

Résumé. *L’adaptation au changement climatique sur les alpages impose de trouver de la flexibilité à différents niveaux. Des leviers peuvent être activés à l’articulation entre l’alpage et les exploitations agricoles. Pourtant les travaux portant sur la gestion de l’alpage considèrent généralement l’exploitation agricole comme une boite noire. L’utilisation d’un alpage – qui se fait parfois de manière collective – confère cependant un certain nombre de particularités aux systèmes d’élevage. L’éloignement de l’alpage des sièges d’exploitation, le mélange des troupeaux, une nécessaire organisation collective, ainsi que les enjeux du multiusage de ces espaces collectifs doivent être pris en compte dans l’analyse de ces systèmes. Nous proposons le concept de système Alpage-Exploitations afin d’analyser les conséquences de ces spécificités dans les analyses à l’échelle de l’exploitation agricole, et avoir une meilleure compréhension des interactions entre alpage et exploitations.*

Mots-clés. *Système agropastoral – Alpage – Adaptation au changement climatique – Flexibilité.*

I – Introduction

For many mountain and Mediterranean livestock farming systems, alpine pastures represent the main forage resource during summer. The pastoral resources sought out by livestock farming systems on the alpine pastures are in fact especially vulnerable to climate change and to the associated increase of extreme weather events, especially droughts. Management requires to be adapted, in order to prevent long-term deterioration that would jeopardise both the resource and biodiversity on alpine pastures.

With the challenges of biodiversity, alpine pastures are the focus of a number of concerns. However, climate change does not impact alpine pastures alone. The increasing occurrence of droughts has taken its toll on all spaces used by farms whose flocks and herds have been moved around the Alps since the start of the 2000s (Nettier *et al.*, 2010). Livestock farmers have had to react and change their farm practices. Such changes may have repercussions on the alpine pastures. Conversely, the adaptations implemented to preserve alpine pastures may have an impact on the farms (Nettier *et al.,* 2010). The current context questions the usual production models and calls for much more flexibility in livestock farming systems (Dedieu *et al.,* 2008).

In order to seek out opportunities for flexibility faced with climate change, a systemic approach seems necessary. The relevant system for analysis is the system made up of the alpine pasture and the farms using it. This is because climate change impacts all of the components making up this system and changes to part of the system are likely to have an impact on the whole. The second reason is that opportunities for improving the flexibility of the system can be found at the articulation between the alpine pasture and the farms (Nettier *et al.,* 2011). We therefore propose to focus on the organisation of the entire "Alpine Pasture-Farms System" (APFS).

II – Differences between the alpine pasture-farms system and the livestock farming system

Research on the management of alpine pasture address the alpine pasture as a system (Deffontaines, 1998) and the farm(s) remain(s) a black box sending up a certain number of animals to the pasture for a certain period time. Conversely, research on livestock farming systems (Darnhofer *et al*., 2012), which studies the trio "Man-Herd-Resource" at the scale of the farm (Landais et Balent, 1993), does not consider the systems using alpine pastures as specific systems. Yet they are systems with specific characteristics, stemming at once from the very specific soil and climate context of alpine pastures, their land status as common areas, and the often collective organisation of summer grazing. Given these specific traits, we need to take a more nuanced approach to the "Man-Herd-Resource" model.

1. "Men": a specific work organisation

In the case of an APFS, the spatial and temporal disconnection between the alpine pasture and the farmstead leads to specific forms of work organisation. Furthermore, one or several herders may be employed. The herder(s) may only work on the alpine pasture, and is/are entrusted with the management of grazing and the state of health of the animals. Such specialisation for a worker in terms of time, space and tasks performed is rare in livestock farming systems.

The APFS is often made up of several farms and therefore several work collectives who from time to time are brought together up on the alpine pastures to perform various tasks (maintenance duties, animal drafting, etc.). Thus, the alpine pasture relieves the farm(s) of animal-related work, which can be essential in summer. However, the alpine pasture also sets a work scheduling, with an impact on the whole work organisation of the different farms.

2. Herds (or flocks): combining different types of livestock management

Using an alpine pasture has an impact on livestock management: issues such as mating time and batching are thought through in relation to the alpine pasture (whether the animals can be fattened, whether they can give birth, the quality of the feeding resources, work organisation and issues such as predation). In the case of collective APFS, the animals of several farms are mixed up together on the pasture. This has consequences in terms of health management: specific attention must be given to the health of the animals before they are taken up to the pasture to prevent them contaminating other herds or flocks, different specifications must be complied with (organic farming, quality labels, etc.) during health treatment.

3. Resources: capitalising on their diversity

The diversity of resources is an essential component in the management of agropastoral systems. In the case of an APFS, this diversity is highly pronounced owing to the considerable altitudinal layering and geographic distance that may exist between the different areas. The combination of resources from several farms increases this diversity, especially given that the farms are located in different geographic contexts, use different types of vegetation, are subject to different climates and weather events, and have different productions. Diversity also stems from resource management modes: on the alpine pasture, unlike in most other areas of an APFS, grazing is often the only management "tool".

4. Management: combining common and individual areas

In most situations, the APFS combines the use of resources used individually on the farms, and common pastoral resources available on the alpine pasture. The latter resources are common owing to their pastoral use, which is sometimes collective, but also because of their land status (most often public areas). In consequence the plants grazed should not only be seen as pastoral resources for livestock farming, but also as biodiversity, landscape and cultural heritage and therefore belong to society as a whole. APFS management must therefore include these other issues, providing sustainable management of both individual and collective resources. In particular, the APFS management must pay attention to the preservation of the commons. The pastoral use of alpine pastures is thus subject to specific rules outlined in grazing agreements and agri-environmental contracts, which differ from the usage rules for individual areas. When an alpine pasture is collective, it is generally coordinated by a collective body representing the different farms. This coordination is essential in order to ensure the right kind of articulation between work, management of herds/flocks and resources, and between the different farms and the alpine pasture.

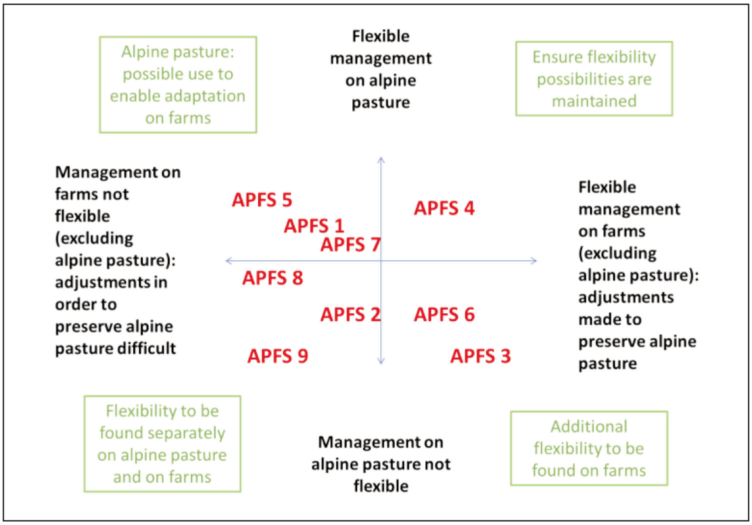

Fig. 1. APFS flexibility analysis framework and relative position of 9 APFS "Sentinelles" in the Ecrins National Park. The boxes list ideas for improving flexibility.

III – For a range of flexibility in Alpine Pasture-Farms systems

To preserve the vegetation on alpine pastures in the face of climate change, without undermining the agropastoral systems, one major avenue that might be explored is how to make APFS operation more flexible.

Potential flexibility may be applied to the alpine pasture, but also to the farmsteads and to the articulation between the alpine pasture and the farm(s) (Nettier *et al.,* 2011). These three sources of flexibility provide an analysis framework that was tested on 9 APFS in the Ecrins National Park in France, as part of the Alpages Sentinelles programme (a network of actors from the Alpine massif working to anticipate the impact of climate change and assess adaptation modes set up to face unexpected climate events).The observation of adjustment practices to counter different events over the past 5 years on these 9 APFS makes it possible to analyse their flexibility, and to position them on a graph (see Fig. 1) according to the level of flexibility implemented on the alpine pasture (vertical axis) and on the farms (horizontal axis), with or without adjustments at the articulation between the alpine pasture and the farm in order to preserve the alpine vegetation (see Table 1 for two examples).

This study of APFS may be of interest to all agropastoral systems using a diversity of resources, articulating individual and collective management and using both common and individual areas.

Table 1. Description and flexibility of 2 alpine pastures-farms systems

	APFS 9	APFS 6
Description of the APFS	5 sheep farms in a mountain village, that use a local alpine pasture. Spring and autumn lambing. Feeding-finishing of spring born lambs on alpine pasture. Salaried shepherd on alpine pasture	3 pastoral sheep farms in South-East of France, that transhume to a distant alpine pasture. Spring lambing only. Lambs go up on alpine pasture. Farmers take turns on alpine pasture.
Flexibility on farms	Long winters, important slopes: No room for manoeuvre: mechanised areas reserved for making hay, sloppy rangelands for spring grazing.	Important adjustments (in response to Mediterranean climatic variability): flocks management, pastoral areas used, grazing schedule.
Flexibility on alpine pasture	Size of the different range allotment reduced, buffer areas limited and best range allotment reserved for lambs: grazing schedule very rigid.	Despite abundant pastoral resource, many constraints limit and rigidify management: lower range allotment short, with late vegetation, higher one big but short grazing period, middle one exposed to predation (no hut).
Adjustments observed at interaction between alpine pastures and farms	Difficult to decrease the animal number or the time spent on alpine pasture. Few evolutions of the management on farms and on alpine pasture. → No flexibility on alpine pasture, or on farms, autonomous management of the different entities.	Important evolutions observed: (1) going up to alpine pasture delayed since 2005, (2) reorganization on farms, with new pastoral areas grazed (ski slopes, firebreaks…). → Lack of flexibility on alpine pasture. Structural adjustment made to preserve it on long-term. Annual adjustments made only on the farms.

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Rangeland management in Nepal with South Asian experiences

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Abstract. Rangelands are located in the high mountains and Himalayan regions at 2500-5000 m a.s.l. in Nepal. Sevety-eight percent of the existing natural rangelands are located in high altitude regions in northern Nepal bordering Tibet. Limited agricultural production is due to the scarcity of water, lack of proper irrigation, low temperatures for long periods and low rainfall. 1.7% of the land is arable with an average landholding surface area of 0.35 ha in Nepal. Livestock grazing play an important role in the fertility and distribution of plants. It is evident that the livestock sector contributes almost half of total agricultural income i.e. 47.3%. Cattle, yaks, Chauries, dzos, sheep, goats, horses, mules and donkeys are the major livestock species reared in rangelands. Transhumant pastoralism is the major form of livelihood in higher altitude pasturelands. The mobility of the animals follows a routine such that seasonal growth of the grasses is best utilized. Conserving the large area of natural ecosystem and sustainable production of diverse niche products are the best way for supplementing their livelihood and protecting the range species. China, Pakistan, Afghanistan and India have the highest share of rangeland in the region. Tibetan Plateau has rangelands covering nearly 70% of the total Plateau area. The plateau has unique traditional features and scientific rangeland management practices. This paper highlights the current pastoralism and rangeland management practices in Nepal with some reference examples.

Keywords. Pastoralism – Transhumance – Biodiversity.

Conduite des parcours au Népal dans le contexte de l'Asie du Sud

Résumé. *Les parcours des régions himalayennes sont situés entre 2500 et 5000 m d'altitude au Népal. 78% des parcours naturels sont situés dans des régions de haute altitude dans le nord du Népal qui borde le Tibet. La production agricole est limitée par le manque d'eau, d'irrigation, les basses températures pendant de longues périodes et les faibles précipitations. 1,7% de la terre est cultivable dans des propriétés en moyenne de 0,35 ha. Le pâturage joue un rôle important dans la fertilité et la répartition de la végétation. L'élevage contribue pour environ la moitié, 47,3% du total du produit agricole. Les bovins, les yaks et leurs croisements, les moutons, les chèvres, les chevaux, les mules et les ânes sont le principal bétail élevé sur les parcours. Le pastoralimse transhumant est la principale forme d'élave dans les pâturages d'altitude. La mobilité des animaux suit une routine qui permet d'utiliser au mieux la croissance saisonnière de l'herbe. Conserver ces grandes surfaces couvertes de végétation naturelle et la production durable de différents produits de niches, constitue la meilleure façon d'apporter un revenu par l'élevage et de conserver les espèces des parcours. La Chine, le Pakistan, l'Afghanistan et l'Inde partagent les parcours dans cette région. Le plateau tibétain est occupé par des parcours qui couvrent presque 70% de la surface totale du plateau. Ce plateau a des traditions de conduites des parcours uniques. Cet article met en avant les pratiques actuelles de conduite des parcours au Népal.*

Mots-clés. *Pastoralisme – Transhumance – Biodiversité.*

I – Introduction

The Rangelands are those areas of the World which by reason of physical limitations –low and erratic precipitation, rough topography, poor drainage, or cold temperatures– are unsuited for cultivation and are a source of forage for free ranging native and domestic animals, as well as a source of wood products, water and wildlife (ICIMOD, 1997). Rangelands in Nepal include grasslands, shrub lands, forest and other areas often used by grazing animals. Polyculture farming systems have evolved through centuries by integrating rangelands, forest, domestic animals and crop production in most parts of the high mountain regions of Nepal. The rangelands and forest provide forages, wild life, medicinal plants and sources for water bodies. The domestic animals provide meat, milk, wool, manure and power for transportation and other agricultural operations. The cropped areas provide cereals, pulses, cash crops, fruits and forages and by-product feed to the animals (Shrestha, 2004).

Livestock production supported through the pasture and rangeland area is providing the major support for livelihood in high-hills and mountain regions. The contribution of the livestock sector to total agricultural income of farmers varies from 20% in Terai to almost 50% in mountain regions (NPAFC, 2011). Livestock in high hills and mountains is mostly managed under a migratory system. The hills of Nepal are reported to have the highest concentration of livestock per unit area of cultivated land anywhere in the world (Miller, 1987), with 10 LU/ha in the mid hills and 15 in the high hills. There is an acute shortage of feed in the high lands during winter and dry season. Rangelands besides being rich in agriculture and livestock biodiversity are the sole source for feeding highland livestock.

The contribution of the livestock sector to Agricultural Gross Domestic Production (AGDP) is 26.8 percent and about 12% to National GDP. In the year 2012, the annual growth rate of cattle, buffalo, sheep and goat was 0.3, 2.8, 0.3 and 3.6 percent respectively (DLS, 2013). Similarly, the annual growth rate of livestock products such as meat, milk and eggs was 3.9, 5.6 and 8.9 percent respectively. The live male buffalo calves and goats are mainly imported from India and Tibet. Besides, the processed meat and milk powder from abroad is also imported for fulfilment of daily requirement.

II – Rangeland resources

Rangelands are diverse in structure and composition, ranging from cold, steppe rangeland dominated by Stipa grass to mountain desert shrublands with Ceratoides, Artemisia to alpine valleys and temperate conifer and deciduous forest meadows. Hindu Kush Himalayan (HKH) Region extends 3500 km over all or part of eight countries where ICIMOD works including the Himalaya, the Karakorum, the Pamir and other neighbouring ranges (Table 1). It is the source of ten large Asian river systems and provides water, ecosystem services and the basis for livelihood to a population of around 210 million people. The people of Himalaya have maintained a rich cultural identity and have maintained biogenetic diversity within the parameters of their own tradition (ICIMOD, 2013).

Table 1. Area of rangelands in HKH region (ICIMOD, 1997)

S. N.	Country	Area of rangeland (km^2)	Percent share of total HKH region
1	China (Tibet)	1,250,000	60.80
2	Pakistan	400,000	19.42
3	Afganisthan	200,000	9.71
4	India	180,000	8.71
5	Nepal	20,000	0.97
6	Bhutan	7,000	0.34
7	Myanmar	760	0.04
8	Bangladesh	290	0.01
TOTAL		2,058,050	100.00

Tibetan plateau covers 2.5 million km^2 and is one of the world's major rangeland ecosystems. With rangeland covering nearly 70% of the total land area the Plateau is an important pastoral region. Most of the area is above 3000 meters and climate is harsh. Precipitation varies from about 2000 mm in southern Himalayan ranges to less than 50 mm in the far north-western part of Tibet.

In the Himalayan country of Nepal, LRMP (1986) estimated the areas of rangeland at about 1.76 mil ha comprising 12% of total land areas of Nepal. The Rangeland Policy 2012 (Ministry of Agricultural Development, 2012) included 1.6 mil ha of shrubland into rangeland comprising now 22.6%. About 37% of the rangeland is accessible to livestock in Nepal (LMP, 1993 and Pariyar, 1998). The rangeland under national parks constitutes about 34.45% of the total rangeland (Yonzon, 1999). About 50 percent of total grassland is found in high mountains, 29 percent in high hills, 16.7 percent in mid hills and 4 percent in Siwwalik and terai. About 50 percent of rangelands are found in mid western region of Nepal.

1. Rangeland biodiversity

In 1992, Nepal became a signatory to the Convention on Biodiversity (CBD) and added one more feather to its conservation efforts when it approved Nepal Biodiversity Strategy (NBS) in 2002. Nepal has come a long way in terms of biodiversity conservation; 18.33% of its total land area is now under protection. Shrestha (1998) reported that among 5160 flowering plants, some 246 species are known to occur in sub-alpine and alpine rangelands. Accordingly, 41 species of medicinal plants out of 700 species were recorded in Nepal, from which 34% are found in rangelands. Nine mammalian orders out of 12 in Nepalese rangelands have been reported survived, of which eight are major wildlife species. For example: Leopard, Grey wolf, Tibetan Argali, Lynx, Brown Bear, Musk Deer, Red Panda, and Tibetan Antelope are commonly found in the region. Similarly around 413 bird species are reported to occur above 3000 m of altitude, whilst 19 species are known to breed in these high grounds.

Stretching for 3500 km from the desert mountain steppes of Afghanistan in the west to the lush alpine meadows in Yunnan Province of China in the eastern Himalayas, the rangeland ecosystems of the HKH encompass an enormous area, estimated to cover about 2 million km^2. Within such a vast region, rangelands differ considerably in plant community structure, depending on altitude, climate, rainfall, soil and the uses they have been subjected to by people and their animals. Each different range type has its own unique assemblage of plants and animals. Situated at the confluence of five major biogeographical subregions (the Mediterranean, Siberian, West Chinese, Indo-chinese, and Indian subregions), the rangeland ecosystem of HKH are rich in biodiversity (ICIMOD, 2013).

III – Pastoral production system

In Nepal, Rangelands are located in the high mountains and Himalayan regions at 2500-5000 m asl. The existing pasturelands are almost natural. Approximately 78 percent of the rangelands are located in high altitude regions in the northern belt of Nepal bordering Tibet (LRMP, 1986). Grazing animals and wildlife obtain forage from rangelands and the contribution of such areas to environment protection is important as well. Pasture lands vary from subtropical grassland at lower elevation to alpine meadows on ride in the mid-hills, high mountain valleys of the inner Himalayan range. The grazing lands except the alpine meadows are under heavy grazing pressure (Pariyar, 1993). The mid-hills and the open grazing lands are stocked about 13 times more than its carrying capacity and the steppe grazing lands about 19 times, whereas the alpine meadows are under-stocked. The alpine meadows are grazed only three to four months in summer (Table 2). However, the carrying capacity of the above rangelands could be significantly improved by adopting improved management practices, by promoting indigenous species such as Kote, Phurcha, Buki, etc. and by introducing some exotic species.

Transhumant pastoralism is the major form of pastoralism in higher altitude pasturelands of Nepal and Tibet. These en route pastoralists and transhumance make it sustainable through high seasonal mobility. It provides a number of particular transhumant herding, promotes trade of animal products such as milk, meat, wool and provides temporary employment (Miller, 1995).

The animals are moved towards the alpine pasture during monsoon seasons and brought back to the lower altitude forest, shrub-land and croplands for winter grazing. The movement of the animals follows a routine such that seasonal growth of the grasses is best utilized at different altitudes. The animal movement schedule is synchronized with crop harvesting at lower altitude for better utilization of their residues. In general, the movement cycle begins from the highest altitude 5000 m alpine rangelands during summer (monsoon period) to the lowest altitude 1800 m subtropical rangelands in winter. The movement cycle is completed in 365 days.

Table 2. Rangeland Status of Nepal (Miller, 1987)

Types of rangeland	Area (km^2)	Productivity (DM ton/ha)	Productivity (TDN ton/ha)	Carrying capacity (LU/ha)	Stocking rate (LU/ha)
Subtropical & Temperate	6293	2.5	0.58	0.54	7.07
Alpine	10141	1.5	1.3	1.42	0.64
Steppe	1875	1.0	0.06	0.09	1.19

In subalpine rangelands, the cocksfoot (*Dactylis glomerata*) established better by transplanting suckers than by seed broadcasting. The cultivation of exotic grass like ryegrass (*Lolium perenne*), cocksfoot (*Dactylis glomerata*) and white clover (*Trifolium repens*) with post monsoon sowing (broadcasting or strip sowing) have shown good performance in establishment and green matter production. Fodder tree species that are identified for winter feeding at the rangelands of up to 2400 m asl are *Ficus nerifolia* (Dudhilo), *Morus alba* (Kimbu), *Brasiopsis hainla* (chuletro), *Sauraria nepalensis* (Gogan), *Quercus semi-carpifolia* (Khasru), *Prunus cerasoides* (Painyu) and *Quercus leucotrichophora* (Sano banjh). For high hills a combination of grass and legumes in rangelands gave better yields. To boost the nutritive value of rangelands in high hill and sub-alpine areas a combination of white clover (*Trifolium repens*), cocksfoot (*Dactylis glomerata*) and ryegrass (*Lolium perenne*) is recommended. The combination of 3 species produced 28.7 tm green matter per hectare where as the combination of white clover and ryegrass and white clover and cocksfoot produced 17.01 and 20.64 tm green matter per hectare, respectively (Pariyar, 1998; Shrestha, 2004).

Pastoralists maintain milking and non-milking herds of yak (*Bos grunniens*), yak-cattle hybrids, sheep (*Ovis aries*) and goat (*Capra hircus*) during herding. Yak provides milk, meat, fibre and hides. They are also used as pack and draft animals. It is doubtful if man could survive in Tibet without the yak (Miller, 1986).

IV – Rangeland management strategies

Nepal approved the Rangeland Policy in 2012. It encompasses the inter-sectoral cooperation for management of rangeland. The government of Nepal has recently prepared the Rangeland Policy Implementation Plan. Nepal has adopted the following strategies: Classifying rangeland Inventory; increasing production and productivity; pasture development program; natural disaster preparedness; systematized grazing; renovation; reseeding of pasture forages and cross-border cooperation between Nepal and China.

Rangeland in Pakistan extends over 60% of the area of the country. The trans-Himalayan grazing land, desert rangeland, Baluchistan ranges contribute mostly in Pakistan range areas. Major range animals are sheep, goat, camel, yak along with some population of cattle and buffalo. Range improvement activities like new plant introduction, natural and artificial reseeding, stock water management, soil and water conservation, rain water harvesting, water spreading, sand dune fixation, range burning and fertilization are carried out.

In Bhutan, permanent grasslands, forest grazing, and the grazing of fallow land contribute over 70% of fodder needs. Bhutan has over 400,000 ha of registered grazing land which belongs to the state and herders have the grazing rights. Over 80% of Bhutanese are engaged in agriculture-related activities contributing 41% to GDP. Bhutan has 4.13 thousand ha registered as grazing land and 1.55 thousand ha as natural grazing land. The predominant exotic plant species are cocksfoot, white clover, red clover, tall fescue, perennial ryegrass and desmodium. Livestock rearing has always been an important source of livelihood, ranging from buffaloes in southern foothills to yaks in the northern high altitude regions.

In China, Sichuan province alone has 20.4 million ha of grassland with the largest ecosystem and biological diversity. The grassland has a productivity of 3.6 ton/ha with ruminant animals accounting for 55%. Vegetation reclamation and improvement of grassland productivity, sustainable animal production systems, decreasing number of herders through enterprise development are the strategies for Sichuan grassland. Similarly Tibet has a total of 82 million ha of grassland. The productivity of Tibetan plateau grassland is relatively low at an average of 1.04 ton/ha. Lhasa-grassland common property, household responsibility system, policies on rural pastoral areas, rehabilitation of traditional cultivation are the rangeland development strategies followed in Tibet along with rejection of agricultural mechanization and providing technologies in close association with farmers.

VI – Conclusions

Since rangelands are often remote, at high elevations, subject to harsh climates and sparsely settled, they have been largely neglected by research and development agencies. This neglect has been further exacerbated by institutional anomalies. The main factor influencing sustainable rangeland management is the productivity, their longevity, palatability and resistance to grazing, and stocking rate of livestock. In many arid and semi-arid rangelands of the tropics with large variations in rainfall from year to year, the stocking rates of livestock cannot be constant. However, a conservative stocking rate can reduce the risks of degradation of rangelands and give better production per animal compared to higher stocking rates. Nevertheless, a major challenge lies ahead to convince pastoral people about the benefits of reducing stocking rates and improving production efficiencies, in order to achieve higher livestock production, an improvement in income and less degradation of the rangeland. However, some basic strategies are common for range management and pastoral development.

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Structural productive and management traits in two Mediterranean large-scale grazing systems

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Abstract. The aim of this study was to analyse structural, productive and pasture traits of dairy sheep (DS) and beef cattle (BC) grazing systems of a cork oak silvo-pastoral area located in NE Sardinia. In 2009, farm and flock size, secondary grasslands/crops land, animal feed and production, crop management of three DS and two BC farms were compared. Eleven fenced pastures were assessed for their herbage mass production (Hm), grazing value (GV), species richness and stocking rate (SR). DS and BC showed a low-input management related to the high incidence of secondary grassland (>80% of total land). Feed from pasture grazing, on average, supplied more than 70% of the total animal energy requirements for both DS and BC. Mineral fertilizer was distributed at low rate, only in the cultivated hay and forage crops which are grown on arable land to improve the grassland pasture. DS pasture showed a higher Hm than BC pasture, both in spring and autumn, and a significantly higher level of SR. The vegetation analysis did not reveal differences between DS and BC pasture in terms of GV and species richness that were relatively high. Subterranean-clover was the most relevant species in the secondary grasslands.

Keywords. Beef cattle – Dairy sheep –Grazing system – Grazing value.

Traits structurels, productifs et de gestion dans deux systèmes de pâturage Méditerranéen à grande échelle

Résumé. *L'objectif de cette étude était d'analyser les caractéristiques structurelles, productives et pastorales de systèmes ovins laitiers (DS) et bovins à viande (BC) dans une région exploitant le chêne-liège comme ressource sylvo-pastorale dans le nord-est de la Sardaigne. En 2009, les tailles des fermes et des troupeaux, les prairies secondaires/cultures, les aliments destinés aux animaux, et la gestion des cultures de trois fermes DS et de deux fermes BC ont été comparés. Onze parcelles clôturées ont été analysées pour leur production de biomasse herbagère (Hm), ainsi que pour la qualité du pâturage (GV), leur richesse en espèces et leur chargement (SR). Nous avons observé que DS et BC représentent des systèmes à bas niveau d'intrants liés à l'incidence élevée des prairies secondaires (> 80% de la surface totale). L'alimentation issue du pâturage a fourni en moyenne plus de 70% des besoins totaux en énergie des animaux pour les deux systèmes DS et BC. L'engrais minéral a été utilisé à un taux faible, seulement pour la production de foin et pour les plantes fourragères cultivées sur les terres arables pour améliorer les prairies pâturées. Le système DS a fourni une Hm plus élevée que BC, tant au printemps qu'à l'automne et permis un chargement animal SR. L'analyse de la végétation n'a pas révélé de différences entre DS et BC du point de vue de la GV et de la richesse en espèces qui était relativement élevée. Le trèfle souterrain était l'espèce la plus importante dans les prairies secondaires.*

Mots-clés. *Bovins à viande – Ovins laitiers – Système de pâturage – Qualité du pâturage.*

I – Introduction

Mediterranean Large-Scale Grazing Systems provide ecosystem services such as forage and animal productions and high levels of biodiversity (Caballero *et al.*, 2009; Kumar P., 2010). In Sardinia, dairy sheep and beef cattle are the most widespread grazing systems. The former include 44% of Italian herd and around 58% of national sheep milk production (Idda *et al.*, 2010) and represents the most important item in Sardinia agricultural budget. Beef cattle traditional farms are dominant in marginal areas where suckler cattle and their calves are bred for meat production (Sitzia *et al.*, 2012). In both systems farms are characterized by relatively small size that constraints their economic competitiveness (Salis, 2011). Rainfed pastures are represented by secondary grasslands that are maintained through recurrent cultivation of hay and forage crops or shrub chaining and fertilization. They represent the main animal feed source but supplements (mainly hay and concentrate) are supplied to livestock in winter, summer and autumn. A vegetation survey performed on a typical cork oak silvo-pastoral system in NE Sardinia, revealed a relatively high level of plant biodiversity and that livestock management practices influenced plant assemblage composition directly and indirectly via their long-term effects on soil features (Bagella *et al.*, 2013). Moreover, grassland tillage did not affect soil characteristics and pasture production (Salis *et al.* 2011).

This study aims to compare the structural, productive and management traits of DS and BC grazing systems in a Long term observatory located in NE Sardinia (Bagella *et al.*, 2013).

II – Materials and methods

The study was performed in 2009, in a cork-oak silvo-pastoral system characterized by acid soils on a granitic substratum and by mesothermal-subhumid climate (Arrigoni, 2006). Average annual precipitation is 632 mm and mean annual temperature is 14.2°C (data ARPA, Dipartimento Specialistico Regionale Meteoclimatico). A survey was conducted on three dairy sheep (DS) and two beef cattle (BC) farms through structured questionnaires about farm and flock size, secondary grasslands/crops land width, milk and meat productions, crop management, animal feed. Energy requirements (ER) of herd expressed as daily milk feed unit (UFL head^{-1} day^{-1}) were recorded at monthly intervals considering animal maintenance, grazing and productions requirements (Jarrige, 1989; Rossi *et al.*, 1985). The energy supplements was calculated considering the total amount of hay and concentrated fed to the animals and their energy content in UFL (Jarrige, 1989). The energy derived from the pasture was calculated by difference between the energy requirements of herd and the offered supplements.

Eleven representative fenced pastures, seven in DS and four in BC farms were surveyed. In each field three grazing exclosure cages (20 m^2) were randomly positioned to measure monthly ungrazed herbage mass production (Hm) on sampling areas of 0.5 m^2 in size. Fresh forage was dried in an oven-dryer at temperature of 65°C to evaluate the dry matter production (DM, t ha^{-1}). Vegetation surveys were performed in spring to assess the specific contribution of each plant species in pasture, richness and grazing value (GV) (Daget and Poissonet, 1971). The average annual stocking rate (SR), expressed as livestock units (LU ha^{-1}) was also calculated for each surveyed field. Hm, GV and SR data were analysed using the GLM ANOVA procedure of the SAS software (SAS, 2002).

III – Results and discussion

In 2009 rainfall and mean annual temperature were slightly higher than long terms values (739 mm and 15.7°C). DS had greater farm and flock size than BC and land use of both systems was characterized by the dominance of secondary grasslands: 81 and 88% (whereas forage/hay crops were 19 and 12%) of total land in DS and BC respectively (Table 1). The DS farms average milk production was 40.5 t y^{-1}, 2.8 t y^{-1} of meat (lambs), less than BC farms that produced 4.8 t y^{-1} of meat (calves). All farmers adopted similar extensive agronomic management. Tillage for hay and forage-crop cultivation was made through disc ploughing (20-30 cm in depth) and harrowing. Seeding was performed with a fertiliser spreader, followed by light harrowing to cover the seed. Mineral fertilizers were distributed at a mean rate of 30 and 14 kg ha^{-1} of N and 77 and 35 kg ha^{-1} of P_2O_5 in DS and BC respectively. Annual animal ER ranged from 1.1 to 6.6 UFL $head^{-1}d^{-1}$ in DS and BC farms respectively. On both DS and BC grazing systems, the secondary grasslands and forage crops were the main source of animal feed.

The BC feeding system was based on a higher proportion on pasture grazing that covered 83% of the animal ER, as the average over the year, and 100% in May and June (Fig. 1). During summer, the calves were supplemented with little amount of concentrate and hay covered the energy gap of the available pasture.

In the DS farms, 73% of herd ER were covered by pasture grazing, with highest proportion observed in spring. Concentrates were mainly supplied in the winter milking period and in summer and covered on average 17% of the annual animal ER. Hay was given overall in autumn, during the pregnancy period, when covered up to 32% of the animal ER.

Table 1. Structural traits and livestock productions (mean ± SE) in the two grazing systems in 2009

Grazing system	Farm size (ha)	Secondary grassland (%)	Flock size (n)	Milk production (t. $year^{-1}$)	Meat production (t. $year^{-1}$)
DS	71 ± 15	81 ± 8	293 ± 13	40.5 ± 4.7	2.8 ± 0.6
BC	48 ± 3	88 ± 10	38 ± 3	–	4.8 ± 0.3

DS = Dairy sheep; BC = Beef cattle.

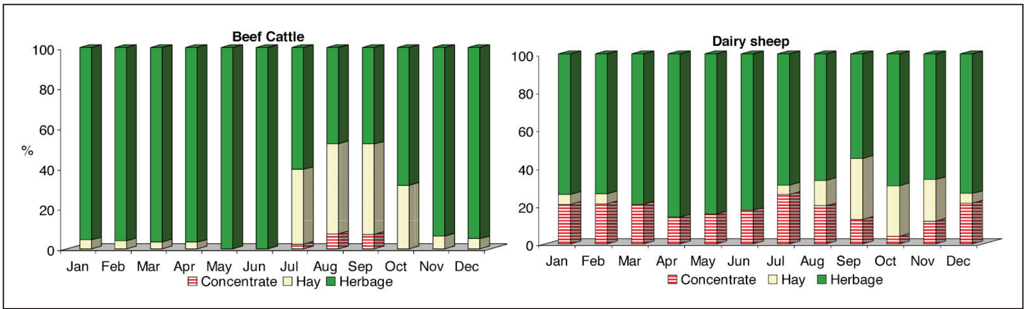

Fig. 1. Relative energy intake (%) from the concentrate, hay and herbage for the beef cattle and dairy sheep farms.

Herbage production showed a typical Mediterranean pattern with the highest herbage mass produced in spring (Table 2). DS pastures showed a significant higher Hm than BC in spring and autumn and a significantly higher SR (2.0 vs 0.6 LU ha^{-1}, $P<0.01$). BC pastures were continuously stocked whereas DS pastures were rotationally grazed.

The vegetation analysis did not reveal differences between DS and BC pastures in terms of GV that showed relatively high values (42.1 and 36.5 in DS and BC respectively). Plant species richness showed similar values in the pastures of the two farming systems, 64 and 61 in DS and BC respectively. *Trifolium subterraneum* was the most abundant species and its specific contribution was on average higher than 10%.

Table 2. Seasonal average and maximum Hm production (t DM ha^{-1}) in the GS

	Spring		Autumn	
GS	Average	Maximum	Average	Maximum
DS	1.6	2.8	1.0	1.2
BC	1.1	2.1	0.6	0.7
P†	<0.05	ns	<0.001	<0.01

Hm = Herbage mass; GS = Grazing system; DS = Dairy sheep; BC = Beef cattle.
† LSD test; n.s.= not significant.

IV – Conclusions

The two Mediterranean large-scale grazing systems investigated, DS and BC, showed small size and extensive management. The feeding technique was based principally on secondary grassland grazing and little supplementation of hay and concentrates. Secondary grasslands were the dominant land use in the landscape but few hay and forage crop cultivations are strategic to reduce the external feed inputs. The grazing management was compatible with a relatively high level of plant biodiversity and GV, and it is consistent with the EU recommendations on the maintenance of good agricultural and environmental conditions (Salis, 2011). Further studies on others ecosystem services are being conducted in the long term observatory to assess the potential of carbon sequestration and forestry productions.

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Trends and drivers of change of cattle systems in the Western Balkans

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Abstract. The paper presents the analysis of the changes of the cattle systems in the former Yugoslav republics which are now independent nations. It is assumed that cattle systems in former Yugoslavia gained in intensity of production but suffered from a decrease in the number of animals and in the number of farms over the last few decades, with a continuous negative trend. Development differences among the countries were present both before and after the split, but development gaps have widened even further since then. The aim of our study was to analyse the cattle trends and their drivers of change in the newly formed republics before and after the breakup. Therefore, we made a comparison of the evolution of cattle numbers in the Western Balkan countries so as to expose the results of our research to a wider public so that they can be used in priority setting and as a basis for a general foundation on livestock development. The analysis provides information about the intensity and influence of the main drivers of change affecting the dynamics of cattle numbers, taking into account the social conditions of the different countries.

Keywords. Cattle systems – Trends – Drivers of change – Western Balkans.

Dynamique des systèmes d'élevage bovin dans les Balkans occidentaux

Résumé. *Ce papier présente l'analyse des évolutions tendancielles des cheptels bovins dans l'ancienne république Yougoslave, qui est aujourd'hui composée de nations indépendantes. On suppose que les systèmes d'élevage dans l'ancienne Yougoslavie ont gagné en intensité de production mais ont diminué en nombre d'animaux et en nombre de fermes au cours des dernières décennies, avec une décroissance continue. Les niveaux de développement différents dans les pays étaient présents à la fois avant et après la séparation, mais les écarts de développement se sont creusés depuis lors. L'objectif de notre étude était d'analyser les évolutions tendancielles des cheptels bovins et les moteurs de ces changements dans les nouvelles républiques, avant et après la scission. Par conséquent, une comparaison de l'évolution du nombre de bovins dans les pays des Balkans occidentaux a été faite, en vue d'exposer les résultats de la recherche à un large public et de servir comme base pour définir des priorités pour le développement du bétail. L'analyse fournit des informations sur l'intensité et l'influence des moteurs des changements affectant la dynamique des systèmes d'élevage bovins, en tenant compte des conditions sociales des différents pays.*

Mots-clés. *Systèmes d'élevage bovin – Tendances – Moteurs de changement – Balkans occidentaux.*

I – Introduction

Given the complexity of agro ecosystems and the scale dependency of land-use change drivers, the need for approaches which integrate socio-economic and geo-bio-physical drivers is now widely recognised (Liu, 2001; Taillefumier and Pie´gay, 2003). There is a considerable literature from a development perspective on how farming systems may change in response to key drivers (see the review of Thornton *et al.*, 2009). For example, a general model of crop-livestock interactions and intensification first developed by Boserup (1965) and expanded by McIntire *et al.*

(1992) describes system change as an endogenous process in response to increased population pressure. Examples of direct and indirect legislation influences on animal numbers are provided by Milne (2005). Land use change, depopulation, abandonment and modernisation affecting livestock systems are analysed and explained by many authors, for example by Mac Donald *et al.* (2000).

This study aims to provide information about the influence of the main drivers of change in the cattle sector of the former Yugoslav republics, taking into account their different conditions. Our assumption is that, despite having similar bio-geographic and climate conditions, the countries had different trends in terms of livestock system evolution which resulted in creating a difference in socio-economic development.

II – Materials and methods

For the purpose of this study, a database for six countries was compiled. The database contained nineteen variables grouped according to the type of information we obtained: (i) land use; (ii) livestock; (iii) social (Table 1). Variables were chosen in order to determine the trends of cattle numbers and the related drivers of changes.

Table 1. List of collected variables used for the statistical analysis

Land Use	Livestock	Social
Total agricultural area (TAA, ha)†	Stocking density†	Total population†
Arable land (ha)†	Total livestock units (LU)†	Population density (person/km²)†
Area under cereal production (ha)†	% Cattle in total LU†	Total rural population††
% Grassland in TAA†	LU per TAA†	% rural population of total population††
Area used for fodder crops (ha)†	Cattle number†	Rural population growth (%)††
	Grassland (ha)†	% of population between 15 and 64 years of age††
		Independency (0-no, 1-yes)
		Social turbulence (0-peace, 1-turbulence, 2-war)

† Statistical yearbooks; †† World Bank and FAO-stat.

The data used for the analysis were obtained from various statistical services and sources from the analysed countries (Table 2).

Cattle number was the only variable used for the trend analysis and served as dependent variable in the discriminant analysis. A Student's *t*-test was used for the trend analysis of cattle numbers between six decades within each country.

In order to reduce the number of explanatory variables, facilitate the interpretation of discriminant functions, ensure the requirements of normality and to reduce multi-colinearity among the independent variables, a Principal Factor Analysis (PFA) on the collected variables was performed (Table 1). The PFA with varimax rotation was performed to obtain the main factors (eigenvalue > 1) that summarized the observed changes.

The relationships between the evolution of cattle numbers through decades (dependent variable) and other explanatory variables were analysed using a discriminant analysis. A forward stepwise discriminant analysis using the *stepdisc* function in SAS 9.1 was carried out on the new variables (factors) resulting from the previously performed PFA. The method involves inserting the independent variables into the discriminant function one at a time on the basis of their discriminant power, determining the optimal combination of variables so that the first function provides the highest total discrimination between groups, the second provides the second most, and so on (Hair *et al.*, 2006). The *discrim* function in SAS 9.1 was used to obtain variances explained by each discriminant function per country analysed.

Table 2. Sources of the collected data

Country	Source	Reference period
B&H	National First Release reports for agriculture and livestock of the Federation of Bosnia and Herzegovina	2005 to 2013
RS	Jovanović Z., 1998, Agriculture of Serbia 1947-1966 providing 50 annual series of statistical data	1947 to 1966
	SYB of the Republic of Serbia	1998 to 2012
RS, MNE	SYB of Serbia and Montenegro	2003 and 2004
	SYB of Yugoslavia	2001 and 2002
MNE	SYB of Montenegro	2006 to 2012
	Online data from the Statistical Office of Montenegro	2004 to 2011
CRO	SYB of the Republic of Croatia	2010 to 2012
	Statistical Information of the Republic of Croatia	2005 to 2013
MC	SYB of the Republic of Macedonia	1999 to 2002, 2005, 2008 to 2013
	Livestock statistical reviews of the State Statistical Office of Republic of Macedonia	2007 to 2012
SLO	SYB of the Republic of Slovenia	1990 to 2012
B&H, RS, MNE, CRO, MC	SYB of Yugoslavia	1950 to 1991
	FAO stat online database	1950 to 2012
	World Bank online database	1950 to 2012

B&H: Bosnia and Herzegovina, RS: Serbia, MNE: Montenegro, CRO: Croatia, MC: Macedonia, SLO: Slovenia, SYB: Statistical Yearbook.

III – Results and discussion

The analysis of the evolution of cattle numbers per country (Table 3) showed that the trends of the cattle population did not occur with the same intensity and with the same sign between the Western Balkan countries. In B&H, a continuous decrease in cattle number has occurred since 1960s, in CRO since 1970s, and in MC and RS since 1980s. A total decrease by 41% of the cattle population of all the countries has been recorded over the last sixty years. The highest total decrease occurred in B&H (-55%) and MNE (-52%). A relatively high decrease occurred in Montenegro in the 2000s (-44%) which was responsible for the total decrease recorded in this country (-41%). Serbia's cattle population increased until the 80s, then a steep decrease followed until now. Slovenia so far is characterized by the smallest decrease in cattle number, although a significant negative trend can be observed during the 90s ($P<0.001$).

A total of twelve factors with eigenvalues greater than one were obtained from the PFA. The number of factors obtained per country ranges from five (CRO) to seven (RS). The stepwise discriminant analysis resulted in the incorporation of factors that showed significant differences between decades ($P<0.05$) and therefore had discriminatory power.

Rural population turned out to be a good discriminant factor for five of the six countries. Social turbulence scored second to rural population with three significant cases. Also independence discriminated cattle evolution with three significant cases. Most factors with no significant effects included the types of land use, concluding that they did not properly discriminate cattle trends in the analysed countries over the last few decades. Social factors had the most frequent and significant discriminatory power. Intensification (area for fodder crop and cereal production) and extensification (grassland, % grassland in TAA, stocking density) had significant discriminatory power just in two countries (B&H and MC).

Table 3. Changes of cattle numbers in the former Yugoslav republics over the last six decades

Country	1950s†	Changes of cattle numbers (% difference)					
		1960s	1970s	1980s	1990s	2000s	Total diff.††
B&H	1,099,296	-0.96	-5.57*	-5.67*	-8.34	-34.58**	-55.13**
Croatia	1,006,936	+8.18**	-7.96**	-8.13**	-34.26**	-9.7**	-51.87**
Macedonia	375,821	-14.26**	+4.37	-3.43	-10.8*	-6.37	-30.51**
Montenegro	183,918	-8.61**	+4.14*	+5.34*	+1.83	-43.97**	-41.28**
Serbia	1,859,300	+20.15**	+7.19	-7.22	-24.50**	-35.06**	-39.44**
Slovenia	505,780	+9.56**	-3.51	+5.23	-14.45**	-4.39	-7.57**
Total	5,031,051	12.46*	-0.03	-7.86	-33.87**	-12.08*	41.38**

† Average cattle number in the first decade is used as reference; †† Diff.: difference; *P<0.05; **P<0.001.

Socio-economic indicators were the most significant drivers of change for cattle numbers in most of the analysed countries. In B&H, four discriminant functions, explaining 83, 13, 3 and 1% of the total variance were obtained: social turbulence and an increased senility of the population resulted in a decline in rural population, extensification and lower stocking density. For Croatia 77, 18, 4 and 1% of variance were explained by the four following discriminant functions: rural population decline, land use and total population changes. Macedonia's drivers resulted in four discriminant functions which explained 76, 18, 4 and 2% of variance: social turbulence, independence declaration, change in the number of rural population and farming intensification. Montenegro's drivers of change generated four discriminant functions explaining 90, 7, 2 and 1% of variance: independence declaration, abandonment, decreased stocking density and migration of the population led to a decrease in cattle numbers. For Serbia, all variance was explained by one discriminant function: despite orienting towards cattle breeding, the decline in rural population and abandonment of rural areas led to a decrease in cattle numbers. Drivers of change in Slovenia resulted in four discriminant functions explaining 71, 18, 9 and 2% of the variance: abandonment of rural areas, land use changes and the decline in rural population had the most discriminant power explaining the cattle changes over the analysed decades.

IV – Conclusions

For all the six countries analysed, cattle evolution resulted in negative values concerning the number of animals. Most of the decrease took place over the last two decades which were mainly characterised by social turbulences. Rural population had such high discriminant power for most of the countries that depopulation of rural areas by emigration affected cattle systems the most. Further investigations on some other different factors affecting cattle trends could provide deeper insight into their way of functioning and path of evolution. The direct and indirect effects and constrains of legislation and policies have to be analysed and addressed additionally. On-farm analyses could provide the needed information to identify the needs and options for the development of livestock systems in different environmental conditions.

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The emerging dairy sheep industry in New Zealand

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Abstract. Sheep milking has not featured strongly in New Zealand. However, the importation of the East Friesian and Awassi breeds has provided an opportunity to enter the sheep milking industry. During the late 1990's some sheep milking occurred though progress was slow due to limited marketing opportunities. Recent developments are providing further impetus for expansion. Three major enterprises have emerged at very different scales and targeting different markets. Each one has their own infrastructure and supply chain. The first are small cheese makers with flocks of 100-300 ewes. These are profitable intensive operations selling sheep cheese into local markets. The second enterprise is a mixed sheep and beef farm of 2200 ha farming approximately 20,000 stock units. Of these, between 3,000 and 6,000 ewes are milked and products include yoghurt and raw milk, sold locally and to Australia. The third enterprise produces ice cream, cheese, milk powder and infant formula for export from a flock of 25,000 ewes. The establishment of significant scale and reliable supply chains has provided a base for the instigation of a research programme to support the further development of the industry. This research programme is jointly funded by both Government and the industry enterprises to address industry-identified issues and opportunities. The programme includes elements of functionality of sheep milk, processing and product composition, sheep production and environmental impact.

Keywords. Dairy sheep – Environment – Feeding – Product composition – Product functionality – Research.

L'émergence de l'élevage des brebis laitières en Nouvelle-Zélande

Résumé. *Jusqu'à récemment, la traite des brebis n'était pas très développée en Nouvelle-Zélande. Cependant, l'importation des races Frisonne Orientale et Awassi a été l'occasion de débuter l'industrie laitière ovine. Pendant la fin des années 1990, la quantité de lait de brebis produite s'est accrue, même si les progrès étaient lents à cause du peu de possibilités de commercialisation. Les développements récents ont fourni un élan nouveau à l'expansion. Trois principaux types d'entreprises s sont apparus à des échelles très différentes et ciblant des marchés différents. Le premier est constitué de petits fromagers avec des troupeaux de 100 à 300 brebis. Il s'agit d'exploitations intensives rentables vendant du fromage de brebis aux marchés locaux. Le deuxième est constitué d'exploitations mixtes d'ovins et de bovins à viande de 2200 ha et d'environ 20 000 têtes de bétail. Dans celles-ci, entre 3000 et 6000 brebis sont traites et les produits, incluant yogourt et lait cru, sont vendus localement et en Australie. Le troisième type d'élevage produit des crèmes glacées, du fromage et de la poudre de lait (y compris du lait pour nourrissons) pour l'exportation à partir d'un troupeau de 25.000 brebis. L'atteinte d'une taille significative et la mise en place de chaines de distribution fiables ont permis le démarrage d'un programme de recherche visant à développer l'industrie davantage. Ce programme de recherche est financé conjointement par le gouvernement et les entreprises de l'industrie, pour aborder les problèmes et opportunités identifiées par l'industrie. Le programme comprend des éléments de fonctionnalité du lait de brebis, de transformation et composition des produits, de production ovine et d'impact environnemental.*

Mots-clés. *Ovins laitiers – Environnement – Nutrition – Composition des produits – Fonctionnalité des produits – Recherche.*

I – Introduction

The New Zealand sheep industry has a long history of innovation, pioneering the first successful frozen meat shipments in 1882 (Hewland, 1958). Sheep milking, however, has not featured strongly in our past. Most recently, the importation of East Friesian (Allison, 1995) and Awassi sheep has provided an entry point as an opportunity to enter the sheep milking industry. During the late 1990's some sheep milking flocks were formed though progress was slow due to limited marketing opportunities. Some recent developments are providing further impetus for expansion. This paper describes the current sheep dairy industry in New Zealand and outlines a research plan to support the future growth of the industry.

II – Description of the New Zealand dairy sheep flocks

Currently the sheep milking flock numbers approximately 30,000 of the 21,000,000 breeding ewes in New Zealand (Agricultural Statistics, 2013). The industry has a range of scale of operation, with several small enterprises (100-300 ewes), one medium enterprise (3,000-6,000 ewes) and one large enterprise (25,000 ewes). The East Friesian breed is the base of all of the milking flocks and average milk production is between 120 and 130 l/ewe/annum. One estimate of the potential of the industry suggests that it may build to more than 2 million ewes (10% of the national flock) within 10 years (Anon, 2013).

The small enterprises primarily provide milk for boutique cheese production and are often vertically integrated with the cheese-making operation. There are less than 10 of these enterprises throughout New Zealand. An example of this type of enterprise, Kingsmeade Cheese, milks 220 ewes on 11 ha and employs 5 staff. Lambs are reared on their mothers for 6 weeks before weaning. Product is available through specialist food outlets nationwide.

The large enterprise (Blue River Dairy) produces ice cream, cheese, and milk powder for export from a flock of 25,000 ewes. The company started milking sheep in 2000, and expansion began with further investment in 2002. There are between 1,000 and 3,000 ewes lambing for 10 months of the year supplying 3 farms of approximately 350 ha each. Lambs are removed from their mothers at birth and artificially reared. Ewes are primarily pasture-fed with some supplementation during the late autumn, winter and early spring. Ewes are intensively recorded and these records are used in a significant genetic improvement programme. Approximately 80% of the milk powder is exported with markets including China, Indonesia, Malaysia, Singapore, and the United States, with a developing market in Korea. A new product, infant formula is about to be launched. Blue River is vertically integrated, owning its farms, milk, and sheep, transporting its milk to the factory, processing the milk into cheese, ice-cream and milk powder, and marketing its products. It employs approximately 70 staff.

The second biggest producer in New Zealand is an order of magnitude smaller, and milks between 3,000 and 6,000 ewes from an available pool of 13,000 ewes and hoggets. The Waituhi Kuratau Farm Trust farms 2715 ha in the Central North Island and has been milking sheep since 2005. Mating is staggered over four months to provide a milking season of approximately 5 months from October to February (spring and summer). Lambs are weaned onto a concentrate diet at approximately 1 month of age before the ewe enters the milking flock. The flock is milked in an 80 bale rotary shed. The milk is either frozen for export to Australia as a raw material for further processing or made into yoghurt for the national market. As demand for yoghurt increases then a greater proportion of the current production will be locally processed. These three enterprises collectively produce 97% of the NZ sheep milk.

III – A research programme for the future

The establishment of significant scale and reliable supply chains has provided a base for the instigation of a research programme to support the further development of the industry. This research programme is jointly funded by both Government and the industry enterprises to address industry-identified issues and opportunities. The programme includes elements of functionality of sheep milk, processing and product composition, feeding and health and environmental footprint and whole farm analysis.

The proposed research program will contribute to growing exports from the emerging NZ dairy sheep industry by providing new science-based evidence of (1) the nutritional and functional characteristics of sheep milk necessary for product development, marketing, and regulatory purposes; (2) optimal nutrition systems to increase net volume and value of harvested milk, and improved early weaning outcomes; and (3) criteria to ensure the environmental sustainability of sheep dairying in the New Zealand grazed pasture environment.

The underpinning methodologies deployed across the entire value chain integrate innovative farm systems research to improve feeding systems and the environmental sustainability of sheep dairying with analytical and functional food research designed to optimise milk production and processing, and substantiate claims for sheep milk-derived ingredients. Results will support the development of products tailored to market and consumer demand for quality and safety. On-farm benefits and associated profitability will assist existing farmers, and promote sheep milking as a compelling choice for new entrants to this industry. The program will contribute to the development of guidelines for sustainable dairy sheep farming to ensure that the industry can operate within the regulatory framework.

IV – Conclusions

In summary, there is enormous potential for growth in the sheep milk industry. Conservative estimates by industry partners suggest that a $200M industry could be created by having between 200,000 and 500,000 ewes in milk. This equates to 2.5% of the national breeding ewe flock and could be achieved by 2030 if, on average, 14 sheep farms (average flock size: 3,500) convert annually to dairy. A holistic value-chain approach to providing research to support sustainable sheep dairying will result in a more attractive industry to new entrants and suppliers, further boosting its growth.

Acknowledgments

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Contribution of camel breeding to the household economy in southeast Tunisia

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Abstract. Southern Tunisia is highly dependent on the agricultural sector and especially on pastoral breeding for livelihood. The Tunisian government has until now given little attention to the sector, especially to camel breeding. A better understanding of the socio-economic dynamics in the study area is needed in order to develop camel breeding. This work shows the importance of camel breeding as a source of income (on average 79% of the household income) and employment (on average 43% of family labour) for the people in southeast Tunisia, and the impact of drought on related activities (feeding and shepherding). Despite the resilience of these farmers to adverse weather conditions, this study also shows the breeders' concerns and willingness to develop camel breeding.

Keywords. Camels – Household economy – Livestock – Rural development – Pastoralism.

Contribution de l'élevage du dromadaire dans l'économie des ménages du sud-est tunisien

Résumé. *La population du Sud Est tunisien dépend grandement du secteur agricole et en particulier de l'élevage pastoral comme moyen de subsistance. L'Etat tunisien a pourtant mis de coté le secteur de l'élevage et en particulier la filière cameline. La promotion de l'élevage camelin passe par une meilleure connaissance de sa dynamique socio-économique dans la zone étudiée. Ce travail montre l'importance de l'élevage camelin, comme source de revenus (en moyenne 79% du revenu pour un ménage) et de travail (en moyenne 43% du temps de travail familial) pour la population du Sud-est de la Tunisie, ainsi que le poids des sécheresses sur les charges liées à cet élevage (alimentation et bergers). Malgré la capacité d'adaptation de ces éleveurs aux conditions climatiques difficiles, la présente étude atteste aussi de l'attachement des éleveurs à l'élevage camelin et de leur envie de le développer.*

Mots-clés. *Elevage camelin – Economie familial – Développement rural – Pastoralisme.*

I – Introduction

Geographically restricted to arid and semi-arid areas, camel breeding plays an important economic role in these areas, providing a wide diversity of goods and services (Faye, 2009): food (milk and meat), maintaining population in remote areas, secondary products (wool, skin, bones and feaces), transport and agricultural works. Its social importance is also major both in religious, cultural and traditional practices as well as in providing security for income where it is considered an alternative source of cashflow (Vias and Faye, 2009). Tunisia, where threatened areas are estimated at 94% of the country, is characterized by the magnitude of the desertification processes (CNEA, 2007). The main arid pastoral areas are located in southern Tunisia where the economy is based on agriculture (olive and date palms) and pastoral livestock (small ruminants and camels), followed by tourism and finally mineral resources (Béchir *et al.*, 2011). Family farms represent the major part of the farming systems. This activity is practiced by 92.5% of the population in southeast Tunisia (Jaouad, 2010). The present paper aims to contribute to the assessment of the role played by camel rearing in household economies, and to identify the areas for improvement and innovation to enhance this breeding system.

II – Materials and methods

The data were collected through a socio-economic survey based on semi-directive questionnaires, conducted between May and July 2013 in the four governorates: Gabès, Kébili, Médenine and Tataouine. The study area is regarded as the cradle of the Tunisian camel breeding. Indeed, 83% of the camel breeders of the country are located in the Southeast. (Ould Ahmed, 2009). The questionnaire included 52 questions separated into five sections. Sections 1 and 2 were relative to the household head and family composition. Section 3 provided information on the lands owned by the household and theirs uses. Section 4 was the main part of the questionnaire, and regarded livestock (species, animal purchase and sales, animal production, animal feed). Finally, the last section was an opening question on drought adaptation. The breeders were chosen randomly based on the list of camel breeders obtained from local authorities[1]. As a whole, 61 camel farmers were interviewed and analysed in this study.

From the 52 questions, 16 quantitative variables were selected due to their variability and convenience for describing the farming systems. These data were analyzed by PCA (Principal Component Analysis) in order to extract the main combinations of variables (factors) explaining the most important part of the observed variability in the farmers population. Then, an AHC (Ascending Hierarchical Classification) was applied on the datatable to identify homogeneous groups. These groups help set typology of household. These analyses were carried out with XLSTAT software (Addinsoft ©).

III – Results

The principal component analysis highlighted three main factors axes explaining 57% of total variability. The first factor (28%) described the households according to the importance of their size and to the contribution of income from camel breeding to total income. The second factor (16%) reflected households by their family labour. The third one (13%) described the households according to the presence of sheep and goats in the herd and agricultural activities. The first factor expressed the size of the farm (usually the size of the family is linked to the size of the herd), the second, the contribution to agricultural wage and the third, the diversification of the activities.

The cluster analysis identified five main groups. Following these multivariate analyses, a test of means' comparison was carried on more contributive variables: HHD_taille, %.trav_fam_cam, %trav_fam_PR, %trav_fam_agri, Rev_cam, Rev_ov, and Rev_cap.

The first group (**big specialized camel farm**) was represented by one household only (less than 1% of the sample). This household was made up of 38 people, the head of family (father) and his seven sons and their family. They owned three herds, 510 camels, 1300 sheep, and 300 goats, but no income was declared from the small ruminant activity: all revenues were directly attributed to camel breeding. The camel herd provided 100% of income. It was also the principal family labour time (60% of their time).

The second type (**crop-livestock farmer with camel predominance,** 4% of the sample) included farmers located in Ben Guerdan and consisted of medium-size households (7 and 11 people) with large camel herds (mean = 112). The family labour was shared between camel breeding (46%) and agriculture (43%). It was camel breeding which brought most of the income (75% of total income) to the household.

[1] Arid Regions Institute(IRA), Office of Livestock and Pasture (OLP) and Regional Offices of Agriculture Development (CRDA).

The third type (**traditional small camel breeders)** reflected the major part of the sample (44%). It characterized the Southeast of Tunisia where many people practice camel rearing for a livelihood. Camel breeding represents 85% of the household income, but they had a small herd (mean = 47) and 44% of family labour was allocated to camels.

The fourth type (**mixed agro-breeder,** 30% of the sample) was mainly localized in the periphery of towns such as El Hamma and Douz and was characterized by the main part of household income coming from camel breeding (64%), then from olive culture (24%) and the remaining from small ruminants (12%). This group had the smaller size camel herd (mean = 41). The family labour was shared equally between these three activities, 33% of their time each.

The fifth and last type was **traditional mixed livestock owners** who obtained their income from the camel herd (65%) and the remaining from small ruminants. They had medium-size herds (mean = 62) and were located in rangeland areas such as Ben Guerdan (Medenine), Douz (Kébili), and Dhiba (Tataouine). The family labour was essentially invested in breeding, 72% in the camel herd and the remaining in the sheep and goat flocks (28%).

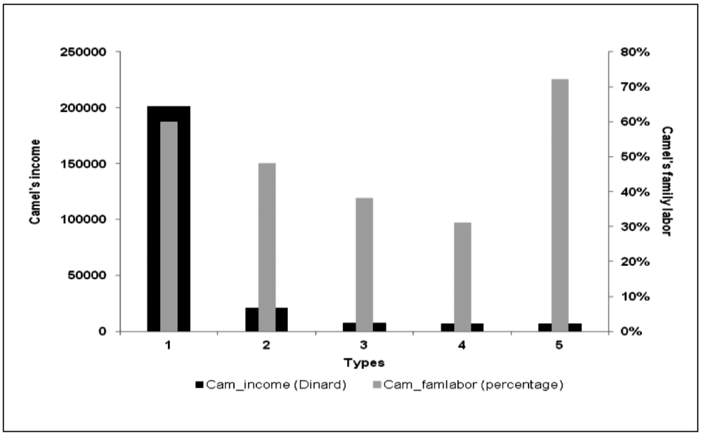

Fig. 1. Level of camel income and time spent of camel activity.

There was no difference between the 5 types identified in the present cluster analysis regarding the percentage of income coming from the camel breeding activity. This observation highlights the huge importance camel breeding has in household economies. Indeed, the camel activity allows comparable levels of income regardless of the identified types and the importance of the camel herd (Fig. 1). The other sources of income were variable according to the types. Sheep and goat incomes differentiated the types 4 and 3 ($p<0.05$), but the breeders of type 4 had higher income than those of type 3. Family labour was not similar according to the types. For camel labour, types 5 and 1, where the time spent on camel breeding was more important, were different from types 3 and 4 ($p < 0.001$). The labour time spent on small ruminants was higher in types 4 and 1 than in types 2 and 3 ($p <0.001$). Finally, the agricultural labour time differentiated types 1 and 5 ($p<0.001$) from the others who did not practice agriculture.

IV – Discussion

A farm typology is basal information and useful to all projects on sustainable agriculture development because providing insight into the different profiles of breeders and into the identification of the possible changes (Abdallah and Faye, 2013). The present classification confirms the changes in socio-economic structures observed in the study area for thirty years (Abaab, 1986) regarding the pastoralism practices, the animal breeding, the use and the landscape occupation. The main change regarded drought adaptation. Before the independence, the only adaptation practice was the population moving to more humid areas. This movement was long, random and the mortality rate in the herd was high. Between good and poor years, the animal numbers were regularized and stable thanks to considerable loss and many years of recapitalization. Later, these changes were characterized by the diversification of livestock activities as it was observed in Sahelian countries (Correra *et al*., 2009). Such diversification assures livelihood for households in a rapid changing situation but, this securization and relative autonomy is allowed in the frame of the social group organization. There was complementarity between camel and small ruminant breeding, although their respective rearing modes are in opposition. Camel breeding remains more pastoral and is conducted by a specialized herd keeper whereas small ruminant breeding is subject to intensification. Moreover, the main objective of small ruminant breeding activities is meat production, while the camel still plays a symbolic role of social success. However, some changes are also observed regarding camel rearing with the increasing demand for camel milk and meat with, in consequence, a better market integration of the camel products (Faye, 2013).

In Saudi Arabia, a typological survey identified also some adaptations of the Bedouins to the new urban demand for camel products. Thus, when pure camel breeders remained in the desert in a traditional way, the new farmers types started to be located increasingly more in periurban areas with higher market integration for providing meat and milk to urban consumers (Abdallah and Faye, 2013), despite the low organization of the milk sector (Faye *et al*., 2014).

Our typology highlighted the uncertainty in the breeder definition: it consisted of traditional breeders, officials, merchants, immigrants rearing only with the objective of making interesting investments and marking their entitled status on the collective lands and to get it in a future share. Lots of breeders only wish the government to acknowledge their activity. Yet, the government supported sheep production with subsidies and few of them for camel production. Pastoral breeders (types 1, 2 3 and 5) would like to continue to manage their farming system, with a better organization of the camel sectors. A few breeders, like those of type 4 and the ‘investors’ of type 3 would look for technical innovation (artificial insemination and grouping oestrus) and to start a more structured milk production. This typology showed that the most discriminant differentiation between breeders was between those keeping pastoral system and those changing to more intensive production system or at least more market integrated.

V – Conclusion

Camel breeding is a major source of income (79% on average) and represents the biggest part of the time in family labor (43% on average). Their socio-economic importance is undeniable. But for this activity to be developed, advanced knowledge and acknowledgment are needed. Moreover, breeders are aware of the importance of camels for the Tunisian southeast, such as social, cultural, economic and environnemental aspects and the fact that dromedaries have multiple functions since they provide a diverse range of consumer goods and services (Faye and Konuspayeva, 2011; Senoussi, 2011).

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Parallel workshops
Introductory article

Agroecology and herbivore farming systems – principles and practices

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Abstract. To achieve the sustainability goals of future agriculture, agroecology was often mentioned and discussed in the last decade. Surprisingly, the very large majority of publications on agroecology are related to cropping systems and different issues of plant production, whereas only rare publications are related so far to livestock systems and animal production. In this paper we analyse this relation between agroecology and herbivore farming systems by defining six groups of principles and seven categories of agroecological practices. The principles we propose for agroecological herbivore farming systems can be classified into (i) knowledge, culture and socio-economics, (ii) biodiversity conservation and management, (iii) resource management, (iv) system management, (v) food and health, and (vi) social relations. The agroecological practices which could or should be implemented to establish sustainable herbivore farming systems can be grouped into (i) diversification of land use, land cover and productions, (ii) resource management in mixed crop-livestock systems, (iii) biodiversity conservation, (iv) grassland management, (v) livestock management, (vi) food and food system, (vii) diversification of income sources. These underlying groups of principles and categories of practices should be considered for the development of sustainable agricultural herbivore farming systems.

Keywords. Agroecological practices – Agroecological principles – Cattle management – Biodiversity conservation – Diversification – Grassland management – Ruminant livestock systems – Sustainable animal production.

Agroécologie et systèmes d'élevage de ruminants. Principes et pratiques

Résumé. *L'agroécologie est souvent mentionnée et analysée dans le cadre du développement et de la mise en œuvre de l'agriculture durable du futur. Etonnamment, la majorité des publications sur l'agroécologie sont en rapport avec des systèmes de culture et différents aspects de production végétale, tandis que peu de publications abordent jusqu'à présent les systèmes d'élevage et la production animale. Dans cet article, nous analysons cette relation entre l'agroécologie et les systèmes d'élevage d'herbivores en définissant six groupes de principes et sept catégories de pratiques agroécologiques. Les principes que nous proposons pour les systèmes d'élevage en agroécologie peuvent être classés dans les groupes suivantes : (i) connaissances, aspects culturels et socio-économiques, (ii) conservation et gestion de la biodiversité, (iii) gestion des ressources, (iv) gestion des systèmes, (v) alimentation et santé, et (vi) relations sociales. Les pratiques agroécologiques qui devraient ou pourraient être mises en œuvre pour établir des systèmes d'élevage durable peuvent être groupés dans les catégories suivants : (i) diversification de l'utilisation et la couverture du sol et des productions, (ii) gestion des ressources dans les systèmes mixtes bétail-culture, (iii) conservation et gestion de la biodiversité, (iv) gestion des prairies, (v) gestion du bétail, (vi) alimentation et système alimentaire, et (vii) diversification des sources de revenu. Ces groupes de principes et catégories de pratiques devraient être pris en compte pour le développement de systèmes agricoles durables comprenant des herbivores.*

Mots-clés. *Conservation de la biodiversité – Gestion des praires et pâturages – Gestion du bétail – Diversification – Pratiques agroécologiques – Principes agroécologiques – Production animale durable – Systèmes d'élevage de ruminants.*

I – Introduction

It is highly desirable that sustainable farming systems are established in all parts of the world. This type of agriculture should produce sufficient quality food, be economically beneficial for farmers, be socially fair, conserve (agro)biodiversity, and not harm the environment. Livestock is an important part to this puzzle, also because livestock is the largest land use sector on Earth (Herrero and Thornton, 2013). Moreover, livestock is a major player in global environmental issues (FAO 2006). To achieve the sustainability goals of future agriculture, agroecology was often mentioned and discussed in the last decade. Although different concepts and interpretations are present among the different stakeholders dealing with agroecology, the main interpretations of agroecology are that it is a scientific discipline, a practice, or a movement (Wezel *et al.,* 2009). Within agroecology as a science a major approach is to apply ecological concepts and principles to the design and management of sustainable farming systems, agroecosystems, and food systems (Altieri 1995, Gliessman 1997, Francis *et al.,* 2003, Gliessman 2007). The current scales of application for research are the plot/field scale, the farm/agroecosystem scale, and the food system scale (Wezel and Soldat, 2009). When dealing with agroecological practices the scale of application is mostly the plot/field scale, but for certain practices such as integration of landscape elements on farms or in landscapes the scale can be larger (Wezel *et al.,* 2014). The movement of agroecology appears more with the agroecosystem scale (for environmentalism and rural development movements in agroecology) and at the food system scale for different political and social movements within agroecology (Wezel *et al.,* 2009, Altieri and Toledo 2011, Rosset and Martínez-Torres 2012, Gonzalez de Molina 2013, Sevilla Guzmán and Woodgate 2013). Surprisingly, the very large majority of publications on agroecology are related to cropping systems and different issues of plant production, whereas only rare publications address so far to livestock systems and animal production.

Gómez *et al.* (2013) found in their analysis of 115 original (empirical) agroecology papers including the word 'agroecological' in the title that only seven were related to livestock and livestock system. These publications deal with diseases and fertility of cattle, milk production, and productivity and management of pastures. Wezel and Soldat (2009) mention 28 out of 711 publications on agroecology that used the word 'livestock' in the title, with a broad variety of topics related to livestock and livestock systems.

Whereas agroecological practices for cropping systems have been described and defined in various publications (e.g. Arrignon 1987, Altieri 1995, 2002, Gliessman 1997, Wojtkowski 2006, Wezel *et al.,* 2014), this is only found in very few publications for the case for agroecological practices in livestock system, as well as for agroecological principles. Gliessman (2007) integrated a chapter about animals in agroecosystems in his book, but did not explicitly describe or define principles or practices for agroecological livestock systems. It is only recently that Dumont *et al.* (2013) defined five groups of agroecological principles, but they do not explicitly define agroecological practices. Bonaudo *et al.* (in press) analysed more specifically agroecological principles that can help farmers to redesign and improve integrated crop-livestock systems. They also defined agroecological practices for crops, crop-livestock integration, and livestock.

In this paper we explore the link between agroecology and herbivore farming systems with ruminants. We propose different groups of agroecological principles which in our opinion should be the basic rules to be followed for agroecological herbivore production systems. We will also describe agroecological practices in herbivore farming systems and group them in different categories. In our understanding, agroecological practices are agricultural practices aiming to produce significant amounts of food, which valorise in the best way ecological processes and ecosystem services in integrating them as fundamental elements in the development of the practices.

II – Agroecological principles

Although livestock systems over the world can considerably vary from extensive to intensive systems, from pasture-based to in-stable (factory farming) systems, from one breed to mixed breeds or multiple species systems, from specialised to mixed crop-livestock systems, they have the common primary objective to produce optimal quantities of meat, milk, or fibre in relation to resource inputs. Nevertheless, the underlying principles to attain this objective can be quite contrasting, e.g. feeding the animals with only grass fodder produced on the farm to almost complete concentrates feeding from imported maize, soybean or other resources. But what are or should be the principles of agroecological livestock systems?

In the following paragraphs, we list and discuss different principles of agroecological herbivore farming systems which we consider as relevant, also reflecting the basic principles of agroecology by having a system approach, considering simultaneously multiple scales, and having multi-stakeholder involvement when developing agroecological systems (Wezel and David 2012). Agroecology is inspired by the biomimicry principle (Benyus, 1997); it tries to adopt the principles of nature functioning such as diversity at all scales, nutrient cycling, permanent soil cover and self-regulation processes. In contrast with the Green Revolution and other strong commercial oriented input based systems, it does not rely on massive use of fossil fuel but it is ecosystem-based: it aims to restore ecosystems and to rely on ecosystem services provided by different types of biodiversity present in agroecosystems (Peeters *et al.,* 2013). The principles we propose for agroecological herbivore farming systems with ruminants can be classified into six groups: (i) knowledge, culture and socio-economics of farmers, (ii) biodiversity conservation and management, (iii) resource management, (iv) system management, (v) food and health, and (vi) social relations in the society (Fig. 1).

Principles of agroecological herbivore farming systems:

Knowledge, culture, socio-economics of farmers

- Systems should be economically viable for farmers (decent income) and ‘liveable’ (quality of life of farmer’s family).
- Systems should be ‘inheritable’ (could be transferred to the next generation).
- Farmers’ knowledge should be combined with the most up-to-date scientific knowledge and techniques.
- Systems should be locally and culturally adapted.

Biodiversity conservation and management

- Ensuring a central place to biodiversity as the driver of the agroecosystem: e.g. multi-breeds, multi-cultivars and multi-species ecosystems, and diversity of habitats.
- Conservation of all biodiversity types (agrobiodiversity, functional and heritage biodiversity).
- Conservation and development of semi-natural landscape elements on the farm or at landscape scale (e.g. semi-natural grasslands, hedges, thickets, herbaceous field margins, ditches, ponds).

Resource management

- Optimisation of nutrient cycling, favouring organic fertilisation with on-farm produced manure or slurry and nitrogen fixing legumes.
- Guaranteeing permanent soil cover for optimal nutrient cycling, carbon storage, and soil erosion protection.

- Minimum or ideally no use of inorganic nitrogen, other chemical fertilizers, pesticides and drugs.
- Minimum irrigation water.
- Optimisation of energy use.

System management

- Design and establishment of ecosystem-based and not fossil fuel-based systems.
- Development of low commercial input systems (high commercial input systems only if not in contradiction with other agroecological principles).
- Development of diverse systems (e.g. over time, in space, land use and land cover types, plant traits, biodiversity types).
- Development of mixed crop-livestock systems if possible.
- Development of a maximum rate of self-sufficiency (protein, fodder) at farm, landscape, and regional scale.
- Creating conditions for best possible animal health.
- Priority to systems instead of individual techniques or breeds. Sustainable systems, adapted to local conditions, should be designed first and then techniques should be chosen and developed, cultivars and breeds should be adopted or bred in the perspective of these systems. Adoption of highly productive breeds often leads to modifications of the production systems that are unsustainable. Farming systems should thus not be adapted to techniques and breeds, it should be the opposite.

Food and health

- Reconciling supply and demand for food (food processing, short marketing chains).
- Production of healthy and tasty food.

Social relations in the society

- Founding human social relations on collaborations and the development of synergies instead on competition and antagonisms.

Figure 1 shows schematically that agroecological herbivore farming systems are driven by farmers and their families who take decisions on the basis of ecological, sociological and economic environments. In this process, they use their own knowledge with the support of technical and scientific information they got from advisers and diverse media. This knowledge is used for managing biodiversity as the key-component and driver of the system. Systems are designed and implemented. In advanced agroecological systems, they are managed in a way that optimize resource use and provide optimum quantity of quality food for consumers. In these systems, social relations seek to develop a new harmony in human societies.

Dumont *et al.* (2013) defined five groups of principles: (i) adopting management practices aiming to improve animal health, (ii) decreasing the inputs needed for production, (iii) decreasing pollution by optimizing the metabolic functioning of farming systems, (iv) enhancing diversity within animal production systems to strengthen their resilience and (v) preserving biological diversity in agroecosystems by adapting management practices. These groups of principles are not contradictory to ours, but they are much more specific and technical. They do not explicitly mention our three important principles that are related with the future and the role of agriculture in society: principle i) knowledge, culture, and socio-economics, principle v) food and health, and principle vi) social relations in human societies. With the food systems approach in agroecology (Francis *et al.,* 2003, Wezel and David 2012), these three groups of principles are also important to be considered. In contrast, Dumont *et al.* (2013) have defined one special group on animal health, which we consider under the principles of system management. Bonaudo *et al.* (in press) also deal with agroecological principles, but they focus specifically on integrated crop-livestock systems. They provide some principles which are more related to cropping systems within crop-livestock systems, but not explicitly defining the principles of the livestock system. Their major principles also are based on diversity, maximisation of ecological interactions, closing nutrient and energy cycles, optimising nutrient availability, and collective management at the landscape scale.

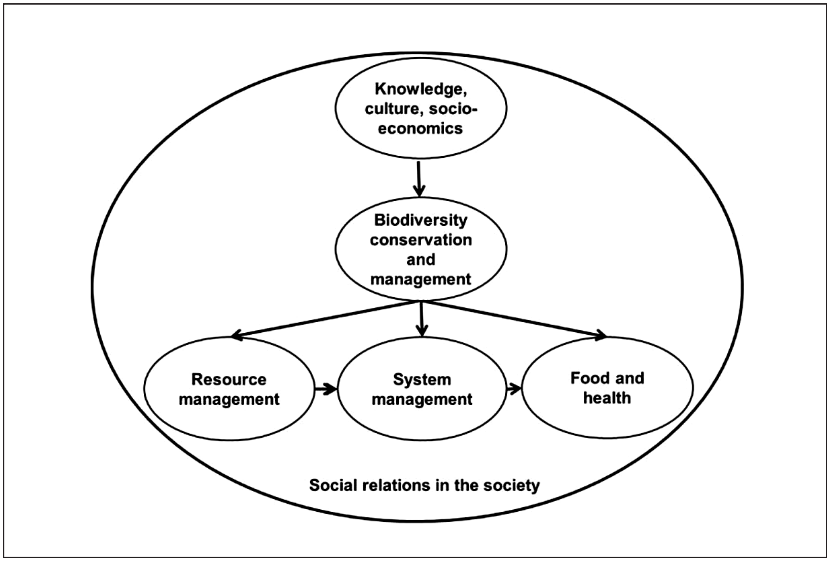

Fig. 1. The six groups of principles of agroecological herbivore farming systems.

III – Agroecological practices

If it is important to define a list of principles, the main concern for farmers is to translate them into concrete measures, practices and management. Therefore, we define here seven categories of agroecological practices which could or should be implemented to establish agroecological herbivore farming systems (Figure 2). Three categories of practices are related with land and resource management: (i) diversification of land use, land cover and productions, (ii) resource management in mixed crop-livestock systems, and (iii) biodiversity conservation. Two categories of practices are linked with technical aspects of (iv) grassland management, and (v) livestock management. The last two categories of practices (vi) food and food system and (vii) diversification of income sources are related with socio-economic aspects through the strong synergies and collaborations that exist in agroecological systems between different types of stakeholders and especially between farmers and consumers/citizens.

Diversification of land use, land cover and productions

- Increase diversity of livestock species and breeds to increase resilience of the system.
- Establish mixed livestock herds and flocks (e.g. cows, sheep, goats) whenever possible to improve resource use of different pastures and rangelands and control parasites.

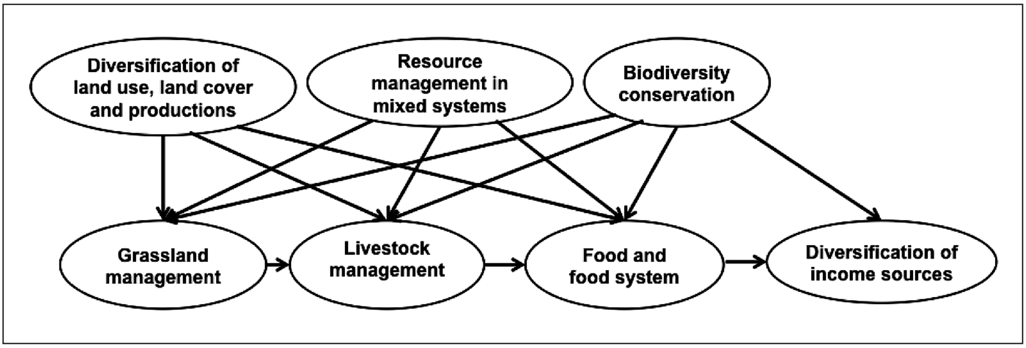

Fig. 2. The seven categories of agroecological practices related to herbivore farming systems. Arrows indicate which category of practices are strongly related to practices in other categories.

- Combination of the use of different grassland types for different types of animals: permanent/ temporary, mown, grazed, grazed/mown, intensive/extensive/semi-natural to improve resource use and decrease production costs.
- Use of semi-natural grasslands in combination with more intensive permanent and/or temporary grasslands to improve resource use in areas where semi-natural grasslands are available to maintain biodiversity and improve product quality.
- Favour high diversity of crops and long crop rotations including the integration of nitrogen-fixing legumes to improve fodder quality, reduce nutrient inputs, increase soil fertility, control weeds, disease and parasites in mixed crop-livestock systems.
- Integrate trees into the system for establishment of silvo-pastoral systems: e.g. fruit trees, trees for timber and fire wood, hedges e.g. to increase land productivity, diversify productions, provide shade to livestock, fix carbon.

Specific resource management in mixed crop-livestock systems

- Temporary grassland (ley) – crop combination for optimized weed, pest and disease control (to reduce pesticide use) and for fertility transfer from grasslands to crops.
- Large use of nitrogen fixing legumes in temporary grasslands and fodder crops (e.g. green cereal-legume mixtures) to reduce N inputs.
- Optimum management of organic matters and transfer between livestock and arable land (manure) and between arable land and livestock (litter, forage, by-products) to close the matter and nutrient cycling.
- Establish cooperation between arable farmers and livestock farmers for manure, crop residues, and forage (hay or silage) exchange to reduce energy for transport, to optimise nutrient, and matter cycling on local scales.
- Favour grass-based systems (in combination with local arable forage production) to reduce fodder imports (Figures 3 and 4).
- Orient towards self-sufficiency for fodder by using locally or regionally produced forage and feed to limit external fodder imports and reduce production costs.

Biodiversity conservation

- Use adapted stocking rates on semi-natural pastures and late or less frequent mowing on semi-natural meadows (to increase plant species richness, to improve product quality).
- Apply adapted grazing and re-use of marginal land (e.g. sheep and goat), for example in dry grasslands, open woodlands, and other types or rangelands (Figure 3 right) (to conserve biodiversity of these systems, to conserve specific species, to decrease production costs).
- Maintain or establish semi-natural landscape elements on the farm or in the landscape (Figure 3 left) (e.g. semi-natural grasslands, hedges, ponds) to increase species richness, ecosystem diversity and animal welfare.
- Conserve rare or less productive breeds to conserve genetic resources and to produce quality meat and dairy products.

Grassland management

- Large use of nitrogen fixing legumes in temporary and permanent grasslands to reduce N inputs.
- Choice of a multifunctional grazing method (e.g. rotational grazing to reduce parasites occurrence, to control weed and to increase forage quality).
- Adoption of optimum stocking rate according to seasons and grassland plot potential to maintain or improve sward quality, to avoid diseases, nitrate and phosphate pollutions and soil erosion.
- Favouring multiple species swards in grasslands for increasing yield, resilience and improving feeding quality.
- Apply reduced or no tillage techniques for temporary grasslands establishment to reduce soil erosion, to increase carbon storage, to limit nutrient leaching, to favour soil biodiversity, to promote biological activity, and to reduce energy inputs.
- Favouring tannin-rich forbs/legumes/woody species (e.g. *Taraxacum* spp., *Lotus* spp.) or essential oil-rich forbs for decreasing methane production and improving animal health (see below).

Livestock management

- Apply integrated disease and parasite control:
  - systematic use of prevention methods (e.g. rotational grazing, balanced feeding, adapted housing, hygiene, rustic breeds, mixed grazing of different livestock species).
  - when necessary disease treatment with plant extracts or essential oils (phytotherapy) to replace chemical disease treatments when possible.
  - use of tannin-rich forage species for parasite control).
- Giving priority to feed (e.g. fresh grass, hay, silage) (Figures 3 and 4) compared to food (e.g. cereal, pulses).
- Use of locally adapted breeds for maximum use of grasslands to reduce concentrate feed including commercial feed.
- Use of modern types of double-goal breeds to have both meat and milk production to limit hyper-specialization of high yielding animals while conserving good income. Hyper-specialization induces health and fertility problems, reduces animal welfare and lifetime expectation, and limits the possibilities to use green forage in animal feeding which induces its replacement by concentrates (e.g. food like cereals and soy).

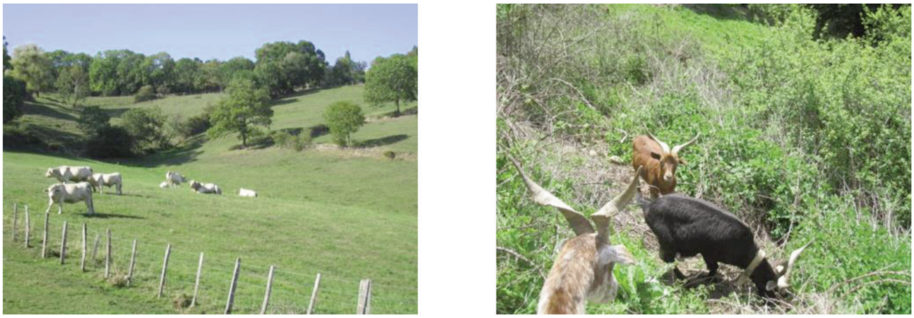

Fig. 3. Pasture-based system in mountainous areas (left), and grazing of shrub rangelands (right) in south-eastern France.

Fig. 4. Livestock systems based on alternating and combined use of pastures and meadows for fodder and feed production in southern Germany.

Food and food system

- High quality of products (nutrition, taste):
  - Adopt grass-based productions to decrease total and saturated fats, to increase omega3/omega6 fatty acid ratio and conjugated linoleic acids (CLA), in dairy and meat products.
  - Favour species-rich vegetation to improve milk quality, polyphenol content, and livestock and human health.
- Local dairy and meat product processing to reduce transport energy, and to provide local employment.
- Adoption or development of quality labels (e.g. geographical indications) and trade marks to increase selling price and income.
- Short and medium marketing chains to reduce transport costs and energy, to link to consumers and increase selling price and income.
- Cooperation, collaboration and development of synergies between farmers, between consumers/citizens and farmers (e.g. by signed agreements like those of Community-Supported Agriculture), and between consumers/citizens (e.g. urban agriculture) for increasing and stabilizing farmer's income, for improving access to quality food and decreasing food prices for consumers, for increasing contacts between cities and rural land, for improving contacts of citizens with nature and farming.

Diversification of income sources

- Product diversification to increase economic resilience of farmers, and to reduce dependence on global and national market prices, including ‘minor’ (niche) productions instead of large-scale productions integrated in global value chains.
- Diversification of activities (e.g. agri-tourism).

Dumont *et al.* (2013) presented and discussed also agroecological livestock practices, and provide valuable details for some practices. They also included practices of non-ruminant systems with pigs, poultry, and rabbits, or of aquaculture systems. A specific agroecological practice related to nutrient cycling, fertilisation of grasslands with vermicompost, is described by Boval *et al.* (2013). Different agroecological practices for crops, crop-livestock integration, and livestock are stated in Bonaudo *et al.* (in press). For agroecological livestock practices they mention calving periods, animal batches, the ratio permanent grassland/main fodder area, herd mixity, learning, pythosanitary practices, share of grazing in the feed, and choice of species and breeds. These practices are mainly referring to our practices categories ‘grassland management’, ‘livestock management’, and ‘diversification of land use, land cover and productions’. The practices for crop-livestock integration stated by Bonaudo *et al.* (in press) are feed production, recycling by-products for feed and litter, organic fertilisation, effluent management, and gazing pressure. These practices are naturally in strong accordance with our category ‘resource management in mixed crop-livestock systems’, but also with our category ‘grassland management’.

Grassland management is central for agroecological herbivore farming systems. Grasslands are the basis of livestock feeding systems. They ensure a high rate of forage and protein self-sufficiency, and reduce production costs compared to systems based on the use of commercial concentrates. They can contribute a lot to animal welfare and health. They play an important role in soil fertility building on the whole farm. This role is direct in the case of temporary grasslands that take part in crop rotation and increase organic and nitrogen contents of arable soils. Fertility accumulated during the temporary grassland episode is largely available for the following crops of the rotation. Green forages harvested on temporary and permanent grasslands are fed to livestock and a large part of their nutrients are found in effluents. This organic manure can then be spread on crops or grasslands which closes the cycle and increases nutrient availability for plants and yield. Perennial legumes of grasslands have a much higher biological nitrogen fixing ability than annual legumes cropped for grain such as pea or faba bean. Lucerne and red clover for instance can fix up to 300 to 400 kg N/ha annually while temperate pulses (e.g. pea and bean) fix usually less than 100 kg N/ha annually. The incorporation of forage legumes in agroecological herbivore farms is thus essential for the productivity of their production system. Grassland-based products are healthier than grain-based products for human health. Compared with grain-fed beef or milk, grass-fed beef or milk are for example lower in total fat, lower in saturated fatty acids, linked with coronary heart diseases, higher in total omega-3 and higher in conjugated linolenic acid that is anti-cancer (Dhiman *et al.,* 1999, Couvreur *et al.,* 2006, Duckett *et al.,* 2009). In addition, the principle of biodiversity conservation and management is important in agroecology. Therefore two crucial questions are how to manage grasslands in (i) assuring biodiversity conservation and (ii) using biodiversity as an asset for ruminant production systems? Metera *et al.* (2010) and Gaujour *et al.* (2012) provide in their reviews significant insights in showing that different management options exist. Gaujour *et al.* (2012) also state that it is necessary to go beyond simply looking at management practices such as grazing, fertilisation, and mowing, implemented at the field scale, but considering also the landscape scale as this can influence significantly species pools and species richness on grasslands. This multiple scale approach is specifically important when dealing with agroecology (Wezel and David, 2012).

Agroecological cropping practices are specifically important for mixed crop-livestock systems in order to have the complete system oriented towards sustainable production. These practices were defined and described in Altieri and Rosset (1995), Maljean and Peeters (2003), and Wezel *et al.* (2014), but will not be presented in detail here. Among them are practices related to crop choice, crop rotation management, cover crops, fertilisation, irrigation, weed, pest, and disease management, tillage management, and management of landscape elements. These practices do not exclude other ones that have a lower general scope such as production of biogas from manures and use of residues on fields or grasslands to optimize nutrient cycling and produce energy.

IV – Application of practices to selected farming systems

The application of principles of agroecological herbivore farming systems into real practices can vary significantly according to farming system types in diverse locations with variable climate, soil, natural vegetation, and relief. Some examples of practices which are or could be applied to mountain or Mediterranean farming systems in Europe are presented in Table 1.

V – Livestock systems and food value chain

Food value chains are can be quite different from on livestock production system to another. In general, food value chains tend to be shorter in agroecology than in industrial farming (Figure 5), also for systems with livestock. Industrial farming such as ‘Intensive conventional agriculture’, ‘Green Revolution’ (Gaud 1968), ‘Doubly Green Revolution’ (Conway 1997) and ‘Sound Farming’ (‘Agriculture raisonnée’ in French) (Paillotin 2000) are fossil fuel-based. The value chain starts from fossil fuel pits and finish in the plate of consumers. Upstream and downstream industries are important parts of the system. Farmers devote a large part of their revenue for buying inputs and paying loans to banks. Farmers’ margins are limited because of low prices paid by strong dealers. A large part of total profit is captured by food processors and retailers. In agroecology, shorter value chains are favoured. They are ecosystem-based. Biodiversity fulfil several functions that drive the system such as biological nitrogen fixation by legumes, pollination, parasite and disease control by natural enemies. A proportion of the food produced is processed in farms and sold in short marketing chains to consumers. Production costs are thus reduced and a large proportion of increased profit is kept in farms. Since producers (farmers) and consumers are in close contacts, the food chain is more transparent than in long industrial value chains. This induces higher consumer trust in product quality. Although short value chains are often favoured in agroecology, also midscale value chains may provide many positive aspects to farmers (Lev and Stevenson 2011, Stevenson *et al.,* 2011). These midscale food value chains are often based on strategic alliances among small and midsized sized farms and other agri-food enterprises that operate at regional levels.

A well-known example is the Comté cheese production in France where both a short value chain and a midscale food value chain can be found, but also a more conventional long value chain (Torre and Chia 2001, Ricard 2009, Jeanneaux *et al.,* 2011). The Comté cheese is recognized by a PDO (Protected Designation of Origin) label which certifies a geographical indication with the territory where it is produced as well as that production is in agreement with defined production rules, e.g. to only use pastures and meadows with a certain minimum of plant species diversity for the production of the milk. The cheese is either produced directly on farms and sold on farm, or in local shops (short value chain), produced in dairies in the production area and sold regionally and nationally (mid-scale value chain), or produced in dairies in the production, but sold nation-wide and on the European market by retailers (long value chain). In general, the Comté cheese can be sold with higher prices on the market because of his geographical indication, and his reputation as a high quality product.

Table 1. Some examples of agroecological practices in mountain or Mediterranean herbivore farming systems in Europe

Practices	Example of practices: Mountain areas	Example of practices: Mediterranean areas
Diversification of land use, land cover and productions		
• Diversity of livestock species and breeds	Conservation of rare or less productive cattle breeds (e.g. Villard de Lans, Vercors area in the French Alps)	Conservation of rare or less productive cattle breeds (e.g. Avileña – Negra Ibérica in Spain)
• Mixed livestock herds and flocks	Mixed grazing with cattle, sheep and goats	
• Combination of the use of different grassland types	Complementarity between permanent/temporary meadows of the valleys and natural and semi-natural pastures at high altitudes	Complementarity between (irrigated) lucerne, grazed dry areas, grazed fallows and grazed annual medics or clovers on arable land
• Use of semi-natural grasslands in combination with more intensive grasslands	Vertical transhumance between plains or mountain valleys and summer grazing on alpine pastures	Transhumance between winter and summer pastures
• High diversity of crops and long crop rotations.	Use of temporary grasslands (grass/clover mixtures) in crop rotations to improve fodder quality, reduce nutrient inputs, increase soil fertility, control weeds, disease and parasites in mixed crop-livestock systems	In the Dehesa, use of annual legumes during several years in alternation with cereals
• Integrate trees into silvo-pastoral systems	Integration of trees into silvo-pastoral systems: Park grasslands of Jura grazed by cattle	Integration of trees into silvo-pastoral systems: - Dehesa and Montado grazed and browsed by cattle, sheep and pigs and harvest of cork, fire wood, timber and acorn; - Matorral grazed by goats
Specific resource management in mixed crop-livestock systems		
• Temporary grassland (ley) – crop combination	Integration of temporary grasslands (grass-clover mixtures) in crop rotation including potato and cereals	Integration of irrigated lucerne in crop rotation with maize
• Optimum resource management	Adapted fertilisation of meadows and pastures with on-farm produced manure	Guaranteeing permanent soil cover with low stocking rates in sensitive areas
• Large use of nitrogen fixing legumes	Use of cereal-pea mixtures	
• Orient towards self-sufficiency for fodder	Low purchase of concentrates	
Biodiversity conservation		
• Adapted stocking rates	Plant diversity conservation in pastures and meadows in the Comté cheese production area (Jura region, France)	
• Adapted grazing and re-use of marginal land		Support of goat shepherds in woodlands and matorral for shrub and fire control
• Maintain or establish semi-natural landscape elements		Tree and hedge plantations for animal shelter (e.g. sun)
• Conserve rare or less productive	Sheep breeds: Vicenza,	Sheep breeds: Serrai,

breeds	Cadore and Friuli in Italy; Cattle breed: Ferrandaise in Puy de Dôme, France	Katafigion, Chalkidiki, Roumloukion, Thraki, Argos and Chios in Greece; Cattle breed: Alistana-Sanabresa in Spain
Grassland management		
• Large use of nitrogen fixing legumes		Use of annual medics and clovers for establishing productive pastures
• Adoption of optimum stocking rate	Low stocking rate adapted to grassland growth and inducing efficient lung and livestock internal parasite control	
• Favouring multiple species swards in grasslands	Grazing of species-rich swards in high mountain areas	Grazing of species-rich plant communities
• Use of tannin-rich forbs/legumes/woody species		Use of tannin-rich plants by browsing trees and shrubs improving animal health
Livestock management		
• Integrated disease and parasite control	See above	
• Priority to feed compared to food	Low use of complements (e.g. cereals)	
• Use of locally adapted breeds	Example of cattle breed: Montbéliard in Jura (France)	Example of cattle breed: Avileña – Negra Ibérica in Spain
• Use of modern types of double-goal breeds	Example of cattle breed: Brown Swiss	
Food and food system		
• High quality of products (nutrition, taste)	Very large adoption of grass-based productions Production of high quality cow cheese on farms or in local dairies for short or mid-scale supply chains Examples: - Beaufort cheese in Savoie (France) - Fontina cheese in the Alps of Italy	Very large adoption of grass- and shrub-based productions Production of high quality sheep and goat cheese on farms or in local dairies for short or mid-scale supply chains. Examples: - Roquefort cheese in Savoie (France) - Ragusano in Sicily
• Local dairy and meat product processing	Local dairies and cooperatives for milk collection and processing	
• Adoption or development of quality labels	Large development of quality and geographical origin labels	
• Cooperation, collaboration and development of synergies between farmers, between consumers/citizens and farmers, and between consumers/citizens	Multi-stakeholder cooperation for herbivore farming systems in mountain areas and conservation of cultural landscape for tourism activities	Good cooperation between transhumant herders, municipalities and biodiversity conservation institutions such as parks, forest departments for best management of rangelands (and communal pastures)
Diversification of income sources		
• Product diversification	Combination of cheese making, honey, cooked and/or dried meats, …	
• Diversification of activities	Agri-tourism (e.g. ski, hike)	Agri-tourism (e.g. hunting)

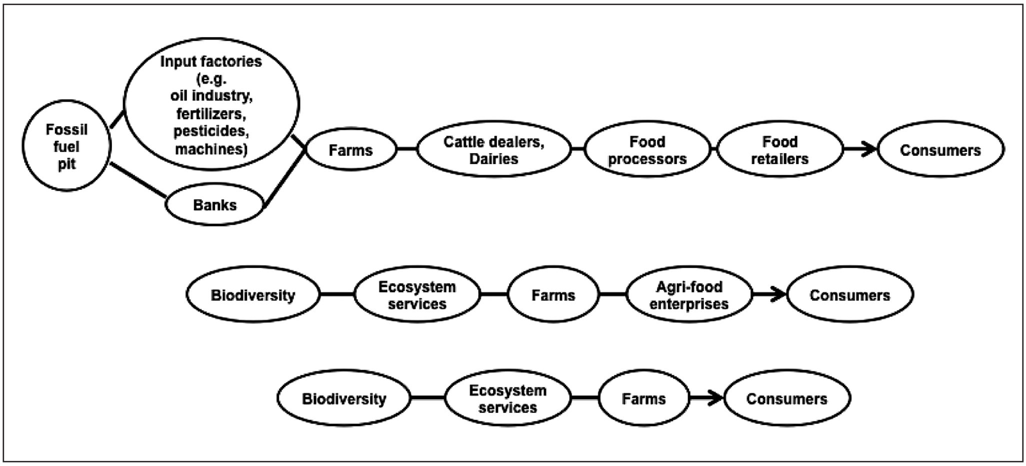

Fig. 5. Industrial (above) and agroecological mid-scale (middle), and short (below) food chains.

VI – Conclusions

The development of sustainable agricultural systems is needed to feed the world but in assuring simultaneously limited negative environmental impacts, and providing economic and social benefits for farmers and other stakeholders. The underlying principles necessary for agroecological herbivore farming systems can be classified into six groups: (i) knowledge, culture and socio-economics, (ii) biodiversity conservation and management, (iii) systems management, (iv) resource management, (v) food and health, and (vi) social relations. The agroecological practices which could or should be implemented to establish sustainable herbivore farming systems and which are based on the above mentioned principles can be grouped into seven categories: (i) diversification of land use, land cover and productions, (ii) resource management in mixed crop-livestock systems, (iii) biodiversity conservation, (iv) grassland management, (v) livestock management, (vi) food and food system, (vii) diversification of income sources. Taking into consideration these principles and the practices which derive from them, the development of agroecological herbivore farming systems can be implemented.

A fast transition from conventional to agroecological systems would require a strong political will, corresponding budgets and a strong involvement of many types of stakeholders: farmers at the first place, and also scientists, teachers of technical schools, farmer's advisers, traders of the food sector. It will require in priority (Peeters *et al.,* 2013):

- new agricultural policies;
- a reform of the training of future farmers, technicians and farmer's advisers in technical schools;
- a reform of the specialization training (master) of agricultural scientists in higher education institutions;
- a restructuration of agricultural research that will define new priorities. The dominance of reductionist research should be inverted at the benefit of holistic and participatory research. In the short term, groups of pilot farmers should be created and associate different types of stakeholders (ex.: holistic researchers, reductionist researchers, farmers' advisers, technical and higher education schools, consumers, nature conservationists).
- a technological revolution for designing and developing agroecological methods and systems, adapting them locally, disseminating them, supporting farmers in their transition period;

- the design of a biodiversity friendly agriculture: the integration of heritage biodiversity enhancement in methods and practices;
- giving priority to agroecological products in school and administration cafeterias (canteens).

Besides changes in policy, budget allocation, and involvement of diverse stakeholders in the development of agroecological herbivore farming systems, also research has an important role to play. Major implications for research would be:

- to have a more systemic approach in taking into account the whole livestock farming system and its location in a socio-technical network of stakeholders and policy frame;
- to reinforce research on use of pastures and rangelands and their integration into herbivore farming systems;
- to broaden research for systematic use of prevention methods for integrated disease and parasite control;
- to take into account biodiversity conservation when developing new practices and adapting farming systems.

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Workshop no. 1

Research contribution to Agroecology

Impact of grazing on the agro-ecological characteristics of a Mediterranean oak woodland. Five years of observations at Monte Pisanu forest

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Abstract. In the Mediterranean areas, silvo-pastoralism represents a territorial management system where trees and shrubs grow together with herbs and where livestock takes advantage on such botanical association. This system still plays an important role for the socio-economic subsistence of rural populations, representing an externality against the progressive abandonment of rural areas. From an ecological point of view, a correct grazing management, related with the potential forage availability and quality, can encourage the conservation of high biodiversity. The forest of Monte Pisanu is a protected area in the Central North Sardinia and represent an interesting example of multifunctional silvo-pastoral management. The aim of this work was to contribute to this management considering, with a five-year experience, the agronomic and ecological value of the site and the impact of grazing on the agro-ecological status of the herbaceous cover. Five years of observation show that grazing activity keeps high biodiversity levels and, on the other hand, negatively impacts the pastoral value.

Keywords. Pastoral value – Specific indices – Grazing – Biodiversity.

Impact du pâturage sur les caractéristiques agro-écologiques d'un bois de chênes méditerranéens. Cinq années d'observations dans la forêt Monte Pisanu

Résumé. *Dans les régions méditerranéennes le sylvopastoralisme représente un système de gestion territoriale où les arbres et les arbustes se développent en association avec les plantes herbacées et où l'élevage profite de cette complexité. Ces systèmes jouent encore un rôle important pour la subsistance socio-économique des populations rurales, ils représentent une externalité contre l'abandon progressif des zones rurales. D'un point de vue écologique, une gestion appropriée du pâturage, liée au potentiel fourrager, à sa disponibilité et à sa qualité, peut encourager la conservation d'une biodiversité élevée, évitant des phénomènes négatifs de sous ou sur pâturage. La forêt de Monte Pisanu est une zone protégée dans le centre nord de la Sardaigne et représente un exemple intéressant de gestion sylvo-pastorale multifonctionnelle. Le but de ce travail était de contribuer à cette gestion, par une évaluation durant cinq ans des valeurs agronomiques et écologiques du site et de l'impact du pâturage sur l'état de la couverture herbacée. Cinq ans d'observation montrent que l'activité pastorale préserve la biodiversité, mais pourrait affecter négativement la valeur pastorale.*

Mots-clés. *Valeur pastorale – Indices spécifiques – Pâturage – Biodiversité.*

I – Introduction

Myers *et al.* (2000) defined Mediterranean basin as one of the main 25 hotspots of Earth biodiversity with over 25,000 vegetal species and 770 vertebrate species. Forests of *Quercus suber* L., *Quercus ilex* L. and *Quercus pubescens* Willd., widespread in the Mediterranean agro-silvo-pastoral landscape, have been forged by the livestock presence and still nowadays play an important role in the socio-economic context. Currently, many inlands are severely concerned by rural abandonment and exposed to changes of their agro-ecological functions. The main objective of this work was to assess the effects of five years grazing exclusion on agro-ecological indicators, such as Shannon Index (SH) and Pastoral Value (VP), in a Sardinian oak woodland.

II – Materials and methods

The trial was carried out during five years (2007-2011) in the Forest of Monte Pisanu (Central Sardinia, Italy), identified as Site of Community Importance (SIC). The vegetation is characterised by *Quercus ilex*, *Quercus pubescens*, *Taxus bacata*, *Ilex aquifolium, Quercus suber* and *Castanea sativa*. In this area, the grazing is rotational heavy for dairy sheep and continuous light for cattle, with an estimated livestock of 650 L.U. per year on a total forest surface of 2,000 ha. Forest grazing is commonly carry out only in less dense or open (gaps, cleared areas), with moderate to heavy stocking rates. Twenty-three representative grazed areas, located between 600 m and 1200 m a.s.l., were identified. Since 2009, a representative fenced area of 4 m x 4 m was identified into each grazed area, to follow the vegetation dynamic of the herbaceous layer in ungrazed conditions. Botanical analyses were carried out both in grazed (G) and ungrazed areas (NG). Vegetation data were collected by applying a point intercept method (Daget-Poissonet 1969) on 2 x 50 m line intersect transects in G (total counts = 200), and on 2 x 4 m line intersect transects in NG (total counts = 40). The surface recorded was about 2500 m^2 per site. For each site was determined the pastoral value (Daget and Poissonet 1969) using the following formula: VP = 0.2 x (Σ SCi x Si), were SCi is the Specific Contribution (%) to single species and Si is the Specific Index (Roggero *et al*. 2002; Cavallero *et al.* 2007). The ecological value was estimated by Shannon Index SH (Shannon, 1948).

III – Results and discussion

Around 200 species were identified over five years, mainly *therophytes*, *hemicryptophytes* and *geophytes*, referable to 34 families, mainly Graminaceae, Leguminosae and Compositae, with high presence *of Asphodelus microcarpus* Salzm. et Viv. and any endemic species as *Armeria sardoa* Spreng, *Bellium bellidioides*, *Oenante crocata* L.*, Paeonia morisii* (Viv.) Cesca, Bernardi et N.G. Passal and *Ptilostemon casabonae* (L.) Greuter.

Shannon index (Table 1) was significantly different between G *vs* NG areas, ranging from 2.49 in mp19 (2008) to 4.77 in mp3 (2007) in grazed areas and from 1.31 in mp14 (2011) to 3.82 in mp18 (2008) in ungrazed areas. Average SH differed significantly among G and NG areas, ranging respectively from 3.7 to 2.7.

Pastoral Value (Table 2) ranged from 8.1 in mp7 (2011) to 44.9 in mp20 (2008) in unfenced areas and from 12.5 in mp7 (2009) to 52.3 in mp22 (2011) in fenced areas showing inter and intra annual statistical significant differences among sites and between G and NG ($p \leq 0.05$) (Table 3).

The highest values of VP were due to the presence of perennial grasses (*Lolium perenne* L, *Dactylis glomerata* L.) and annual legumes (subclovers and medics). According with Alrababah *et al.* (2007), in fenced areas were found a high number of grazing-sensitive groups composed by high palatable species. Moreover, GLM model for SH and VP (year as random variable) exhibit that the two indicators were influenced significantly by locations of sites and grazing regime, while year influenced significantly only VP. Interactions Site x Grazing were significantly different only for SH, showing that the effect of grazing exclusion on species richness had a different impact depending on the site ecological traits. According with Daget and Poissonet (1969) and Daget and Godron (1995), the potential carrying capacity estimated in this silvo-pastoral context ranged between 1.05 LU ha^{-1} $year^{-1}$in more fertile sites and, 0.2 in more marginal sites.

Table 1. Shannon Index (SH) of the 23 observation areas

		2007	2008	2009		2010		2011	
Sites	**m a.s.l.**	**G**	**G**	**G**	**NG**	**G**	**NG**	**G**	**NG**
mp2	1172	4.03	3.13	3.20	2.66	3.56	n.a.	n.a.	n.a.
mp3	1080	4.77	4.06	4.14	1.88	4.07	n.a.	n.a.	n.a.
mp4	1195	4.09	4.02	3.76	2.58	3.93	3.35	3.87	2.88
mp6	946	4.02	4.34	4.49	3.64	4.37	3.03	4.24	n.a.
mp7	1166	3.68	4.04	3.48	2.57	3.44	2.63	3.33	n.a.
mp10	781	4.23	3.95	4.18	3.49	4.34	n.a.	4.01	n.a.
mp13	705	4.20	3.79	4.27	3.46	3.90	2.68	3.73	2.80
mp14	739	3.95	3.58	3.66	1.42	3.57	2.05	3.89	1.31
mp15	683	3.75	4.08	3.64	2.05	3.74	n.a.	n.a.	n.a.
mp17	727	4.38	3.71	3.61	2.03	3.62	n.a.	4.00	n.a.
mp18	693	4.05	4.25	4.63	3.82	4.48	3.76	4.21	n.a.
mp19	670	3.02	2.49	2.65	1.88	3.14	n.a.	3.84	n.a.
mp20	601	4.10	3.72	3.79	2.43	3.93	n.a.	3.57	n.a.
mp21	727	3.72	4.11	3.79	3.34	4.19	2.92	3.97	2.96
mp22	725	3.52	3.49	3.68	3.12	3.17	2.77	3.30	2.82
mp24	736	4.33	3.89	3.77	3.73	3.95	n.a.	4.24	n.a.
mp25	736	3.73	3.44	3.14	2.27	3.63	2.20	3.27	1.48
mp26	722	3.49	3.34	3.53	2.46	3.62	2.16	3.28	2.64
mp27	726	4.07	3.83	3.44	2.68	4.00	2.83	3.56	3.44
mp28	752	3.43	3.90	3.86	3.67	4.00	3.30	3.85	2.79
mp29	697	3.64	4.05	4.04	3.41	4.01	3.35	4.07	3.56
mp30	690	3.49	3.87	3.47	3.33	4.17	3.49	4.48	3.71
mp31	689	3.90	3.63	4.11	2.64	4.37	2.60	3.95	1.99
Average		***3.90***	***3.77***	***3.75***	***2.81***	***3.88***	***2.87***	***3.83***	***2.70***

* NG = Not grazed area, G = Grazed area.

** n.a.= Data not available (stolen or damaged fence).

IV – Conclusions

Monte Pisanu silvopastoral system, based on transhumance as an integral part of the livestock feeding calendar, represents in Sardinia, an example of pacific coexistence between livestock farmers and foresters. The current variable grazing management applied in the observed forest has opposite effects on ecological (Shannon Index) and agronomic value (Pastoral Value) of the pasture vegetation. Higher pastoral values were observed in ungrazed areas, as a consequence of the selective action of variable grazing toward the most palatable species. On the other hand, lower Shannon Indeces were found inside the exclusion cages, pointing out the positive effect of moderate to heavy grazing on biodiversity.

The high variability of pastoral types and their specific livestock carrying capacity suggests an adequate and site-specific grazing management, aimed at combining ecological and productive aspects.

Table 2. **Pastoral Value (VP) of the 23 observation areas**

	2007	2008	2009		2010		2011	
Sites	**G**	**G**	**G**	**NG**	**G**	**NG**	**G**	**NG**
mp2	34.2	33.0	24.3	21.0	30.1	n.a.	n.a.	n.a.
mp3	26.5	32.9	18.8	32.3	28.5	n.a.	n.a.	n.a.
mp4	17.5	20.7	9.8	18.0	22.9	19.3	15.9	41.0
mp6	17.1	19.7	16.8	26.5	17.9	22.5	13.3	n.a.
mp7	13.0	19.9	10.9	12.5	22.5	31.5	8.1	n.a.
mp10	31.9	28.2	27.9	35.3	32.1	n.a.	28.5	n.a.
mp13	28.8	30.9	26.3	37.0	35.1	40.5	29.4	36.0
mp14	25.0	25.2	25.1	22.3	21.5	21.3	17.8	21.5
mp15	38.4	30.6	34.3	37.8	38.1	n.a.	n.a.	n.a.
mp17	34.9	29.6	30.9	35.0	29.7	n.a.	30.0	n.a.
mp18	25.9	28.2	33.7	30.0	38.1	46.3	25.6	n.a.
mp19	23.0	21.7	26.7	22.0	23.5	n.a.	26.7	n.a.
mp20	40.2	44.9	26.8	30.0	41.4	n.a.	38.5	n.a.
mp21	17.9	25.8	19.8	26.8	26.9	37.0	20.8	40.8
mp22	21.5	26.2	22.1	29.8	24.2	42.0	27.9	52.3
mp24	24.9	39.1	26.0	36.0	24.4	n.a.	23.4	n.a.
mp25	19.1	27.1	23.4	17.5	21.6	21.3	25.4	26.5
mp26	27.4	36.0	27.1	37.5	26.9	39.5	29.2	39.5
mp27	17.2	26.0	19.9	25.0	22.7	22.5	24.1	36.5
mp28	24.4	29.2	29.4	31.5	30.4	28.3	26.8	22.8
mp29	16.6	25.5	21.2	28.8	21.9	25.3	23.8	33.8
mp30	22.9	28.1	24.1	24.3	28.1	34.5	27.1	30.8
mp31	23.5	25.4	28.1	30.5	31.0	25.8	24.3	24.8

Table 3. **Analysis of variance for the dataset of 2009, 2010 and 2011 (grazed *vs* fenced areas) – GLM model for VP and SH. C as random variable**

Source	**Df**	**Mean Square**		**F-ratio**		**P**	
		VP	**SH**	**VP**	**SH**	**VP**	**SH**
A: Site	22	137.5	0.9	5.4	10.8	***	***
B: Grazing	1	761.1	28.8	26.3	354.1	***	***
C: Year	2	182.2	0.1	7.3	1.0	***	n.s.
Interaction A x B	22	38.8	0.3	1.6	3.7	n.s.	***

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Investigating genotype by supplementation interaction in an Alpine low-input dairy system

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Abstract. Two contrasting dairy cow types were compared at two different concentrate supplementation levels in an Alpine low-input dairy system. The two genotypes were conventional Brown Swiss (BS) and a specific strain of Holstein Friesian (HFL). The latter was primarily selected for lifetime performance and fitness under low-input conditions. Both genotypes were assigned to one of two concentrate supplementation levels, receiving 635 kg (C) or 277 kg (L) of concentrates per lactation. Until Dec. 2013, 19 and 26 lactations were completed for BS and HFL, resp., and were analysed using a mixed model. There was no evidence for a significant breed by supplementation interaction. Milk and milk solid yields were significantly lower in the L treatment for both breeds, but no significant difference was observed for body condition score or reproductive performance between breeds or supplementation level.

Keywords. Dairy cattle – Pasture – Seasonal – Breed – Supplementation level.

Evaluation de l'interaction génotype x complémentation dans un système d'élevage alpin de vaches laitières à faible niveau d'intrants

Résumé. *Deux types très différents de vaches laitières ont été comparés pour deux niveaux de complémentation en concentrés au sein d'un système d'élevage alpin à faible niveau d'intrants. Les deux génotypes consistaient en la race conventionnelle Brune des Alpes (BS) et une souche spécifique de Holstein Friesian (HFL). Cette dernière a été sélectionnée principalement pour sa longévité et sa capacité d'adaptation à des conditions de bas niveau d'intrants. Les génotypes ont été assignés à un des deux niveaux de supplémentation, recevant 635 kg (C) ou 277 kg (L) de concentrés par lactation. En décembre 2013, 19 et 26 lactations avaient été menées à terme par BS et HFL respectivement. Les données ont été analysées au moyen d'un modèle mixte. Aucune interaction significative entre la race et la supplémentation n'a été détectée. Les rendements en lait et en matière sèche étaient significativement plus bas pour les deux races dans le cas du traitement L. En revanche, aucune différence significative n'a été observée pour la note d'état corporel ou la performance reproductive entre les races ou entre les niveaux de supplémentation.*

Mots-clés. Bovins laitiers – Pâturage – Saisonnier – Race – Niveau de complémentation.

I – Introduction

The technical performance and the economic competitiveness of organic and low input dairy systems depend, among other factors, on the suitability of genotypes for a given environment. Recent studies from Alpine regions indicated that different cow types are likely to differ in their suitability for Alpine pasture-based, seasonal low-input dairy systems (Horn *et al.*, 2013; Piccand *et al.*, 2013). The aim of the present study was to compare the impact of a reduction in concentrate supplementation level on two different dairy cow types within such an Alpine low-input system.

II – Materials and methods

The study was carried out between October 2011 and January 2014 at the experimental organic dairy farm of the Agricultural Research and Education Centre Raumberg-Gumpenstein, Trautenfels, Austria (680 m altitude, 7°C average temperature; 1,014 mm [±63] precipitation year^{-1}).

The two genotypes compared were conventional Austrian Brown Swiss (BS) and a specific strain of Holstein Friesian (HFL). Compared to the Austrian BS population genetic merits of the BS animals included in the study were slightly below average for milk production and slightly above average for fitness. HFL was selected for superior lifetime milk yield and fitness in an alternative breeding programme and was mostly managed under lower input conditions. A detailed description of both genotypes can be found at Horn *et al*. (2013). Until December 2013 data of 19 lactations of 12 individual BS cows and 26 lactations of 18 individual HFL cows were collected.

The two genotypes were assigned to one out of two dietary treatments which differed in concentrate supplementation level (control [C] and low [L]; 11, 10, 14 and 14 lactations in groups BS C, BS L, HFL C and HFL L, resp.). During the barn feeding period both treatments were fed 4.4 kg DM/d of hay and had free access to grass silage. For C daily concentrate supply increased from 2 to 7.5 kg DM from day 1 to 21 in milk (DIM), resp. Between 21 – 35 DIM concentrate supply was maintained at 7.5 kg. Afterwards it depended on milk yield, with cows yielding more than 16 kg receiving 0.5 kg DM of concentrate for every additional kg of milk yield, but with an upper limit of 7.5 kg DM/day. Animals had free access to a continuously grazed sward between Apr. 3 and Oct. 27 and between Apr. 8 and Nov. 5 in experimental years 1 and 2, resp. During the grazing season only animals yielding more than 24 kg received 0.5 kg DM of concentrate for every additional kg of milk yield in the C treatment. The amount of concentrate was reduced by 50% for group L as compared to group C during the whole study period, but formulation and supplementation pattern was the same for both groups.

During the two years of the study calvings took place between Oct. 10 and Feb. 18 and Sep. 26 and Feb. 27, resp. Cows were artificially inseminated at the earliest after 30 DIM.

Individual milk yield was recorded twice daily and milk contents were analysed three times a week. Animals were weighed weekly and body condition scoring (BCS, 5 point scale) was done fortnightly. During the barn feeding period individual rations were provided in calan gates. Feedstuffs were sampled monthly and the results of the chemical analysis are given in Table 1.

Table 1. Nutrient and energy content of grass silage, hay, concentrate and pasture

	Grass silage	Hay	Pasture	Concentrate
DM (g/kg FM)	365 (45.3)†	833 (28.9)	170 (18.2)	866 (9.4)
XP (g/kg DM)	145 (13.1)	135 (11.4)	220 (24.4)	138 (11.4)
NDF (g/kg DM)	458 (31.7)	498 (37.2)	413 (34.2)	189 (26.8)
ADF (g/kg DM)	304 (18.1)	303 (16.0)	259 (29.2)	67 (11.0)
NEL (MJ/kg DM)	6.1 (0.18)	5.6 (0.13)	6.6 (0.29)	8.0 (0.04)

† Standard deviation in brackets.

The data were analysed using a mixed model (SAS 9.1), including the fixed effects of breed (BS and HFL), supplementation level (C and L), year (1 and 2), lactation (primiparous or multiparous) and the interaction of breed and supplementation. To correct for different calving dates during the barn feeding period, the DIM at turn out to pasture was included as a continuous co-variable. Furthermore the animal was included as a random effect and week of lactation was the factor for which measurements were repeated (auto-regressive co-variance structure). Wilcoxon rank-sum test was used to analyse the number of services per cow. Significance was defined at P = <0.05 and the results are presented as least square means and residual standard deviations (s_e).

III – Results and discussion

The results of selected traits of productivity, body weight, body condition and reproductive performance are presented in Table 2. No significant interaction between breed and supplementation level was observed for any of the traits. As intended, the total concentrate supplementation differed (P = <.001) between dietary treatments and was 635 and 277 kg for the C and L, respectively. While length of lactation was not influenced by breed or treatment, milk yield (P = 0.012) and milk solid yield (P = 0.008) were higher for C compared to L. There tended to be a significant interaction of breed and treatment for fat content (P=0.095), which stayed relatively stable for BS, while it increased for HFL when comparing C and L. Protein contents were not influenced by treatment but tended to be higher for BS than for HFL. No differences between breeds or treatments were observed for energy-corrected milk yield per kg of metabolic body weight and somatic cell count. BS was heavier throughout lactation (P = 0.006), while treatment did not affect mean body weight. There were no significant differences between breeds or treatments for BCS at nadir, but BCS at calving was significantly higher for BS than for HFL. Neither days to conception nor number of services per conception were significantly influenced by breed or treatment.

Table 2. Influence of breed and supplementation level on selected traits of productivity, body weight, body condition score and fertility

	BS		HFL		s_e	P_{breed}	$P_{suppl.}$	$P_{breed\times suppl.}$
Trait	Control	Low	Control	Low				
Concentrate consum., kg	664	273	602	282	141.1	0.569	<.001	0.430
Lactation length, d	312	297	296	288	26.6	0.243	0.234	0.617
Milk yield, kg	6,235	5,537	5,802	5,343	573.7	0.390	0.012	0.538
Milk solid yield, kg	456	396	419	388	42.0	0.376	0.008	0.320
Fat content,%	4.13	4.11	4.29	4.44	0.901	0.031	0.248	0.095
Protein content,%	3.45	3.39	3.31	3.29	0.195	0.095	0.122	0.458
ECM yield/kg $BW^{0.75}$, kg/d	0.14	0.13	0.15	0.14	0.032	0.249	0.153	0.707
Somatic cell count, n/ml	82,313	75,238	101,660	95,764	27,479	0.164	0.414	0.941
Body weight, kg	602	608	549	551	40.5	0.006	0.743	0.866
BCS at calving	3.41	3.45	3.13	3.27	0.313	0.020	0.333	0.563
BCS at nadir	2.29	2.26	2.28	2.30	0.179	0.862	0.931	0.673
Days to conception, d	79	68	81	78	33.9	0.646	0.539	0.708
Services per conception, n	1.6	1.4	1.4	1.6	–	0.861	0.893	–

Varying responses to concentrate supplementation between dairy cows with different genetic merits were reported previously (Yan *et al*., 2006). Comparing milk yields during lactation and concentrate consumptions, milk yield increased by 1.8 kg and 1.4 kg per additional kg of concentrate for BS and HFL, respectively, which is slightly higher than reported by Delaby *et al*. (2009). The higher conversion efficiency might be explained by the differences in supplementation strategies, as in the present studies cows were mainly supplemented during the first third of lactation. However, in contrast to the study of Horan *et al*. (2005) neither in the present paper nor in the study of Delaby *et al*. (2009) a significant interaction between genotype and supplementation level for milk and milk solid yield over the entire lactation could be found. This might be explained by the smaller differentiation of supplementation in the present study as compared to Horan *et al*. (2005), 356 kg versus 950 kg of concentrates, respectively, as the presence or absence of a genotype by environment interaction mainly depends on the degree of difference between genotypes or environments (Hammami *et al*., 2009). The slightly higher protein content of BS compared to HFL was reported in a previous study comparing both genotypes in a pasture based dairy system and reflects the different selection focus (Horn *et al*., 2013). In contrast, the higher fat content of HFL, especially in the L treatment, does neither agree with the genetic predisposition of HFL nor with the results of the study mentioned above. A slightly higher body condition of BS compared to Holsteins under predominantly grazing condition was already reported by Piccand *et al*. (2013) as well as the lack of an interaction between breed and supplementation level for other body condition variables by Delaby *et al*. (2009). The lack of influence of concentrate supplementation on the course of body condition score seems to be in agreement with the comparable reproductive performances in both treatments. However, the similar reproductive performance does not reflect the breed differences in genetic merit for fertility. Compared to an earlier study, reproductive performance of HFL was observed on a similar level, while a considerably longer calving to conception interval was reported for BS (Horn *et al*., 2013). However, due to the relatively low number of animals conclusions on reproductive performance must be done with caution.

IV – Conclusions

There were no significantly different reactions to the reduction of concentrate supplementation observed for the both genotypes compared. This might be due to the relatively small differences between supplementation levels in the present work, compared to other studies with a similar scope. However, the results indicate that the reduction of concentrate supplementation in a pasture based milk production system does not necessarily have a negative impact on the course of body condition score.

Acknowledgments

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Analysis of the feed self-sufficiency as indicator of the durability of the *Majorera* breeding goat systems in the Canary Islands

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Abstract. The *Majorera* goat is a native breed of the Canary Islands and an excellent milk producer whose production is associated with the protected designation of origin "Majorero Cheese". Although its origin arises from Fuerteventura Island, it is the most extended goat breed in the entire archipelago, exerting a very important function from a social, economic and environmental point of view. With a focus on the environmental indicators, the present work aimed to study how the feed self-sufficiency degree of farms contributes to their sustainability. Data from a sample of 38 farmers were treated by a multivariate analysis (SPSS V.21.). The different kinds of production, availability of pasture and fodder crops, as well as their influences on the sustainability of the systems were studied. This work concluded that systems with a higher use of available feed present a higher total sustainability. Equally, the most intensive systems are more vulnerable in terms of sustainability and they do not always seem to have the greatest degree of profitability.

Keywords. Dairy goats – Multivariate analysis – Sustainability.

Analyse de l´auto-suffisance alimentaire comme indicateur de la durabilité des systèmes d´élevage de la chèvre « Majorera » dans les îles Canaries

Résumé. *La chèvre Majorera est une race originaire des îles Canaries et une excellente productrice de lait dont la transformation est associée à l'appellation d'origine protégée « fromage Majorero ». Même si son origine provient de l'île de Fuerteventura, c'est la race caprine la plus répandue dans l'ensemble de l'archipel, exerçant une fonction très importante d'un point de vue social, économique et environnemental. En mettant l'accent sur des indicateurs environnementaux, ce travail vise à étudier la façon dont le degré d'autosuffisance alimentaire des fermes contribue à leur durabilité. Les données d'un échantillon de 38 agriculteurs ont été traitées par une analyse multivariée (SPSS V.21.). Les différents types de production, la disponibilité en pâturages et en cultures fourragères, ainsi que leur influence sur la durabilité des systèmes ont été étudiés. Ce travail a conclu que les systèmes avec une plus grande utilisation des aliments disponibles présentent une durabilité totale plus élevée. De même, les systèmes les plus intensifs sont plus vulnérables en termes de durabilité et ils ne semblent pas toujours avoir le degré de rentabilité le plus élevé.*

Mots-clés. *Chèvre laitière – Analyse multivariée – Durabilité.*

I – Introduction

Majorera goat is an autochthonous Spanish breed from Fuerteventura Island (Canary Islands) with excellent adaptation to the semi-arid environment characteristic of its region of origin. It is the goat breed with the larger census in the whole archipelago (represents 70% of total count). Adding to this, there exist the possibility to transform the milk into a widely recognized quality cheese, the Protected Designation of Origin (PDO) "Majorero Cheese". These facts allow the *Majorera* goat to gain a special place for the local development, not only in economic terms but also in the social and environmental areas. A recent study on the characterization of the *Majorera* goat sector within the Canary Islands (Navarro *et al.*, 2011) showed that an important amount of goat producers were also making cheese, and this situation helped them to increase considerably their income due to the added value associated to the selling of cheese, largely contrasting with those producers of goat meat. Besides this, many of the goat-and-cheese producers were selling directly their products, thus increasing the return margin and consolidating their enterprises. However, that study proved that these goat-and-cheese producers were spending a lot of money in feeding costs, since, in spite of the great potential in natural pastures and agricultural land to feed the animals, they put their trust in intensive production systems, heavily depending upon great amounts of subsidized imported feedstuffs. With this background, this study aimed to show how the feeding self-sufficiency indicators of the goat and milk production systems in the Canary Islands have an important role in the measuring of the degree of sustainability, and also to make evident how the utilization of the available natural resources where these enterprises are located can be the key factor to end up this significant weakness of the goat production sector.

II – Materials and methods

Details on the initial census prior to the beginning of the study, the survey design, sampling procedures and data collection, can be found in Navarro *et al.* (2011). Field work was undertaken in 2009.

The different variables for analysis considered in this article refer to the following information groups: (i) technical indicators related to the flock, (ii) technical indicators related to the territorial base, and (iii) productive and economic indicators. The design of the survey was based on the most recent progress obtained from the methodology established by the FAO-CIHEAM sub-network on production systems for sheep and goats, related to the utilization of technical-economic indicators for the analysis of small ruminant's production systems (Toussaint *et al.*, 2009). A multivariate statistical analysis was conducted with the numeric variables, preceded by a factorial analysis of principal components (PCA). The method for sample suitability was Kaiser-Meyer-Olkin (KMO), and the Varimax orthogonal rotation was applied. Factorial numeric results were calculated by K-means cluster analysis in order to classify groups of producers according to the considered variables, and finally, once the groups of producers were established, an analysis of variance (ANOVA) was performed to identify those significantly different ($P<0.05$). Statistical analyses were done using IBM SPSS v.21 software.

III – Results and discussion

The PCA yielded four principal components (PCs) that explained 75.35% of variance. Table 1 shows the principal components selected. Based on the correlations between the PCs and the original variables, their interpretation is as follows: PC 1 is an indicator of land extension associated to farming activities; PC 2 is an indicator of cheese-making activities; PC 3 informs about those farms that do not produce cheese but utilize natural pastures for animal feeding; and PC 4 is an indicator of those farms that grow grass to feed the animals. It is noteworthy to say that the variable feeding cost-per-goat per-day does negatively correlate with those indicators related to the use of land to feed the animals. On the contrary, it correlates positively with the indicator of farms producing cheese (PC 2). From the resulting factors it can be deducted that the aspect related with cheese-making, and the aspect of land area and its use, are the fundamental aspects that differentiate the distinct groups of farmers in this study.

Table 1. Principal components (PCs) selected, the explained and accumulated variances, and squared multiple correlation coefficients of the indicators with the different PCs

	Explained variance %	Accumulated variance %	Indicators and correlations with the PC	
PC 1	25.186	25.186	Rented land (ha)	0.993
			Total area per goat	0.976
			Cereal crops total area	0.986
			Daily feeding expenses per goat (€)	-0.463
PC 2	19.924	45.110	Goat cheese (kg)	0.778
			Cheese sales income (%)	0.909
			Daily feeding expenses per goat (€)	0.490
PC 3	17.168	62.278	Natural pasture area (ha)	0.964
			Meat sales income (%)	0.542
			Daily feeding expenses per goat (€)	-0.521
PC 4	13.074	75.352	Cultivated pasture area	0.925
			Daily feeding expenses per goat (€)	-0.498

These factors were utilized in the present study to classify the simple of farmers in groups. Two of them were obtained: Group 1 (14 farmers) clearly gathers the cheese-making enterprises. These farmers stake for an intensive production model which makes them heavily dependent to the acquisition of imported feedstuffs, in spite of having natural pastures and the possible (but discarded) utilization of cultivated pastures. On the other hand, as it is shown in Table 2, farmers in Group 2 have their major income from the sales of milk. The table shows those variables that resulted significantly different between both groups, except for the variable ‘total natural pasture area’, with a large but not significant difference. Because of these significantly different variables, it is possible to identify that those farmers who do not make cheese are cultivating pastures to feed the animals, which in turn significantly brings down the feeding costs, in contrast with the cheese-making farmers.

Table 2. Means and significance levels (ANOVA) of the quantitative variables by farmer group

Variables	Group 1 (n = 14)		Group 2 (n = 24)		Signif.
	Mean	SD	Mean	SD	
Cultivated pasture area (ha)	0.00	0.00	0.03	0.05	0.050†
Milk income (%)	2.49	8.22	65.91	45.89	0.049†
Cheese income (%)	60.91	41.90	6.80	25.46	0.000†
Daily feeding expenses per goat (€)	0.40	0.28	0.09	0.18	0.000†
Natural pasture area (ha)	2.02	5.58	15.70	30.38	0.070

† $p \leq 0.050$.

It can be established, then, that the main weakness factor within the *Majorera* goat and cheese farm-operations in the Canary Islands, these being the most cost-effective enterprises because of the cheese sales income, is precisely the elevated cost of feeding that they need to afford. Besides, this situation makes these farmers highly vulnerable to sudden increases in the cost of feedstuffs, due to market impacts or to the end of subventions. The utilization of direct marketing channels for the sale of cheeses gives these farmers an edge to stabilize their enterprises and to increase their self-esteem (Bernués *et al.*, 2011); moreover, feed self-sufficiency can be a help for uncertain and volatile markets. Also, low off-farm input dependence (variable costs per animal) and enhanced feed self-sufficiency is crucial for labour profitability for animal farming of autochthonous breeds in less favoured areas (Ripoll-Bosch *et al.*, 2013).It is therefore, the policy to intensify the farm operations, and the lack of use of natural resources that do exist in the environment for pasture or for cultivation of animal feedstuffs, send them away of a true sustainability strategy that could be solved with the promotion of agricultural policies which would turn around these tendencies by promoting the utilization of the natural resources.

IV – Conclusions

Majorera goat and milk operations that also make cheese are the larger proportion of farmers, and they obtain the best results represented by a larger income per-goat and per-year. Many of them sell their products directly, which in turn gives them an even larger profit margin and converts them into a group of successful and more consolidated farmers with greater expansion possibilities. However, as it is shown in the results of this study, their production model is clearly oriented to intensification, making them heavily dependent upon the purchasing of feedstuffs or the acquisition of subsidized feeds for the animals coming from the Continent. This situation significantly increases the feeding costs, as compared with those farmers which make use of their natural resources to cultivate all or part of the feeding requirements. This circumstance turns the meat and cheese farms into very vulnerable operations in the face of very fluctuating feeding costs.

As it can be expected, the possibility for the subvention policies to change by reducing or eliminating such grant to the import of conserved feedstuffs is not foreseen, and thus the risk of speculation with the price of imported feedstuffs from the Continent will continue. In spite of the subvention granted to the import of conserved feedstuffs from the Continent, results of the present study show that there exists a significant difference in feeding costs in favour of those farmers with a large territorial base which utilize their natural resources to feed their animals, which in turn means that there is great potential for the availability of pasture and crop land to feed the flocks. This is why the authors suggest that the subventions to the milking-goat sector should be always headed to the promotion in the utilization of natural and local resources where these operations are found, with the objective to reduce or even to eliminate the large vulnerability within the meat-and-cheese operations, which affects their cost-effectiveness. In this way, there would be large and beneficial synergies within the livestock-environment systems, as a result of the natural resources being put to the service of livestock development, and this in turn favouring the conservation of the natural environment, with a long term benefit to the sustainability of the rural areas.

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Applying agroecological principles to redesign and to assess dairy sheep farming systems

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Abstract. In Roquefort-cheese region, a few farmers' groups are increasing grazed resources in the ewe diet to reduce cost and to improve the efficiency of the farms. A project between researchers and dairy sheep farmers was developed to analyse innovative livestock farming systems and to understand how farming management integrates the agroecological principles. Twenty-seven farmers' interviews about practices, farming management, animals' performances and economic results were carried out and analysed. Four types of farming management were described based on (i) the duration of milking period and the supplementation of the flock, (ii) the diversity of resources, (iii) the genetic gains use. The practices identified can be linked to the agroecological principles. They are implemented by farmers to reach a compromise between three targets: productivity, self-sufficiency and economic efficiency. This study highlighted these practices as levers for action used by farmers to increase their farm's adaptability. Results could be used to design and to assess new farming systems.

Keywords. Agroecology – Livestock farming system – Feed self-sufficiency – Diversity – Milk ewe.

Appliquer les principes de l'agroécologie pour reconcevoir et évaluer des systèmes ovins-lait

Résumé. *En zone Roquefort, quelques groupes d'éleveurs envisagent d'accroître les ressources pâturées dans l'alimentation des brebis pour réduire les coûts de production et améliorer l'efficacité des élevages. Un projet de recherche associant chercheurs et éleveurs a été développé pour analyser des systèmes d'élevage innovants et pour expliquer comment leur fonctionnement intègre les principes de l'agroécologie. Vingt-sept enquêtes menées auprès d'éleveurs sur leurs pratiques, le fonctionnement de l'élevage, les résultats zootechniques et économiques ont été analysées. Quatre types de fonctionnement ont été décrits sur la base de (i) la durée de lactation et la complémentation de l'alimentation du troupeau, (ii) la diversité des ressources, (iii) l'utilisation du progrès génétique. Les pratiques identifiées peuvent être directement reliées aux principes agroécologiques et leur mise en œuvre par les éleveurs conduit à des compromis entre trois objectifs « productivité » - « autonomie » - « efficience économique ». Cette étude montre que les pratiques sont des leviers d'action mobilisés par l'éleveur pour accroitre les capacités d'adaptation de l'élevage. Ces résultats pourraient être utilisés pour concevoir et évaluer des élevages agroécologiques.*

Mots-clés. *Agroécologie – Système d'élevage – Autonomie alimentaire – Diversité – Lait de brebis.*

I – Introduction

The intensification of livestock production and the development of larger and more specialized farm units have resulted in a decrease in grassland use (Kristensen *et al.,* 2005), including in mountain and less favoured areas (Quetier *et al.,* 2005). Such a model of development based on agriculture intensification weakens the sustainability of farms and jeopardise their adaptation to global change (Darnohfer *et al.,* 2010; Tichit *et al.,* 2011). Agroecology is a theoretical and conceptual framework suggested to address the challenges of global change adaptation of agricultural systems: on one hand to increase and on the other hand to secure food production (Gliesman, 1998; Altieri, 2002). Agroecology involves (i) designing farming systems based on biological regulations and interactions between the components of the farm, (ii) increasing local feed resources and self-sufficiency for inputs, and (iii) working with local actors (farmers, farm advisors,…). Altieri (2002) proposed five agroecological principles based on key ecological processes to (re)design sustainable crop systems. The transposition of these principles to design livestock systems (Dumont *et al.,* 2013) and integrated crop-livestock systems (Bonaudo *et al.,* 2013) is recent. However two main limits must be noticed about these studies: (i) these principles differently described by authors are not clearly linked to farmers' practices and the whole farm management; (ii) these principles do not suggest elements to analyse, to re-design and to assess the farms. Thus, to support the agroecological transition of farms, critical issue is to turn these principles into operational levers for action usable by farmers to re-design their livestock farming system. Based on a participatory approach with dairy sheep farmers, the aim of this study is to translate agroecological principles into levers for action. Firstly these levers for action must be directly linked with the farmers' management practices and secondly they must be used to assess the farm's performances. In this paper, we focus on (i) our approach to build a research project intended to testing innovative sustainable practices, (ii) the diversity analysis of some innovative farming systems and (iii) the farm assessment through agroecological properties.

II – Methodology

1. A participatory research with a group of dairy sheep farmers seeking alternative practices

The research project takes place in southern France where is produced the Roquefort cheese. This PDO[1] cheese is made with raw ewe's milk, traditionally sheep grazed local grassland regarded as less-favoured pastures (dryness in summer and cold weather in winter). To overcome the constraints of the area, for many years the milk production has increased the food purchases and inputs in farms. Until the year 2000 the intensification has increased forages harvested use to the detriment of grazing. A wide gradient of resources are used by farmers (Thénard *et al.,* 2013), mainly intensive meadows. Therefore to limit the development of this intensive farming model, the PDO specifications have included new requirements. Since 2000, ewes should be fed with forage coming for 75% from the PDO area and ewes should graze two or three months during the grazing period.

In this region, the farms' economic performances are directly depending on fluctuations in input prices and climate variability. In such a context, for a few years, groups of farmers have shared perspectives and ideas to test innovative sustainable practices to improve their farms adaptability. We worked with one of these farmers' group (composed of 10 farmers) and supported by a farm advisor. These farmers called themselves "Economical and Locally grown Farms[2]" (ELF): they seek to use the local forage resources and to reduce farm input requirements. The research project was built to analyse their innovative sustainable practices.

2. Methods to analyse the diversity of farming systems in an agroecological perspective

The project employed agroecology framework, and was carried out in two steps. The aim of the first one was to translate agroecological principles into levers for action. That means we should draw a comparison between the principles of agroecology, the farmers' practices and the objec-

[1] Protected Designation of Origin.
[2] Elevages Economes et de Terroir.

tives of production in the farmers' group. During two work sessions, farmers, advisors, and researchers have shared different points of views about the practices used to explain three notions "self-sufficiency farming", "economical farming", and "local grow farming". Finally, the knowledge shared has permitted to identity three levers for action linked with the principles of agroecology: (i) Managing diversity, (ii) Renewing resources, and (iii) Limiting inputs (Fig. 1).

The aim of the second step was to use these levers for action to describe the diversity of innovative dairy sheep farms and to assess their performances in an agroecological perspective. We used three agroecological properties: "self-sufficiency" as the synthesis of balance between flock-fed-needs and farm-fed production, "productivity" as the synthesis of the animal performances, "efficiency" as the synthesis of economic results. During spring 2013, semi-directive interviews were carried out among 27 farmers. Farmers surveyed were those of the "ELF" group and about 20 farmers who were identified by farm experts as seeking to increase input self-sufficiency (SSF) and/or to improve local natural resources use (LRF). Interviews focused on farmers' flock and forage management practices. Data about animal performances and economic results were also gathered from respectively milk recording and farm management centres.

Data were analysed with a method to classify the diversity of farmers' practices (Girard, 2006). We built a set of variables and their modalities based on the diversity of the farmers' practices and we classified them according to the levers for action identified in step one. We used a Multivariate Component Analysis (MCA) and Clustering method (CAH) on this set of variables to perform livestock management patterns. Principal Component Analyses (PCA) were performed to identify groups from animal performances and economic results. All statistical analyses were computed with the FactoMineR-Package of R software (R Core team, 2012).

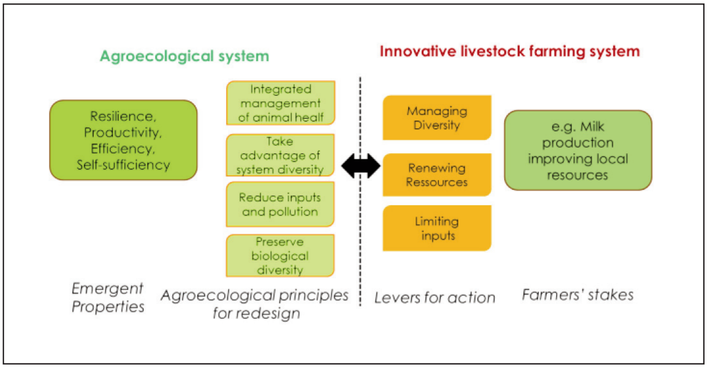

Fig. 1. Translation of agroecological principles into levers for action.

III – Results and discussion

Ten practices were identified. They concern flock management and genetic selection, grassland organisation or animal feeding. Respectively, three and four of them referred to the levers for action "Managing diversity", "Renewing resources" and "Limiting inputs" (fig. 2).

The diversity of practices was structured by MCA on three major axes (50% of inertia). The first one (22%) compared flocks based on a short milking period (less than 6 months) and feed based on grown farm forages *vs* flocks based on a long milking period (between 6 and 8 months) and feed based on forage and concentrate purchases. The second one (14%) compared forage systems with a large diversity of resources and flock based on natural service *vs* forage systems with limited diversity and flocks based on artificial insemination. The third one (13%) compared farmers using “milk yield” as single selection criteria and indoor management for young ewes *vs* farmers using various selection criteria and outdoor management for young ewes.

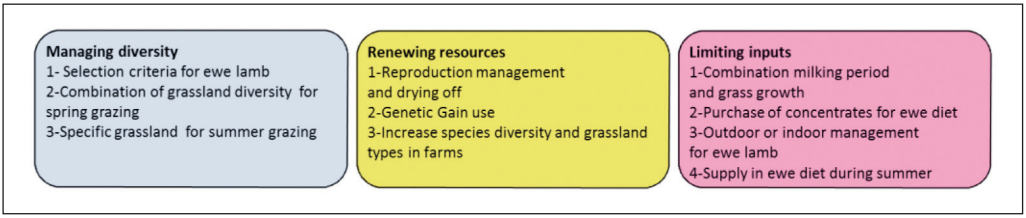

Fig. 2. Classification of the farmers’ practices among the three levers for action to develop agroecological livestock systems.

Four types of dairy sheep farming systems were identified by (CAH): **Economical and Locally grown Farming:** a short length milking period (average 5 months) during the grazing period (including summer); local and natural resources use and limitation of inputs. **Intensive Farming:** a short length milking production during spring; selection based on milk yield; sown pasture use and concentrates purchase. **Organic Farming:** Milk production during the grazing period; local resources with a large diversity of grassland; concentrates purchase with protein content. **Alternative Farming:** a long length milking production during the grazing period (including summer); a large diversity of forages and grazed resources combined with concentrates purchase.

Based on the PCA, the four types of farming management could be assessed according to three properties selected: self-sufficiency, productivity and efficiency. The four farming management types could be analysed as various combinations to reach a compromise between three targets: productivity, self-sufficiency and economic efficiency. Diversity is an important way to increase efficiency. The Organic Farming type could increase the efficiency with a higher milk-price. Intensive farming has a high productivity but efficiency is limited because of higher costs. Finally, alternative farming, under the study conditions (availability of grazing resources), reaches the higher productive and efficient values.

IV – Conclusion

This work is the first stage to design and to assess new farming systems based on agroecological properties. In further work, self-sufficiency will be studied with more attention including from the agronomical and environmental aspects. Farms will be especially regarded through the concept of resilience.

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Workshop no. 2

Challenges and perspectives for research on Mediterranean grasslands

Trade-offs between stocking rate, forage properties and livestock performance in a Mediterranean grassland

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Abstract. Livestock management on Mediterranean rangelands is commonly determined by a combination of trial and error, accumulated experience and standards adopted by the herder. High grazing pressure creates a complex management challenge not only on the forage quality and range performance, but also on the economic consequences of the herder. The constantly changing availability and quality of the pasture that determines both the nutritional intake of the grazing animals and the role of supplementary feeding, create trade-offs between the multiple responses of the vegetation, the livestock and the cost/benefit ratio of the grazing enterprise. The aim of this study was to improve economic and environmental grazing management while quantifying the trade-offs of the system that can contribute to accomplish this goal. A long-term grazing trial was conducted on a Mediterranean species-rich hemicryptophytic grassland. Two stocking rates including moderate (M, 0.55 cows ha^{-1}) and high (H, 1.1 cows ha^{-1}) and two management protocols, continuous and split were examined. Heavier stocking reduced both standing biomass at the end of the growing season and grazing duration during the subsequent dry season but increased the weaned live-weight production per unit area, the amount of supplementary feed consumed, and the number of grazing days per unit area. Quantification of these trade-offs can guide the management of stocking rate and grazing protocol of the herd within the economic context of the grassland-livestock system.

Keywords. Beef cattle – Continuous grazing – Herbaceous biomass – Split-paddock grazing.

Compromis entre le chargement au pâturage, la valeur alimentaire des fourrages pâturés et la performance de bovins allaitants sur un parcours herbacé méditerranéen

Résumé. *La conduite du bétail sur les parcours herbacés méditerranéens est généralement déterminée par une combinaison d'empirisme, d'expérience accumulée et des standards acceptés par l'éleveur. Dans le cas d'un chargement au pâturage élevé, la conduite est complexe car, en plus des conséquences économiques, le chargement affecte la dynamique de croissance, la composition botanique et la qualité nutritionnelle de la prairie. Les changements du couvert végétal et de sa composition affectent la consommation d'herbe et la complémentation et obligent à des compromis entre les performances du bétail, celles de la prairie et le bilan économique de l'exploitation. La quantification de ces compromis peut aider à mettre en œuvre des modes de conduite plus performants. Un essai sur le long-terme a été mené dans ce but, pour caractériser les effets d'une augmentation du chargement. Un chargement élevé réduit la biomasse en fin de saison et la longueur de la saison de pâturage en période sèche mais accroit le poids de veaux sevrés par hectare, la quantité de complémentation apportée et le nombre de journées pâturées par hectare. En quantifiant ces données, on peut optimiser le chargement dans le contexte économique du système bovin allaitant.*

Mots-clés. *Bovins allaitants – Pâturage en continu – Biomasse herbacée – Pâturage en prés fractionnés.*

I – Introduction

Livestock management on Mediterranean rangelands is commonly determined by trial and error, by accumulated experience or by standards adopted by the herder. These methods are usually sufficient where the range is the only source of nutrition for the livestock during the grazing season. However, supplementary feeding has become increasingly common as a means for improving the productivity of rangeland-based livestock systems. This, and rangeland degradation, add a complicating factor to range management but also raises the possibility of increasing the stocking rate and changing the timing and duration of grazing. With higher stocking rates, the impact of grazing on the pasture vegetation and the amount of supplementary feeding increases. In addition to the economic consequences, it influences the vegetation growth dynamics, the botanical composition and nutritional quality of the pasture. The constantly changing availability and quality of the pasture that determine both the nutritional intake of the animals and the role of supplementary feeding, create trade-offs between the multiple responses of the vegetation, the livestock and the cost/benefit ratio of the grazing enterprise. Quantifying the trade-offs can contribute to more effective enterprise management.

In eastern Mediterranean grasslands that are dominated by annual species, the strongly seasonal pasture cycle is characterized by a mild, rainy winter-spring growing season and a hot and dry summer-autumn season. It is difficult to determine the optimal stocking rate over the large area required to maintain viable herds because it is influenced not only by the prevailing climatic factors but also by the vegetative composition of the range and the complex habitat characteristics (Seligman and Van Keulen, 1989). These factors are essential in the analysis of herd management decisions, especially where supplementary feeding interacts with other elements of the production system. Appropriate stocking rates under such conditions are dependent not only on the productivity of the pasture vegetation and the supplementary feeding protocol but also on the response of vegetation and livestock to grazing pressure and timing. Change in the standing biomass of a growing sward depends on the balance between the rate of pasture growth and the rate of forage consumption by the grazing herd (Noy-Meir, 1975). Deferment of heavy grazing at the beginning of the growing season to ensure undisturbed pasture establishment has been shown to prevent a fall to a low stable equilibrium (Gutman *et al.*, 1999). The aim of the current study was to quantify the trade-offs in the multiple responses of pasture growth, performance of the grazing livestock and amount of consumed supplementary feed to relatively high stocking rates in a predominantly annual Mediterranean rangeland.

II – Materials and methods

The experiment was conducted during the years 1994-2010 at the Karei Deshe experimental farm, located in the eastern Galilee, Israel (long. $35^{0}35'$E; lat. $32^{0}55'$N; altitude 60-250 m a.s.l.). The topography is hilly and the landscape is covered with basaltic rocks. The vegetation is a species-rich hemicryptophytic grassland dominated by *Hordeum bulbosum* L., *Echinops viscosus* DC., *Bituminaria bituminosa* L., and many annual species (Sternberg *et al*., 2000). The area has a Mediterranean climate, characterized by wet, mild winters and hot dry summers with an average seasonal rainfall of 560 mm, falling mostly in winter and spring. The study included different grazing scenarios based on two stocking rates and two management protocols: continuous grazing (C) of a single paddock throughout the grazing season, and a split-grazing (S) protocol with animals being moved between multiple paddocks. Grazing was deferred in all paddocks during the initial growth period. The two stocking rates were moderate (M, 0.55 cows ha^{-1}) and high (H, 1.1 cows ha^{-1}). In the split-grazing protocol the paddocks were divided into two equal sub-paddocks. Grazing began in one sub-paddock early (E) in the growing season after deferment of grazing, then the herd was moved to the second un-grazed sub-paddock later (L) in the grazing season when the amount of standing biomass was reduced to a level that subjected the herd to nutritional stress. When grazed, the stocking density was high (1.1 cows·ha^{-1}) in the grazed sub-paddock of the moderate split-paddock and very high (2.2 cows·ha^{-1}) in the heavy split-paddock treatment. The two stocking rates (M, H) and two grazing management protocols (C, S) constituted four main grazing treatments (MC, HC, MS, HS). All treatments were replicated twice. The paddocks were stocked with mature, medium-frame Simford (Simmental × Hereford) crossbred cows. At weaning, the cows and calves were weighed and in September the pregnancy of each cow was determined.

The standing biomass in the paddocks was estimated. The harvested plant material was oven-dried at 65°C and weighed. The biomass was sampled every year at the beginning of grazing (January-February), at the peak of vegetation growth (April), at the end of the abundant dry pasture in early summer and the beginning of supplementary feeding (June), and at the conclusion of the grazing season (August-September). During the green season and the beginning of the dry season, the pasture was the only feed source of the experimental herds. During the later dry pasture period in summer the herds were given *ad lib* access to supplementary feed, mainly poultry litter.

III – Results and discussion

Grazing started at the end of the deferment period and ended at the beginning of autumn when the dry pasture biomass was grazed down to between 55 and 116 g m^{-2} (Fig. 1). At the moderate stocking rate, the herds were on the pasture for almost 280 days of the year and at the heavy stocking rate, just over 200 days (Table 1).

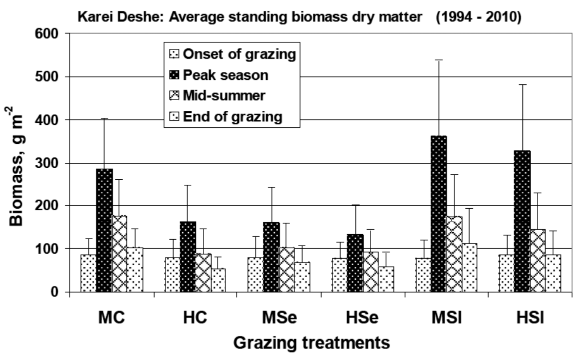

Fig. 1. Standing biomass in the moderate and heavy continuous stocking rate treatments and in the sub-paddocks of the split paddock grazing protocol (Averages and standard deviations, 1994-2010). (Main treatments: MC – moderate continuous, HC – heavy continuous; Sub-paddocks: MS_E – heavy early, HS_E – very heavy early, MS_L – heavy late, HS_L – very heavy late).

The average long-term green standing biomass when the herds entered the paddocks was between 71 and 84 g m^{-2}. Subsequently, the amount of standing biomass reflected the grazing pressure imposed on the different paddocks (Fig. 1). The standing biomass in the continuously grazed paddocks (MC and HC) was inversely proportional to the stocking rates. Adding the biomass consumption by the herd to peak biomass gave 17-year average primary production between 219 and 397 g m^{-2}. The amount of poultry litter consumed was clearly related to the stocking rate and to the availability of dry pasture biomass during the late summer. Even though the animals at the heavy stocking rate were on pasture for a shorter period, the consumption of supplementary feed per head was 64% higher (Table 1). The live-weight of the cows and their conception rates were higher in the split grazing treatments but the differences were relatively small so stocking rate had an overwhelming, almost proportional effect on weaned live-weight per unit area of pasture: the weaned calf production was 87-89 and 41-46 kg ha^{-1} at the high and moderate stocking rates, respectively (Table 1).

Table 1. Pasture utilization, supplementary feed consumed, live-weight, conception rate and weaned calf production of herds in the different experimental treatments (Average ± S.D.)

Treatment	MC	MS	HC	HS
Days in treatment paddocks	279 ± 19	277 ± 18	198 ± 26	205 ± 27
Grazing days per hectare	156 ± 10	168 ± 29	223 ± 28	233 ± 60
Supplementary feed (kg day^{-1})	4.4 ± 2	4.5 ± 2	7.9 ± 2	6.7 ± 3
Cow live-weight on entry (kg)	429 ± 30	448 ± 25	421 ± 19	430 ± 28
Conception rate (%)	73 ± 13	76 ± 13	70 ± 6	78 ± 5
Weaned calf production (kg ha^{-1})	46 ± 12	41 ± 7	89 ± 17	87 ± 17

Under continuous grazing the herd could be maintained on pasture from the end of the early season deferment period until the end of the growing season at both the moderate and heavy stocking rates. The biomass was lower under heavy grazing both at the peak of the growing season and at the end of the dry season (Fig. 1). Nevertheless, the seed production that dispersed early in the dry season was evidently enough to allow the pasture to become established in the following year. The live weight of the cows at weaning and the weaning rates were higher in the split paddock protocol. The relative similarity in animal performance between treatments is related to the *ad lib* access of the herds to supplementary feed when the dry pasture was insufficient to maintain the performance of the herd in summer. A consequence of this procedure was an almost doubling of the weaned live weight production under the heavy stocking rate, albeit at a higher cost of supplementary feed.

IV – Conclusions

When pasture is the main stay of the herd and must supply feed for as long as possible during the year, both the grazing deferment period and the shorter grazing duration at the higher stocking rate exact a heavy cost in additional supplementary feed. The trade-offs between the larger herd required to increase stocking rates, the shorter grazing season and the heavier cost of supplementary feeding must be weighed against the higher animal production per unit area. Different combinations of stocking rate and grazing duration are possible with little effect on the persistence of the pasture vegetation. The practical implications of the trade-offs that were observed in this trial depend on a combination of the grazing strategy of the herd owner and economic context that includes the price of weaned live weight, the cost of supplementary feed and the fixed and variable costs related to rangeland ownership and management. However, under current prices of weaned live-weight and supplementary feed, the heavier stocking that increases the utilization of the pasture when it is at its highest nutritive value is found to be the more profitable use of the vegetation, but it is very sensitive to climate and economic hazards.

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Methane production from the rumen fermentation of Algerian Acacia tree foliage

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Abstract. The present study was carried out to determine the *in vitro* methane production from the rumen fermentation of Acacia tree leaves (*Acacia nilotica, A. cyanophylla, A. albida, A. horrida* and *Albizia julibrissin*) and its reduction by the addition of a tannin-blocking agent (polyethylene glycol, PEG). Gas production was determined when foliage from the five plant species was incubated in diluted rumen fluid for 6, 12, 24 and 48 h, and methane was measured after the incubation at 24 h. The incubations were conducted either without or with the addition of the tannin binder polyethylene glycol (PEG-6000). This has been considered a bioassay of tannin activity, represented by the increase in gas (methane) production upon the addition of PEG (i.e., when tanning are neutralized). The ratio +PEG/-PEG (in total gas production) was highest for *A. nilotica* (2.23 and 1.75 at 12 h and 24h), followed by *A. cyanophylla* (1.73 at 48 h), reflecting the high amount and biological activity of tannins in these plants. PEG addition increased methane production for all the *Acacia* species, thus confirming that tannins in these samples affected methanogenesis. An increase in total volatile fatty acid concentration in samples with addition of PEG was observed only with *A. nilotica* and *A. cyanophylla*. Tannins contained in these plants could be of interest to reduce methane production, providing that other parameters of ruminal fermentation were not inhibited.

Keywords: Rumen – Acacia – Tannin – Polyethylene Glycol – Methane.

Production de méthane issue de la fermentation de feuilles d'acacias collectées en Algérie

Résumé. *La présente étude a été réalisée pour déterminer la production de méthane* in vitro *à partir de la fermentation de feuilles d'acacias* (Acacia nilotica, A. cyanophylla, A. albida, A. horrida et Albizia julibrissin*) dans le jus rumen d'ovins et l'effet inhibiteur des tannins sur cette production par l'ajout d'un agent de blocage des tanins (Polyéthylène Glycol - PEG). Les plantes contenant des tannins ont la propriété de réduire la production de méthane. La production de gaz et de méthane a été déterminée en incubant le feuillage de ces cinq espèces végétales dans du jus de rumen dilué pendant 6, 12, 24 et 48 h. Pour l'estimation de l'activité biologique des tannins, les essais d'incubation ont été réalisés soit en additionnant du polyéthylène glycol (PEG) - 6000 (+PEG) soit sans (- PEG). La neutralisation des tannins, après addition de PEG, a eu pour conséquence l'augmentation de la production des gaz (méthane). Le ratio +PEG / -PEG (dans la production de gaz total) le plus élevé a été enregistré chez* A. nilotica *(2,23 et 1,75 à 12 h et 24 h), suivi par* A. cyanophylla *(1,73 à 48 h), ce qui indique que le feuillage de ces deux espèces végétales est riches en tannins biologiquement plus actifs. L'ajout de PEG a augmenté la production de méthane pour tous les Acacia spp., confirmant que les tannins contenus dans ces échantillons affectent la méthanisation. L'augmentation de la concentration en acides gras volatils totaux dans les échantillons après addition de PEG est observée uniquement avec* A. nilotica *et* A. cyanophylla. *Les tannins contenus dans ces plantes pourraient être d'un intérêt pour réduire la production de méthane, dans la mesure où la fermentation ruminale de ces aliments n'est pas inhibée.*

Mots-clés. *Rumen – Acacia – Tannins – Polyéthylène Glycol – Méthane.*

I – Introduction

Methane emission from ruminants has received special attention because of its contribution to the greenhouse effect and global warming. Methane emitted from ruminant livestock, beyond being a contributor to global warming, entails a loss of feed energy of about 2 to 12% (Johnson and Johnson, 1995) that would otherwise be converted into meat and/or milk.

Nevertheless, methane is a key rumen fermentation end product, and its production is necessary to maintain anaerobiosis in the rumen environment. Understanding why and how methane is produced in the rumen, and its implications to ruminal fermentation, is required before proposing any measure to control its production (Bodas *et al.,* 2012). In this context, plants and plant extracts with high concentrations of secondary compounds appear to be potential candidates for reducing ruminal methanogenesis, without impairing or even enhancing rumen fermentation. Thus, some authors have suggested that tannins, present in the foliage of some Acacia species, may reduce protein degradation in the rumen when used at moderate doses of 20-45 g/kg diet (Min *et al.,* 2003).

The objective of this study was to evaluate the effect of foliage from five *Acacia* spp., rich in condensed tannins, collected from Algerian arid and semi-arid areas, on ruminal gas production and methanogenesis. An *in vitro* gas production bioassay (tannin bioassay) was used to assess the potential biological effect of tannins by incubating tree foliage with and without tannin-binding PEG.

II – Materials and methods

Foliage from five *Acacia* species (*Acacia nilotica*, *Acacia horrida*, *Acacia cyanophylla*, *Acacia albida*, *Albizia julibrissin*) was collected from Algerian arid and semi-arid areas and analysed as described by Bouazza *et al*. (2012). Phenolic compounds were extracted following the procedures described by Makkar (2003). Analytical methods for chemical composition, phenolics and tannins were those described in detail by Bouazza *et al*. (2012).

Three mature Merino sheep fed Lucerne hay (body weight 49.4 ± 4.23 kg) fitted with a permanent ruminal cannula (60 mm diameter) were used for the extraction of rumen fluid. The experiment was designed as a tannin bioassay based on *in vitro* incubations of tannin-containing plant materials with and without polyethylene glycol (PEG) during 48h in buffered rumen fluid (Makkar *et al.,* 1995, Ammar *et al*., 2004). The volume of gas produced in each bottle was recorded at 6, 12, 24 or 48 h after inoculation time, using a pressure transducer. Volatile fatty acids (VFA) were determined by gas chromatography using crotonic acid as the internal standard (Ottenstein and Bartley, 1971). Methane content in fermentation gas was determined according to López and Newbold (2007). Two ways analysis of variance was performed with *Acacia* species and the presence of PEG as the two sources of variation (fixed effects) and source of inoculum (random effect) as a blocking factor.

III – Results and discussion

The chemical composition, phenolic and tannin content of the browse material used in the study have been reported elsewhere (Bouazza *et al*., 2012). The high levels of condensed tannins observed in Acacia leaves are in agreement with values reported by other authors (Rubanza *et al.,* 2005).The concentration of phenolic compounds in the foliage material showed considerable variation among species. These differences may be due not only to plant species, but also to harvest season and plant maturity stage (Makkar, 2003). Leaf samples of *A. albida* were harvested in the late rainy season of May, whereas *A. nilotica* was harvested in autumn. A high proportion of TCT was recovered as FCT, which may be responsible for the possible adverse effects of condensed tannins on microbial fermentation in the rumen (Barry and McNabb, 1999).

Table 1 shows the effect of including PEG during the *in vitro* incubation of *Acacia* species. Polyethylene glycol inclusion increased significantly ($p<0.05$) cumulative gas production of two substrates, *A. nilotica* and *A. cyanophylla*. The greatest and significant ($P<0.05$) response to PEG was recorded after 12 h incubation with *A. nilotica* (a 2.2 fold increase). The PEG-gas production bioassay is not intended to quantify accurately or to characterize the tannins in animal feedstuffs. It does provide, however, an interesting assessment of the biological effects of tannins on depressing ruminal fermentative activity, and allows identification of plant species containing tannins with greater amounts of active anti-nutritional compounds.

Table 1. Polyphenolics content (g/kg DM, standard equivalent) and effects of PEG on cumulative gas production (ml/g) ay 6, 12, 24 and 48 h of incubation and on volatile fatty acids (VFA) and methane production (CH_4) after 24 h incubation

	Species	*A. nilotica*	*A. horrida*	*A. cyanophylla*	*A. albida*	*A. julibrissin*	S.E.M
TEP		213	99	205	31	105	
FCT		609	386	451	26	502	
TCT		726	476	631	60	587	
G6	+ PEG[1]	47.3^{a}	33.3^{a}	44.5^{a}	16.9	43.1	4.62
	- PEG[2]	27.4^{a}	54.6^{a}	39.7	19.9	50.9	4.70
G12	+ PEG	120.6^{ax}	116.8^{a}	103.1^{ax}	51.9^{b}	112.0^{a}	7.65
	- PEG	54.0^{by}	101.9^{a}	59.9^{by}	35.7^{b}	92.2^{a}	7.08
G24	+ PEG	160.5^{ax}	160.1^{a}	140.3^{ax}	73.0^{b}	159.2^{a}	9.95
	- PEG	91.6^{by}	147.2^{a}	$84.0b^{cy}$	53.7^{c}	135.0^{a}	9.63
G48	+ PEG	182.5^{ax}	191.9^{a}	164.7^{ax}	83.6^{b}	189.7^{a}	11.56
	- PEG	118.6^{by}	169.1^{a}	95.4^{bcy}	58.3^{c}	163.0^{a}	11.57
VFA	+ PEG	0.426^{ay}	0.388^{a}	0.385^{ay}	0.195^{b}	0.452^{a}	0.030
	- PEG	0.240^{bx}	0.387^{a}	0.173^{cx}	0.164^{c}	0.410^{a}	0.035
CH_4	+ PEG	0.748^{ay}	0.771^{ay}	0.733^{ay}	0.307^{by}	0.794^{ay}	0.061
	- PEG	0.458^{bx}	0.560^{ax}	0.283^{cx}	0.173^{dx}	0.451^{bx}	0.046
CH_4 Increase		0.290	0.211	0.450	0.134	0.343	

TEP: Total extractable phenols; FCT: Free condensed tannins; TCT: Total condensed tannins. [1] Incubated with polyethylene glycol. [2] Incubated without polyethylene glycol. $^{a, b, c, d,}$ means in a the same row with different superscripts are significantly different ($P<0.05$); $^{x, y}$ means in the same column with different superscripts are significantly different ($P<0.05$). SEM: Standard error of the mean.

The effect of *Acacia* species on total volatile fatty acid (VFA) and methane production is presented in Table 1. Molar concentrations of ruminal VFA were affected by the addition of PEG treatment only when *A. nilotica* and *A. cyanophylla* were incubated ($P<0.05$). However, PEG affected methane production for all substrates ($P<0.05$), which may indicate that reduced methane production is a consequence of reduced gas production and not of reduced methane proportion in the gas produced. The greatest CH_4 increment was observed with *A. cyanophylla* (0.450 mmol/g MS) and the lowest was noted in *A. albida*. These results probably reflect the different levels and biological activity of CT in the species studied (Min *et al.,* 2003). Methane production from ruminal fermentation has been decreased up to 50% in response to tannin (Patra and Saxena, 2010; Goel and Makkar, 2012; Bodas *et al.,* 2012). Condensed tannins have a direct toxic effect on methanogens (Bodas *et al.,* 2012). As it can be seen, high amounts of tannin in substrates are able to reduce methane production in the rumen, but this effect is linked to a depressed rumen fermentation and reduced gas and volatile fatty acid production. It is known that high dietary concentrations of condensed tannins can reduce voluntary DM intake and digestibility and thus negatively affect animal performance and may even possibly be toxic (Barry and McNabb, 1999; Min *et al.,* 2003). However, these secondary compounds offer the possibility of being used as additive to decrease CH_4 productions (Patra and Saxena, 2009).

IV – Conclusions

The results from these experiments highlight the potential of tannins from *Acacia* species to reduce methane emissions from ruminants. However, besides their positive effects, tannins exert a powerful inhibition effect on rumen fermentation (i.e. depressing gas and volatile fatty acid production) that must be considered before making practical recommendations, especially on the level of inclusion of this roughage in the diets of ruminants.

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Changing farm management practices using lucerne for sheep grazing

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Abstract. The climate in the central South Island region of New Zealand is the hottest (maximum temperature +35°C), coldest (minimum temperature -20°C) and driest (300-400 mm annual rainfall) environment in New Zealand. Lucerne (*Medicago sativa*) has been part of the forage resource in this environment for many years. It has been used for conservation to help fill the feed deficit of a 120 day winter feeding period. Recent research into the agronomy and management for the effective grazing of lucerne has provided evidence to support significant changes in the way lucerne is used in these environments. These changes can create major increases in net income if the farming systems adapt to capture those benefits. An on-farm deliberative learning and demonstration programme was instigated to assist farmers understand and implement a lucerne grazing programme to increase farm productivity and profitability. The process and outcomes of this programme are described in this paper.

Keywords. Lucerne – Sheep – Grazing systems – Management – Agronomy.

Changer les pratiques de gestion agricole en utilisant la luzerne pour le pâturage des moutons dans des environnements difficiles

Résumé. *Le climat dans la région centrale de l'île Sud de la Nouvelle-Zélande crée le milieu à la fois le plus chaud (température maximale 35°C), le plus froid (température minimale de -20°C) et le plus sec (300-400 mm de précipitations annuelles) de la Nouvelle-Zélande. La luzerne (*Medicago sativa*) fait partie des ressources fourragères dans ce milieu depuis de nombreuses années. Elle a été utilisée en fourrage conservé pour aider à combler le déficit fourrager durant les 120 jours d'alimentation hivernale. Les recherches récentes sur l'agronomie et la gestion efficace du pâturage de la luzerne ont fourni des preuves à l'appui de changements importants dans la façon dont la luzerne est utilisée dans ces milieux. Ces changements peuvent créer d'importantes augmentations du bénéfice net si les systèmes agricoles s'adaptent pour saisir ces avantages. Un programme de formation et de démonstration participatif en ferme a été initié pour aider les agriculteurs à comprendre et à mettre en œuvre des modalités de pâturage de luzerne qui augmentent la productivité agricole et la rentabilité. Le processus et les résultats de ce programme sont décrits dans le présent document.*

Mots-clés. *Luzerne – Ovins – Systèmes de pâturage – Conduite – Agronomie.*

I – Introduction

Recent developments of the understanding of the growth pattern of lucerne, responses to defoliation and interactions with root reserves have created new opportunities for grazing (Moot *et al.*, 2003). An increase in the understanding of the water use efficiency (Brown *et al.*, 2005) and interactions with nitrogen (Moot *et al.* 2008) has enabled more accurate prediction of the responses of various forages to available soil water. This has increased the ability to predict responses and develop high performing lucerne grazing systems (Kearney *et al.*, 2010; Stevens *et al.*, 2012).

The major opportunity from these studies is to utilise lucerne during spring through grazing. Lucerne is a reliable forage source for lactating ewes to increase milk production or lamb growth rates during spring, providing a more reliable supply of milk or output of finished lambs from weaning onward. This also releases significant areas of pasture on the farm for conservation or other uses during the spring. Knowledge was required to ensure the provision of winter feed, decide how much of the farm could be planted in lucerne and how lucerne grazing would integrate with the wider farm system.

Currently, farms in the Central Otago region of New Zealand use lucerne on soils with low soil moisture holding capacity. Soils with greater soil moisture holding capacity are used for pasture, and are more likely to be irrigated. Traditionally lucerne has been used for conservation to provide one or more harvests per annum to help fill the significant winter feed deficit. These areas of lucerne may also be used for lamb finishing during the autumn if summer rainfall allows regrowth. This use of lucerne in Central Otago has relegated it to a forage crop for hay making, with occasional grazing which has restricted its potential and the related opportunity of sheep grazing systems in this environment.

An on-farm deliberative learning and demonstration programme to assist farmers understand and implement a lucerne grazing programme to increase farm productivity and profitability was done over 3 years (Stevens *et al*., 2012). This paper outlines the development of the lucerne sheep grazing system in the central South Island region of New Zealand and includes feed planning and spring sheep performance and whole farm impacts on productivity and income.

II – Materials and methods

A grazing planner was used to assist with the grazing management of individual farm lucerne grazing as the area sown in lucerne, and its planned use, differed between each property.

Calculations used a soil water budget and published lucerne growth rates (Kearney *et al*., 2010) and soil water use efficiency (Brown *et al*., 2005) to estimate lucerne growth. Feed requirements were calculated including the intake of both the ewe and the lamb. Allowance was calculated using an utilisation factor of 85%. Flock size and stocking rate were then determined. Actual herbage disappearance was calculated by difference between pre- and post-grazing lucerne herbage mass and expressed per ewe grazing.

Previously defined grazing management rules (Moot *et al*., 2003) were applied and grazing was scheduled to begin when an initial lucerne sward height reached 15 cm (approximately 1200 kg DM/ha in local conditions). All of the available forage was assumed to be grazed. The area was then allocated as 6 equal sized paddocks as per recommendations to create a grazing rotation of approximately 42 days, with up to 10 days grazing in any single paddock and a regrowth period of 32-35 days. Graziers recorded the actual grazing outcomes to compare with the plan. Final stocking rates and lamb growth rate was recorded over the period from 4 to 12 weeks of age.

Finally, one of the farms within the demonstration group was used as a case study to document the changes in productivity and income when lucerne grazing was implemented at a whole farm scale over 5 years.

III – Results and discussion

An example of a grazing plan and the actual on-farm outcome are presented in Table 1. The simple grazing planner, using local knowledge, provided a starting point for the grazing management that was finally applied. Adjustments were made by the grazier as the amount of forage varied due to paddock sizes and lucerne growth rate, resulting in the recorded variations. Some yield potential was lost as the grazing began at a later date than proposed, with more forage available than predicted. This led to paddocks later in the rotation reaching peak yield before the grazing took place. It also meant that one paddock (paddock 5) had to be conserved before grazing, leading to a low available forage yield at grazing. These variations are often encountered due to the variable nature of the environment.

Table 1. An example of a calculated simple grazing plan for lucerne and the actual on-farm records that resulted

Predicted grazing plan	Pdk 1	Pdk 2	Pdk 3	Pdk 4	Pdk 5	Pdk 6
Grazing area (ha)	6.7	6.7	6.7	6.7	6.7	6.7
Grazing time (d)	6.4	7.1	7.8	8.5	9.3	10
Forage yield (kg DM/ha)	1200	1423	1671	1943	2240	2565
Allowance (kg DM/ewe/d)	2.8	3	3.2	3.4	3.6	3.8
Actual grazing programme						
Date in	15 Nov.	23 Nov.	2 Dec.	10 Dec.	17 Dec.	27 Dec.
Grazing area (ha)	6.0	6.0	6.5	6.5	14.0	15.0
Grazing time (d)	8	9	8	7	10	9
Lucerne height (cm)	20	25	30	30	6	20
Forage yield (kg DM/ha)	1780	2225	2670	2670	534	1780
Herbage disappearance (kg DM/ewe/d)	1.9	2.7	4.5	5.3	1.6	5.7
Stocking rate (ewes/ha)	65	65	60	60	28	26

The average feed allowance of the ewes and lambs was calculated as 3.3 kg DM/d. The actual disappearance of herbage, estimated from grazing records, was 3.6 kg DM/d. The live weight gain of the lambs (Table 2) was approximately 311 g/d, lower than the predicted gain of 350 g/d. However, the ewes also gained approximately 1 kg live weight over that time. Stocking rate, lamb live weight gain and weaning weight were all significantly higher on the lucerne, leading to an increase in lamb production of 250 kg/ha (Table 2).

Table 2. The comparative performance of ewes and lambs grazing dryland pasture or pure lucerne during spring in Central Otago (mean of 2 years and 9 farms)

	Dryland pasture	Lucerne
Ewe stocking rate (ewes/ha)	3.0	10.0
Lamb growth rate (g/d)	264	311
Lamb weaning weight (84 days of age)	28.5	31.1
Lamb production (kg live weight/ha)	108	358

The next step considered how the lucerne fitted in to the farm system beyond spring. A case study of one of the farms within the project (Table 3) outlines the increases in stock numbers, reductions in ewe deaths and increase in lambs sold prime, at greater carcass weights. An increase in gross income from sheep sales of $97,336 was achieved for an expenditure of $13,510. This expenditure included the costs of tactical irrigation to secure winter crop yields and the maintenance cost of the lucerne forage programme.

Farmer uptake of grazing lucerne as a technology has been significant both within this region and throughout New Zealand as a result of this and other projects. Estimates of seed sales suggest that approximately 7,000 ha of new lucerne plantings have been established per annum over the past 5 years.

Table 3. A case study of whole farm performance when shifting from the conservation of lucerne to the implementation of a lucerne grazing programme

Year		2008	2013
Farm size (ha)		950	950
Lucerne area (ha)		23	100
Ewes	Number	2500	3100
	Death rate	9%	3%
	Ewes sold	475	857
Lambs	Total numbers	2625	3410
	Retained for replacements	700	950
	Number sold prime	960	2460
	Number sold store	965	0
	Carcass weight (kg)	15.5	17.2
Gross income from sheep sales at 2013 prices		$176,731	$274,067
Extra costs associated with lucerne		–	$13,510

IV – Summary

Key to successful lucerne grazing systems are planning, understanding the agronomics of the plant and the influence of grazing and adherence to the rules for grazing. The demonstration of improved sheep performance at both a paddock scale provided confidence for the use of more lucerne. The final demonstration of an increase in net whole farm revenue from case studies has assisted the use of lucerne beyond the farmers in the project. National sales indicate that uptake of lucerne as a grazing option has been widespread.

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Vegetative development, blooming and chemical composition of some Algerian populations of sulla

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Abstract. As part of the assessment of plant genetic resources of fodder and pastoral interest in Algeria, ten populations of sulla (*Hedysarum coronarium* L.) were taken into account. The vegetative development, the blooming and the chemical composition corresponding to the second year of the growth of this biennial plant, were studied. Several parameters (vegetative development, blooming, green matter, mineral matter, organic matter, crude fiber, fat, total nitrogen, calcium, phosphorus, neutral detergent fiber, acid detergent fiber, lignin, hemicellulose) were analyzed. Two ecological factors (altitude, rainfall) of the natural habitat of the populations were also considered. For two variables (total nitrogen, NDF), the analysis of variance showed a significant variation within the populations of sulla. Many significant relations were also found, especially between the variables linked to the chemical composition of the plant. The populations characterized by a weak vegetative development came from the high altitude areas. The cluster analysis highlighted the established variation and its interest in a future selection program.

Keywords. Chemical composition – Fodder legume – *Hedysarum coronarium* – Nutrient contents – Sulla.

Développement végétatif, floraison et composition chimique de quelques populations algériennes de sulla

Résumé. *Dans le cadre de l'évaluation des ressources phytogénétiques d'intérêt fourrager et pastoral en Algérie, dix populations de sulla (*Hedysarum coronarium *L.) ont été considérées. Le développement végétatif, la floraison et la composition chimique relatifs à la seconde année de croissance de cette plante bisannuelle, ont été étudiés. Plusieurs paramètres (développement végétatif, floraison, matière verte, matière minérale, matière organique, cellulose brute, matière grasse, azote total, calcium, phosphore, NDF, ADF, lignine, hemicellulose) ont été analysés. Deux facteurs écologiques (altitude, pluviométrie) de l'habitat naturel des différentes populations ont été pris en compte. Pour deux variables (azote total, NDF), l'analyse de variance a montré une variation significative chez les populations de sulla. Plusieurs relations significatives ont été indiquées, notamment entre les variables relatives à la composition chimique de la plante. Les populations caractérisées par un développement végétatif faible, proviennent des régions de forte altitude. L'analyse hiérarchique a mis en relief la variation établie et son intérêt dans un futur programme de sélection.*

Mots-clés. *Composition chimique –* Hedysarum coronarium *– Légumineuse fourragère – Sulla – Teneur en nutriments.*

I – Introduction

Hedysarum coronarium L., commonly called sulla, is a forage legume in some Mediterranean countries. Through the North East of Algeria, this plant was encountered at variable altitudes and relatively variable rainfall (Issolah *et al*., 2012). It is also an interesting plant for the fight against erosion of steep slopes on which this species is frequently observed. This work enters in the framework of the characterization of plant genetic resources of fodder and pastoral interest in Algeria. It completes the study carried-out on the same populations of sulla, during the first year of the growth of this biennial plant (Issolah *et al.,* 2014).

II – Material and methods

Following a study conducted on some Algerian populations of sulla during the first year of the growth (Issolah *et al*., 2014), ten Algerian populations were subjected to a trial on the vegetative development, blooming and chemical composition during the second year of the growth of the plants. A randomized complete block design with four replicates was used. The texture of the soil was silty clay. The pH was alkaline (8.17). The annual rainfall was 818.2 mm (2011/2012) and average temperatures of the year were 22.34°C (average maximum) and 13.83°C (average minimum), respectively. The plots did not receive N-P-K fertilization before sowing. We surveyed the following parameters: maximum height (MH in cm), maximum width (WM in cm), date of appearance of the first inflorescence (1F, number of days after sowing). Following the cut at blooming stage (cutting date: CD, number of days after the sowing), several analyses were performed: weight of green matter (GM, g/m^2), mineral matter (MM), organic matter (OM), crude fiber (CF), fat (F), phosphorus (P), calcium (Ca), total nitrogen (N), acid detergent fiber (ADF), neutral detergent fiber (NDF), lignin (ADL) and the hemicellulose (Hcell). All the results related to chemical composition are expressed in percent of dry matter (DM) (ISO, 2009). The data obtained (40 for each variable) were analyzed using Anova, Pearson correlation, and cluster analysis. For the two last analyses, two variables describing the ecological conditions of natural habitats of the populations were added (altitude, rainfall). Statistical analyses were performed using the software Minitab (2003).

III – Results and discussion

The analysis of variance indicated that two variables (N and NDF) were significantly different among populations (Table 1). Correlation highlighted also several significant relations between the different variables, especially those linked to chemical composition (Table 2). Concerning the links with the ecological factors, we noted that the populations characterized by a weak vegetative development came from high altitude areas ($P<0.001$***). It also seems, at this stage, that the others variables and the ecological factors were not linked. Through the cluster analysis applied on all variables (vegetative development, blooming, chemical composition, ecological factors), the variation is clearly established at 70% of similarity (ten different groups of populations). Six groups were obtained at about 40% of similarity. All populations seem to have about 30% of similarity only, which is relatively weak (Fig. 1). Thus, the existing variations among populations could be used for a future selection program. Overall, the results showed significant differences within the populations of sulla during the second year of the growth (cut at blooming). The results obtained during the first year of the growth (cut at the beginning of the blooming) indicated that the differences were more pronounced at that period (first year) for several parameters (Issolah *et al*., 2014). Moreover, nitrogen (N) was negatively correlated to the maximum height of plants (Issolah *et al*., 2014) whereas, it was linked only with crude fiber (CF) in the case of the present study (second year). We noted also that the content of N was relatively higher during the first year of the growth of Sulla (Issolah *et al*., 2014) as compared to the second year of the development of this biennial plant.

Table 1. Analysis of variance (ANOVA) of parameters linked to the vegetative development, blooming, and chemical composition (second year of growth)

Parameters	Min	Max	Mean	F observed	*P*
MW (cm)	77.2	166.4	131.5	1.64	0.153
MH (cm)	16.3	42.8	29.05	1.02	0.448
1F (days)	491.8	506	499.32	1.23	0.319
CD (days)	503.3	521.8	512.55	1.26	0.303
GM (g/m^2)	706.7	4974.8	2438.54	1.23	0.317
MM (% DM)	10.5	15.6	12.76	1.68	0.142
OM (% DM)	84.4	89.5	87.24	1.68	0.142
N (% DM)	5.5	11.1	6.77	3.82	**0.003****
CF (% DM)	11.4	15.5	13.75	0.76	0.655
F (% DM)	1	1.5	1.26	0.91	0.530
Ca (% DM)	0.8	1.9	1.44	1.39	0.239
ADF (% DM)	21.4	24.1	22.63	1.54	0.183
NDF (% DM)	30.6	35.6	33.33	2.46	**0.034***
ADL (% DM)	11.5	14.4	12.56	1.49	0.201
Hcell (% DM)	7.6	13.8	10.69	2.09	0.067

Min: mean minimum of populations; Max: mean maximum of populations; Mean: mean of the populations. Probability: *P<0.05, **P<0.01. MH : maximum height ; MW: maximum width ; 1F: date of appearance of the first inflorescences ; CD: cut date ; GM: weight of green matter/m^2 ; MM: mineral matter ; OM: organic matter ; CF: crude fiber ; F: fat ; Ca: calcium ; N: total nitrogen ; ADF : acid detergent fiber ; NDF : neutral detergent fiber ; ADL: lignin ; Hcell : hemicellulose.

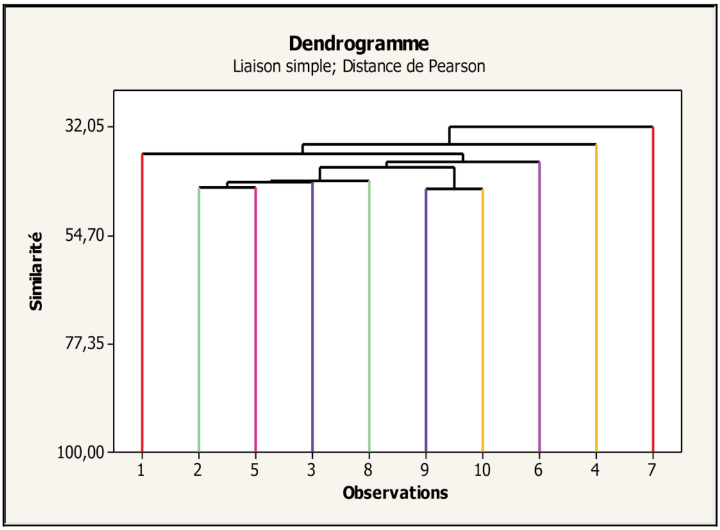

Fig. 1. Cluster analysis of ten Algerian populations (observations) of sulla based on the vegetative development, blooming, chemical composition, and ecological factors (second year of growth).

Table 2. **Correlations between the parameters linked to the vegetative development, blooming, chemical composition and ecological factors (second year of the growth)**

Parameters	MH	1F	MM	OM	TN	CF	F	NDF
CD	NS	0.840**	NS	NS	NS	NS	NS	NS
OM	NS	NS	-1.000***	–	NS	NS	NS	NS
Ca	NS	NS	0.814***	-0.814**	NS	NS	NS	NS
N	NS	NS	NS	NS	–	-0.641*	NS	NS
ADL	NS	NS	NS	NS	NS	NS	0.806**	NS
Hcell	NS	NS	NS	NS	NS	NS	NS	0.875***
R	NS	NS	NS	NS	NS	NS	NS	NS
ALT	-0.882***	NS	NS	NS	NS	NS	NS	NS

Values of r are reported in the cells only when significant. Probability: *P<0.05, **P<0.01, ***P<0.001 ; NS: not significant.

MH: maximum height ; 1F: date of appearance of the first inflorescences ; CD: cut date ; MM: mineral matter ; OM: organic matter ; CF: crude fiber ; F: fat ; Ca: calcium ; N: total nitrogen ; NDF: neutral detergent fiber ; ADL: lignin ; Hcell: hemicellulose ; R: rainfall ; ALT: altitude.

IV – Conclusion

The study of the vegetative development, blooming and chemical composition of some Algerian populations of Sulla permitted to note a variation in certain parameters during the second year of growth. Except the relationship established between vegetative development and altitude, it seems that the chemical composition and the ecological factors of the different populations were linked. Further investigations on a larger number of populations, at different phenological stages, would improve the knowledge on the nature of the variability within the features of this biennial or short perennial plant.

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Workshop no. 3

Challenges and perspectives for research on *Mountain* pastures and product quality

Livestock farming systems in the eastern Italian Alps: Ecosystem services and product quality

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Abstract. This paper analysed the trends of the livestock sector in the eastern Italian Alps, and then examined different case studies focusing on the possible strategies to generate added-value for local products and on the ecosystems services provided by mountain farms. In the last twenty years the number of livestock farms has decreased (-38%), while the average herd size has increased. Alpine summer farms decreased less, but showed a radical change in livestock and especially pasture management. Since only the maintenance of a territorial network of traditional cattle farms is able to contrast the abandoning of grasslands, this evolution resulted into an important reforestation of permanent meadows and pastures (–18%), which host a rich plant and animal biodiversity. In many areas, extensive farms have to deal with constraints and opportunities of the Natura 2000 network, and are increasingly exposed to conflicts with wildlife. An important role for the valorization of traditional and low input livestock farms is played by recognition of products quality [e.g. Protected Designation of Origin (PDO) label, and Slow Food presidia]. In addition, the evaluation of livestock farms sustainability in mountainous areas should also take into account their ecosystem services, for which specific indexes are needed.

Keywords. Livestock farms – Eastern Italian Alps – Products quality – Ecosystems services.

Les systèmes d'élevage dans la partie orientale des Alpes italiennes: services écosystémiques et qualité des produits

Résumé. *Cet article analyse les tendances du secteur de l'élevage dans les Alpes italiennes orientales et examine différentes études d'une part, sur les stratégies possibles pour générer une valeur ajoutée pour les produits locaux et d'autre part, sur les services d'écosystèmes fournis par les exploitations de montagne. Au cours des vingt dernières années, le nombre de fermes d'élevage a diminué (-38%), tandis que la taille moyenne des troupeaux a augmenté. Le nombre de fermes Alpines d'été a moins diminué, mais elles ont connu un changement radical dans l'élevage du bétail et en particulier dans la gestion des pâturages. Étant donné que seul le maintien d'un réseau territorial de fermes bovines traditionnelles semble en mesure de ralentir l'abandon des prairies, cette évolution a conduit à un important reboisement permanent des prés et des pâturages (-18%), qui sont les habitats préférés des nombreuses espèces de haute valeur naturelle. Un rôle important pour la valorisation des fermes d'élevage traditionnelles est joué par la reconnaissance et la valorisation économique de la qualité des produits (par exemple par l'étiquette appellation d'origine protégée AOP et le Convivium Slow Food). En outre, l'évaluation de la durabilité des fermes d'élevage dans les zones montagneuses devrait prendre en considération leur production de services écosystémiques, pour lesquels il est nécessaire d'identifier indicateurs spécifiques.*

Mots-clés. *Fermes d'élevage – Alpes italiennes orientales – Produits de qualité – Services écosystémiques.*

I – Introduction

Livestock farming systems in Alpine regions have experienced a dramatic decline in the last decades, with important structural and management changes. The first aim of this paper is to analyse trends of the livestock sector in the eastern Italian Alps. We then discuss the ecosystems services provided by mountain farms and the different possible strategies to generate added-value for local products by examining literature case studies.

II – Evolution of livestock systems in the eastern Italian Alps

Eastern Italian Alps cover the provinces of Trento, Bolzano, Belluno, and the mountainous municipalities of the provinces of Verona, Vicenza, Pordenone and Udine, bordering with Austria and Slovenia. As a result of the abandoning and intensification processes that affected all the Alpine agriculture, in the eastern Italian Alps cattle farms decreased by 45% from 1990 to 2010; the number of animals decreased much less (-18%), and hence herd size increased by 49% (Table 1). These trends were much stronger in the 1990-2000 decade than in the following one. In addition, they differed greatly within the area: in Trentino-Alto Adige traditional farms based on local forage systems were abandoned much less than in Friuli Venezia Giulia (data not shown in the Table). Sheep and goat farms changed with similar patterns, with the exception of the number of heads, which increased for both species. Cattle farming is now largely predominant over sheep and goat farming. The cattle farms that have survived can now be classified into a variety of systems (Table 2), which represent different steps in the shift from the original, seasonally transhumant system based on the use of local forage resources with autochthonous breeds to a modern, intensive system with highly specialized breeds fed total mixed rations and concentrates.

Table 1. Evolution of livestock systems in eastern Italian Alps (ISTAT, 2013)

	Year of census			Variation (%)		
	1990	2000	2010	1990-2000	2000-2010	1990-2010
Cattle						
Heads	301,178	268,302	247,242	-10.9	-7.8	-17.9
Farms	21,702	14,556	11,934	-32.9	-18.0	-45.0
Heads/farm	13.9	18.4	20.7	32.4	12.5	48.9
Sheep						
Heads	53,989	70,073	84,889	29.8	21.1	57.2
Farms	2,819	2,877	2,175	2.1	-24.4	-22.8
Heads/farm	19.2	24.4	39.0	27.1	59.8	103.1
Goat						
Heads	19,566	26,633	23,264	36.1	-12.6	18.9
Farms	2,128	2,318	1,472	8.9	-36.5	-30.8
Heads/farm	9.2	11.5	15.8	25.0	37.4	71.7

Many farms now move only dry and replacement cattle to summer pastures, and cheese production in summer farms is much less frequent than in the past. Summer farms with facilities for housing dairy cows and cheese making are highly demanded, but many units have not been renovated to meet these requirements (Sturaro *et al*., 2013b). Beef fattening farms are rare, but in certain areas mixed beef farms, often conducted part-time and resulting form the abandoning of milk production, are present (Table 2).

III – Quality of the dairy products in the eastern Italian Alps

The quality and the value of the traditional mountain dairy products is linked to many factors including production area, forages utilized, animal characteristics, farming practices, and milk manufacturing. Cheeses produced in eastern Italian Alps often have better organoleptic and nutritional properties than lowland products (Cozzi *et al*., 2009). The Protected Designation of Origin (PDO) label covers the products of a given geographical area that comply with a detailed specification of the

Table 2. **Cattle farming systems in the eastern Italian Alps. Adapted from Bovolenta *et al.* (2011), Sturaro *et al.* (2013a)**

	Traditional dairy			
	Original	**Stationary**	**Modern dairy**	**Beef**
Herd size (n)	<20	20-30	>40	<40
Breeds(1)	L, DP, B	DP, L, B, HF	HF, B	SB, M
Seasonality(2)	Yes	No	No	Yes
Milk yield (kg/d)	< 20	20-25	>25	–
Housing	Tie Stall	Tie Stall	Loose	Loose, Tie Stall
Use of TMR/silages(3)	No	In part	Yes	No
PDO(4) cheese	yes	In part	No	–
Summer pastures	All cows	Replacement(R)	No or R	In part

(1): listed in order of frequency for each system. L = Local; DP = Dual Purpose; B = Brown; HF = Holstein Friesian; SB = specialized beef; M = mixed. (2): avoidance of calvings before and during the use of summer pastures. (3): TMR= Total Mixed Rations. (4): PDO= Protected Designation of Origin.

production chain and of the product quality. The PDO cheeses produced in the eastern Italian Alps are listed in Table 3. Some of them are partially or mainly produced also in lowland areas. Hence, the PDO specifications are unable to protect the mountain productions, and additional labels are needed. The Grana Padano produced in Trento province (entirely alpine) has obtained a specific geographic indication “Trentingrana”. Asiago and Montasio produced in the homonymous, original upland areas are labeled as “Mountain product” (MP), an optional quality term, for products with PDO labels, established by a national law (L. 289/02, Art. 85, Mipaf 30/12/03). This option has also been recently provided by Reg. UE n. 1151/2012. Recently, PDO Montasio produced with the milk of the local and most frequent breed has received the additional label ‘Only Italian Simmental breed’ (Romanzin *et al*., 2013). For various, but not all, PDO cheeses feeding restrictions require a predominant use of local forages and exclude silages, especially maize silage.

Table 3. **PDO cheeses produced in the eastern Italian Alps (Bovolenta *et al*., 2011)**

	Alpine production		
PDO Cheese	**Total/partial**	**Amount (,000 T)**	**Feeding restrictions(1)**
Asiago	P	418	None for PDO; No silages for PDO-MP
Montasio	P	450	None
Monte Veronese	P	N.A.	None
Piave	T	2,356	≥ 70% of forage and 50% total diet DM from PDO area
Puzzone di Moena	T	396	No TMR or silages; ≥ 60% of forage from PDO area
Spressa delle Giudicarie	T	150	Hay from permanent meadows ≥ 50%; No silages
Stelvio	T	1,112	≤ 15 kg/d grass silage, no maize silage Trentingrana
(Grana Padano)	T(P)	3,515	≥ 75% feeds from PDO area; ≤ 50% concentrates

No silages for Trentingrana (1): certain PDO exclude specific and uncommon by-products or supplements, not mentioned here.

The price of milk processed for PDO and MP cheeses, but also for many unlabeled local, traditional cheeses, is higher than that processed into other cheeses. This is important for the traditional farms that, in contrast with modern ones, do not use maize silage and can have therefore access to these production chains (Sturaro *et al*., 2013a). In addition to these labels, also “Slow Food Foundation” Presidia sustain local productions (e.g. the Monte Veronese cheese) or traditional processing methods (e.g. *Latteria Turnaria*, a kind of dairy managed directly in turn by farmers), and local breeds (e.g. Grigio Alpina cow).

IV – Ecosystems Services of livestock farming: case studies

Non-productive functions of livestock farming in Alpine regions include grassland maintenance, protection of natural and domestic biodiversity, maintenance of landscape attractiveness, and custody of cultural heritage, which can be classified as “ecosystem services” (MEA, 2005). In eastern Italian Alps, meadows and pastures declined by 17% during 1990-2010. The natural re-afforestation of abandoned meadows has been particularly massive in steeper areas and in the valleys slopes (Cocca *et al.,* 2012), where grasslands host a richer biodiversity (Marini *et al*., 2011). Along the bottoms of the main valleys re-afforestation has been less pronounced, but many meadows have been converted into arable crops by modern farms, which may also incur in the risk of excessive nutrients output per unit of land (Sturaro *et al*., 2013a). Both these processes have also been detrimental to landscape attractiveness. For livestock farms located in Nature 2000 areas, the implementation of management plans will introduce regulations or limitations to management practices. Incentives will depend on agricultural policies, and hence on their link, which presently is uncertain, with the environmental policies. Following re-afforestation, wild ungulate populations have largely increased, and damages to meadows and pastures by wild herbivores are an emerging problem (Marchiori *et al*., 2012). The recent return of the wolf (*Canis lupus*) will increase, in the next future, the conflicts between wildlife and livestock farming.

V – Conclusions

Livestock farming in eastern Italian Alps suffered a strong abandonment in the last 20 years, although with a lower rate in the last decade than in the previous one. Farming systems are now heterogeneous, with a strong prevalence of dairy cattle farms. The link between traditional dairy farms and PDO and other traditional cheeses contributes to reducing the economic handicap with respect to the intensive farms, and in some cases the guidelines for PDO cheeses production help guarantee the supply of ecosystem services. In fact, only the traditional farms are able to use autochthonous breeds, to maintain grasslands and their biodiversity with extensive practices, to make full use of summer pastures, and conserve the traditional landscape. In addition, these farms are more often subjected to Natura 2000 regulations and exposed to increasing conflicts with wildlife. Therefore, the future of grassland-based systems will depend not only on remuneration from high added-value products but also on regulation and compensation of ecosystem services (EEA, 2010). A comprehensive evaluation of livestock farms sustainability in mountainous areas should also take into account their ecosystem services, for which specific indexes, to be implemented in LCA methods, are needed.

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Carotenoids and tocopherol in plasma and fat to authenticate forage feeding in cattle

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Abstract. Forage-feeding in cattle carcasses can be authenticated using an estimator of carotenoid pigment concentration (SUM). Therefore, it is suggested that plasmatic carotenoids and α-tocopherol could be used to authenticate it *in vivo*. Plasmatic concentrations of carotenoids and α-tocopherol, fat colour and SUM were studied in concentrate-fed bulls (C) and two groups of steers until slaughter (500 kg). Both groups of steers were fed a total mixed ration (50% lucerne hay + 10% straw+ 40% corn) during 159 days (winter) and grazed on a mountain meadow plus 1.8 kg DM corn/d for 85 days. Thereafter, one group was finished on a meadow (G) plus 1.8 kg DM corn/d for 75 days and the other group was finished by means of a total mixed ration during 55 days (finishing period) (TMR). During winter, G and TMR steers had greater plasmatic carotenoids concentrations than C bulls ($P < 0.001$). Conversely, C bulls had greater plasmatic α-tocopherol concentration than both groups of steers on day 29 ($P < 0.001$) and 55 ($P < 0.05$) but similar thereafter. During the finishing period, G steers had greater plasmatic β-carotene, lutein and α-tocopherol concentrations than TMR steers ($P < 0.001$). Fat colour of G steers had lower lightness but greater yellowness and SUM than C bulls. Steers finished with TMR had intermediate values for lightness and yellowness. Plasmatic carotenoids content and SUM were useful to detect differences in diet.

Keywords. Authenticate – Forage – Cattle – Carotenoids.

Caroténoïdes et tocopherol dans le plasma et les tissus adipeux pour authentifier l'alimentation fourragère chez le bovin

Résumé. *Une alimentation à base de fourrages peut être authentifiée par l'estimation de la concentration en caroténoïdes (SUM) dans les tissus adipeux de la carcasse, mais la concentration plasmatique en caroténoïdes pourrait l'authentifier* in vivo. *Les concentrations en caroténoïdes et tocopherol dans le plasma, ainsi que la couleur et le SUM des tissus adipeux ont été étudiés sur des taurillons alimentés avec des rations à base de concentré (C) et sur deux groupes de bouvillons alimentés en hiver avec une ration mixte complète (50% luzerne foin + 10% paille + 40% maïs grain: 159 jours), puis au pâturage. Après 85 jours de pâture les bouvillons ont été, soit finis au pâturage pendant 75 jours (G), soit ont reçu la ration mixte complète pendant 55 jours (TMR). Au pâturage, tous les bovins ont reçu 1,8 kg MS maïs/j. Pendant l'hiver, les bouvillons G et TMR ont eu des concentrations en caroténoïdes plus élevées que les taurillons. À l'inverse, les taurillons C ont eu une teneur plus élevée en α-tocopherol que les bouvillons les jours 29 ($P < 0,001$) et 55 ($P < 0,05$), mais similaire par la suite. Pendant la finition, le groupe G a eu des concentrations en caroténoïdes et α-tocopherol plus élevées que le groupe TMR ($P < 0,001$). Le tissu adipeux des bouvillons G a été moins lumineux et plus jaune que celui des taureaux C, alors que les TMR ont eu des valeurs intermédiaires. En conclusion les teneurs plasmatiques en caroténoïdes et SUM peuvent servir à détecter des différences du régime alimentaire.*

Mots-clés. *Authentification – Fourrages – Bovins – Caroténoïdes.*

I – Introduction

In dry mountain areas, forage has been introduced in the diets at the expense of concentrates mainly due to the increase of cereal prices and to satisfy the societal demands regarding environmental and ethical concerns about food production (Bernués *et al.*, 2011). Nowadays, consumers associate healthy beef with grazed cattle, fed with natural feedstuffs and raised outdoors (Verbeke *et al.*, 2010) and there is an increasing interest in guaranteeing the traceability of these production systems. The authentication of forage feeding in meat from ruminants can be achieved by measuring carotenoid pigments in plasma and fat deposits. Carcasses form forage-fed cattle can be accurately traced by measuring subcutaneous fat colour (Dunne *et al.*, 2009, Blanco *et al.*, 2011). In order to detect forage feeding *in vivo*, carotenoids content in serum have been investigated (Serrano *et al.*, 2006). Our objective was to study the evolution of carotenoids and α-tocopherol during the fattening period to check the feasibility of their use to trace forage feeding in beef cattle.

II – Materials and methods

1. Animals

This study was conducted in La Garcipollera Research Station, located in the Spanish Pyrenees (Spain, 42º37' N, 0º30'W; 945 m a.s.l.) and in CITA Research Centre, located in the Ebro Valley (41° 43' N, 0° 48' W; 225 m a.s.l.). During the winter housing period, a group of 8 intact young bulls (C) received commercial concentrates plus straw until they reached the target slaughter weight (500 kg) and 2 groups of steers received a total mixed ration (50% lucerne hay + 10% straw + 40% corn) until mid-April. Both groups of steers rotationally grazed together in valley meadows and were supplemented with 1.8 kg DM corn/day/head during 85 days. Thereafter, one group of steers (G; n = 8) remained on the meadows during 75 days with 1.8 kg DM corn/head/day until they reached the target slaughter weight and the second one (TMR; n = 8) was finished for 55 days with the same total mixed ration fed during the winter period.

2. Sampling

Samples of the different feedstuffs were collected fortnightly. They were immediately frozen and freeze-dried. The animals were bled monthly except for the first two months of the grazing season and the first month of the finishing period, when they were bled weekly.

Fat cover was scored on a 15-point scale at 24 hours *post-mortem*. Subcutaneous fat colour at the 10th rib was measured with a Minolta CM-2006d spectrophotometer. The estimator of fat carotenoid pigments content (SUM) was calculated as proposed by Prache and Theriez (1999).

3. Analyses of carotenoids and tocopherol concentrations

The contents of β-carotene, lutein and α-tocopherol were determined by HPLC following the procedures of Chauveau-Duriot *et al.* (2010). The analyses were modified for the determination in plasma as described by Molino *et al.* (2012). The dry residues were dissolved in 0.5 ml of acetonitrile–dichloromethane–methanol (75–10–15). HPLC was run on a HPLC 1100 Agilent equipped with a photodiode array detector. β-carotene and lutein were detected at 450 nm, and α-tocopherol at 295 nm.

III – Results and discussion

Average carotenoids and α-tocopherol contents of the feedstuffs used in the experiment are detailed in Table 1. Pasture contents remained unchanged during the grazing season (data not shown). However, Dunne *et al.* (2009) reported that carotenoids in pasture are affected by season. In the current study, the meadow was rotationally grazed, thus, the stage of maturity of consumed pasture was probably constant throughout the grazing season.

Both groups of steers had greater plasmatic β-carotene and lutein concentrations than C bulls throughout the winter feeding period, reflecting differences in carotenoid intakes (Serrano *et al.*, 2006). However, both groups of steers had lower plasmatic α-tocopherol concentration than C bulls on day 29 and 55 ($P < 0.05$) (Fig. 1), which is a result of the greater content of α-tocopherol in the concentrate. When the steers were turned out to pasture, the plasmatic carotenoids and α-tocopherol concentrations increased in both groups of steers, which had similar plasmatic concentrations during the first 85 days of the grazing season.

Table 1. β-carotene, lutein and α-tocopherol concentrations in the feedstuffs

	Lucerne hay	Straw	Concentrate	Pasture	Corn
β-carotene, mg/kg DM	1.3 ± 0.42	n.d.	n.d.	370.7 ± 12.27	n.d.
Lutein, mg/kg DM	9.0 ± 0.32	0.6 ± 0.02	n.d.	232.1 ± 2.17	1.4 ± 0.05
α-tocopherol, mg/kg DM	2.1 ± 0.14	2.1 ± 0.10	6†	117.2 ± 13.75	1.3 ± 0.46

† Incorporated in the concentrate as 10 mg/kg of tocopheryl acetate n.d.: not detected.

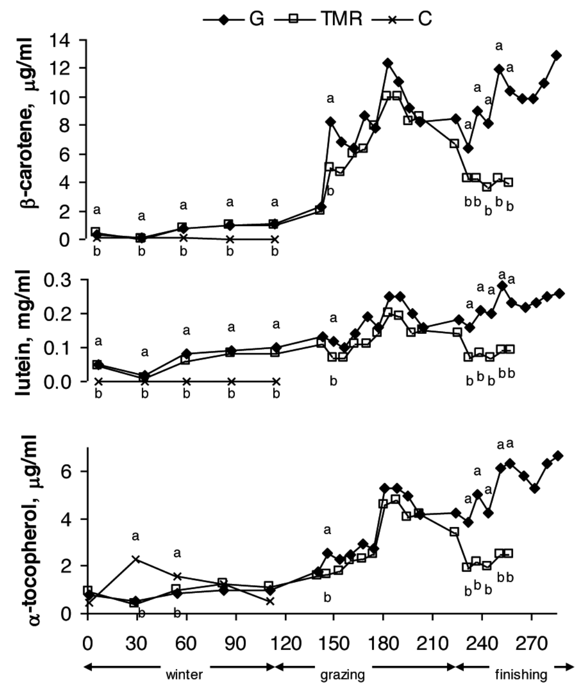

Fig. 1. Plasmatic β-carotene and lutein concentrations according to the management strategy throughout the experimental period. G: grazing steers; TMR: indoors finished steers; C: concentrate-fed bulls. Within a date, means with different letters differ at P<0.05.

As carotenoids and α-tocopherol contents in pasture did not change through the grazing season, the increase in the plasmatic concentration would reflect an increase in forage intake. During finishing, G steers had greater plasmatic carotenoids and α-tocopherol concentrations than TMR steers, as consequence of the sharp decrease observed when steers started eating the total mixed ration, based on dry-preserved forages and grain.

Fat of both groups of steers had greater yellowness, redness and SUM than that of C bulls since yellowness is caused by carotenoids of green forage (Dunne *et al.*, 2009). Regarding fat colour differences between both groups of steers, the 55 day finishing period on a low carotenoid content diet after grazing only affected fat yellowness and Chroma (Table 2). These results agree partially with those reported by Blanco *et al.* (2011) and Serrano *et al.* (2006). In both studies, a low carotenoid diet (concentrates or hay) reduced fat yellowness and SUM after 58 and 150 days, respectively. However, as carotenoids deposition in fat depends on the amount of fat accumulated during finishing (Dunne *et al.*, 2009), when SUM was covariated with subcutaneous fat score, G steers had greater SUM than TMR steers (368 vs. 325, P = 0.03).

Table 2. Effect of the management strategy on the subcutaneous fat colour and estimator of carotenoid pigments content in fat (SUM)

	G	TMR	C	s.e.m.	Pr > F
Lightness (L*)	68.3b	71.2ab	72.8a	1.9	0.03
Redness (a*)	2.8a	2.7a	1.4b	0.6	0.02
Yellowness (b*)	18.1a	16.3b	9.2c	0.9	0.001
Chroma (C*)	18.4a	16.5b	9.4c	0.9	0.001
SUM	353a	334a	140b	26.2	0.001
Covariated with fatness score	368a	327b	133c	21.1	0.001

G: grazing steers; TMR: indoors finished steers; C: concentrate-fed bulls. Within a parameter, means with different letters differ at P<0.05.

IV – Conclusions

Subcutaneous fat colour and SUM are useful to trace forage feeding in carcass. Both β-carotene and lutein in plasma were useful to detect differences in diets in growing cattle. However, plasmatic α-tocopherol concentration is not useful to trace forage-feeding because it is usually added to commercial concentrates.

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To what extent do French mountain grasslands provide simultaneously biodiversity and forage services?

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Abstract. The key role of permanent grasslands for the conservation of biodiversity, and more generally for the preservation of environment quality, is clearly established. However, the total area covered by grassland is regularly declining in most EU countries. A way to stop the decline of their surfaces is to underline the economic potential of grasslands for breeders and their value. In this perspective, we studied the links between forage services and biodiversity through the survey of a network of 47 permanent grasslands from Pyrenees, Massif Central, Jura and Vosges. Grasslands were followed during 2 years (2009-10) considering the seasonal dynamic of forage characteristics and botanical and functional composition. Forage services of grasslands were estimated measuring production and quality (digestibility, crude protein content), and biodiversity by indicators of botanical diversity (species richness, percentage of entomophilous species, number of oligotrophic species, botanical families). We showed a strong link between quality of permanent grasslands and biodiversity. The productive grasslands presented a lesser interest for biodiversity. We also showed that permanent grasslands could provide simultaneously biodiversity and forage services or only forage services or biodiversity.

Keywords. Permanent grasslands – Forage services – Biodiversity.

Les prairies permanentes de montagne en France apportent-elles simultanément des services fourragers et de la biodiversité ?

Résumé. *Le rôle des prairies permanentes dans la conservation de la biodiversité, et plus généralement dans la préservation de la qualité environnementale est maintenant bien établi. Cependant, leur surface totale diminue régulièrement dans de nombreux pays européens. Une alternative pour stopper ce déclin est de souligner l'intérêt économique de ces surfaces dans le système fourrager et leur valeur. Dans cette perspective, nous avons étudié les liens entre les services fourragers et la biodiversité à travers l'étude d'un réseau de 47 parcelles de prairies permanentes des Pyrénées, du Massif Central, du Jura et des Vosges. Ces surfaces ont été suivies durant deux années (2009-10) en prenant en compte leur dynamique fourragère saisonnière et leur composition botanique et fonctionnelle. Les services fourragers des prairies ont été estimés à travers la mesure la production et de la qualité de celles-ci (digestibilité et teneur en matières azotés), et la biodiversité par des indicateurs de diversité botanique (richesse spécifique, pourcentage d'espèces entomogames, nombre d'espèces oligotrophes, familles botaniques). Nous avons réalisé une ACP sur les indicateurs de biodiversité. Nous avons montré un lien important entre la qualité des prairies permanentes et la biodiversité. Les prairies productives présentent un intérêt moindre pour la biodiversité. Nous avons également montré que ces surfaces pouvaient rendre simultanément des services fourragers et présenter un intérêt en termes de biodiversité.*

Mots-clés. *Prairies permanents – Services fourragers – Biodiversité.*

I – Introduction

The role of permanent grasslands in the preservation of biodiversity and more widely in the delivery of ecosystemic services (for environmental or economical purposes) is today well established (Leroux *et al.*, 2008). However, these surfaces are decreasing for several years in several European countries. European Union policy tries to maintain permanent grasslands in the landscape, especially because of their environmental interest. A way to stop the decline of their surfaces is to provide evidence about the joint interest of grasslands, in terms of economy and environment. It is thus important to underline the economic potential of grasslands for breeders related to their production and nutritive value (Jeangros and Schmid, 1991; Michaud *et al*., 2012). In this perspective, we studied the links between forage services and biodiversity, with the aim to underline the diversity of services they can return: forage services, ecosystemic services or both. Links between indicators of forage services and these services were established by Michaud *et al.* (2011). To this end, we analyzed data collected in an original set of permanent grasslands distributed along a large mountain gradient in France.

II – Materials and methods

A set of 190 French permanent grasslands was studied on 78 farms (Michaud *et al.*, 2011). We extracted within this network all the plots of land located at more than 600 meters above sea level. Forty-seven permanent grasslands were thus studied from 4 mountainous massifs: Pyrenees, Massif Central, Jura and Vosges. They were studied during 2 years (2009-10) considering the seasonal dynamic of forage characteristics and botanical/functional composition.

Botanical composition was determined in spring 2009 on each grassland in a homogeneous plant community (vegetation structure and floristic composition) of *c*. 1 ha. The list of species was compiled from eight randomly located sampling areas (0.25 m²) and completed by an overview of the global plant community in order to note the presence of other species in the sampled area. In each 0.25 m² sampling area, species dominance was determined by visual estimation of the relative volume of each species in the biomass (Benizri and Amiaud, 2005). The botanical lists were entered into the e-flora-sys software (*http://eflorasys.inpl-nancy.fr,* Plantureux *et al.*, 2010). From the botanical composition, e-flora-sys calculated the proportion of entomophilous species and the number of oligotrophic species.

The seasonal dynamic of forage production and nutritive value was assessed during 2009 and 2010 on the dominant homogeneous plant community of each grassland. In three areas of that plot (1.5 × 3 m), samples were taken on four occasions each year: two samples in spring (one at the beginning of spring and one at the end of spring), one in summer and one in autumn. At each measurement, two samples were collected to study:

- The proportions of grasses, legumes and forbs, estimated visually, according to volume;
- The biomass production and grass nutritive value of permanent grasslands. By means of the dried sample and the dry matter content, the biomass production of each grassland was calculated for all cutting dates. The nutritive value of the herbage (organic matter digestibility and crude protein content) was estimated using NIRS (Michaud *et al*., 2012).

Relationships between forage services and biodiversity was analyzed by investigating the links between production and nutritive value (organic matter digestibility, crude protein content) on one hand and indicators of botanical diversity (species richness, number of oligotrophic species, proportion of entomophilous species, grasses, legumes and forbs proportion) on the other hand. We studied the distribution of grasslands according biodiversity and forage indicators. For that, a Principal Component Analysis (PCA) was performed on SAS, package 3.0.2. Biodiversity indicators were considered as active variables and forage indicators as illustrative variables.

III – Results and discussion

Grasses, legumes and forbs proportion showed colinearity: we only kept legumes and forbs proportions in the analysis. Only independent variables were kept for the analysis. Axes 1 and 2 take into account about 50 % of the overall variability of data.

1. Links between the indicators of the forage services and the indicators of biodiversity

In Fig. 1, directions of axes are explained for axis 1 by proportion of legumes and number of oligotrophic species, and for axis 2 by forbs proportion, percentage of entomophilous species and species richness at the opposite. The number of oligotrophic species is related with the legumes proportion of grasslands. The percentage of entomophilous species stayed rather related to forbs proportion. In fact most of entomophilous species are forbs.

Moreover Fig. 1 underlined links between indicators of forage production and of biodiversity. Nutritive value was related to legumes proportion and oligotrophic species. The effect of legumes on crude protein content or organic matter digestibility was described by several authors (Bruinenberg *et al*., 2002; Daccord *et al.*, 2006; Baumont *et al.*, 2008). Moreover forbs proportion and percentage of entomophilous species contributed to explain grasslands nutritive value at the end of spring. Daccord *et al.* (2006) classified forbs into two categories: stemmy and leafy forbs. Leafy forbs could help to improve nutritive value of grassland whereas stemmy forbs would decrease it. In contrast, biomass production of grass was set against the nutritive value indicators and against the indicators of biodiversity as legumes proportion.

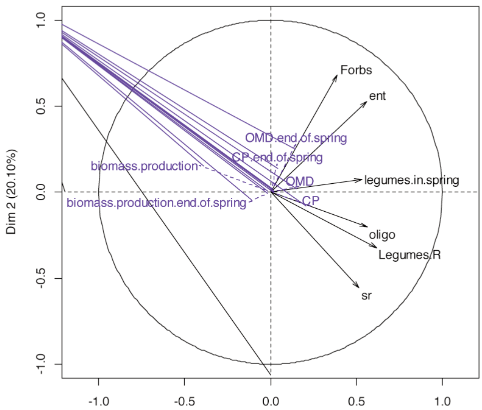

Fig. 1. PCA of active variables and indicators of forage services.

Ilustrative variables: ent: entomophilocus species; oligo: oligothophic species; Legumes R: legumes for regrowths; OMD: organic matter digestibility for the rest of the year; CP: crude protein content for the rest of the year.

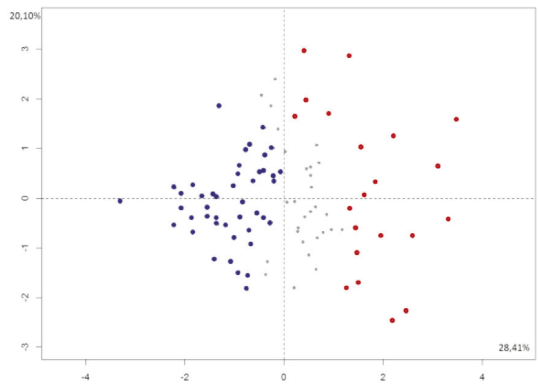

Fig. 2. Distribution of grasslands according to biodiversity indicators. Values of 2 years are represented.

- grasslands presenting and interest for biodiversity
- grassland presenting and interest for forage services
- grassland presenting an interest for biodiversity and forage services.

2. Can the permanent grasslands of mountains return forage services and present an interest in terms of biodiversity?

The distribution of grasslands in the PCA plan showed a group of productive grasslands which deliver forage services linked to production. A more scattered distribution of grasslands was showed for those which present an interest for biodiversity (Fig. 2). Here we find grasslands which only return interest for biodiversity (on the right of Fig. 2) and those which provide both: services linked to quality of grasslands and biodiversity interest (close to center of circle). So we can set a gradient in relation to the services and biodiversity, from left to right: permanent grasslands, which provide only forage services linked to production, to those who consider forage services linked to nutritive value and biodiversity, and those which favor rather the biodiversity.

IV – Conclusions

The study of links between indicators of forage services and biodiversity showed a strong positive relation between quality of permanent grasslands and biodiversity and in contrast a negative relation between biomass production and biodiversity. We also showed a homogeneous distribution of grasslands in the plan of study: we found grasslands which return rather forage services linked to biomass production, others which presented rather an interest for the biodiversity and finally others which reconciled both (quality of the grass and biodiversity, average productivity and biodiversity). Thus, mountain permanent grasslands can provide simultaneously forage services related to nutritive value of grass and environmental services related to biodiversity. Considering that, various strategies could be driven at the level of fodder system management to reconcile biodiversity and forage services. However it depends on the objectives of the breeder and on constraints at farm level.

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AlpFUTUR – Herders, home farm size and direct payments are key factors for the future of summer farming in Switzerland

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Abstract. With inter- and trans-disciplinary approach, the research programme AlpFUTUR (www.alpfutur.ch) identified the future prospects of Swiss summer pastures for the next decades. Summer pastures are a distinctive feature of the cultural landscape in Switzerland. However, recent polarization of land use – intensification on the one hand, extensification or abandonment on the other hand – leads to the loss of agricultural land, biodiversity, tradition and identity. Although a survey of AlpFUTUR showed that summer farming is highly motivated by tradition and appreciated by the Swiss population, 24 km^2 of summer pastures are abandoned every year and turn into forest. At the farm level, AlpFUTUR showed that capable employees are of significant importance for successful business. Economic analyses revealed that summer pasturing is economically strongly dependent on sufficient herd size. The steadily increasing area of the home farms may become a key factor for abandonment, because sufficient fodder is available all year round at the home farm. Since 2014, the financial support of summer farming has been increased substantially and ecological direct payments have been introduced. These political measures are intended to counteract the current dynamics but have to prove their effect in the near future.

Keywords. Interdisciplinary research project – Land use change – Summer pastures.

AlpFUTUR – Bergers, taille des fermes en vallée et paiements directs sont les facteurs clés pour l'avenir des estivages en Suisse

Résumé. *Le programme de recherche inter- et transdisciplinaire AlpFUTUR (www.alpfutur.ch) a identifié les perspectives d'avenir des pâturages d'estivage suisses pour les prochaines décennies. Les pâturages d'estivage de montagne sont une particularité du paysage culturel en Suisse. Cependant, la récente polarisation de l'utilisation des sols – intensification d'une part, extensification ou abandon d'autre part – conduit à la perte de terres agricoles, de biodiversité, de traditions et d'identité. Alors que la pratique de l'estivage est fortement encrée dans les traditions et apprécié par la population suisse, environ 24* km^2 *de pâturages sont abandonnés chaque année et se transforment en forêt. A l'échelle de l'exploitation individuelle, AlpFUTUR a trouvé que le personnel qualifié est d'importance majeure pour le succès d'une saison d'alpage. L'analyse économique a montré que les fermes d'estivage dépendent fortement du nombre suffisant de bétail. Le fait que les exploitations principales en vallée sont sans cesse en train de s'agrandir est un facteur clé pour l'abandon des estivages, car de plus en plus le fourrage produit en vallée suffit pour toute l'année. Depuis 2014, le soutien financier de l'agriculture d'estivage a été augmenté sensiblement et des paiements directs écologiques ont été introduits. Ces mesures politiques sont attendues pour contrecarrer la dynamique actuelle mais doivent prouver leur efficacité dans un avenir proche.*

Mots-clés. *Programme de recherche interdisciplinaire – Changement d'utilisation des sols – Pâturages d'alpage.*

I – Introduction

The inter- and transdisciplinary research programme AlpFUTUR started in 2007 and focused on the most relevant factors, relations and interactions for actual and future mountain summer farming in the next 10 to 40 years in Switzerland. 80 scientists from 17 institutions were directly involved in research and knowledge transfer, over 40 foundations, federal, cantonal offices and NGOs supported the project financially. Twenty-two projects conducted scientific surveys, field work and literature studies on animal production, grazing intensity, effects of climate and land use change, dynamics of biodiversity and forest area, jobs and education, history, laws and regulations, market potential of alpine products, economic efficiency, innovation, tourism, demands of society, policy, infrastructure and implementation. This paper summarizes a subset of results of AlpFUTUR. For the complete results refer to the synthesis book by Lauber *et al*. (2013), which is available in German, French and Italian (www.alpfutur.ch).

II – Importance of mountain summer pastures

One third of the agriculturally used area in Switzerland consists of summer pastures (BfS, 2012 and Fig. 1). This natural fodder source allows to increase the Swiss livestock number by 11 percent. Over 400,000 cattle, 210,000 sheep, as well as goats, horses and other ruminants spend the summer in the mountains, they stem from 48 percent of the farms owing livestock. The 7000 summer farms generate 11% of the total income of the Swiss agricultural sector (BLW, 2012). Considering that summer farming lasts only three to four months every year, this is a remarkable amount.

Most of the high nature value farming in Switzerland is related to summer pastures (Riedel *et al.,* 2012), which were shown to host highest plant species richness compared to other habitats in Switzerland (BDM, 2006). The significance of the cultural landscape in summer pasture areas for tourism, its contribution to Swiss' identity and the mitigating effects of adapted land management on natural threats also add to the high estimation for summer farming.

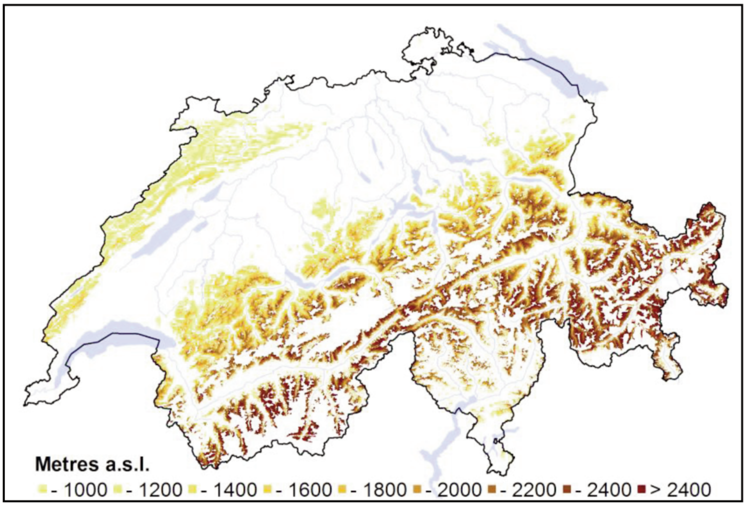

Fig. 1. Swiss summer pastures in the Jura mountains and in the Alps are diverse in elevation and topography. They extend from below 1000 to over 2400 m above sea level. (Data: Arealstatistik 1992-97 © BFS/ Geostat; Background: Vector200 © swisstopo; Map design: E. Szerencsits) Agrocope, in Lauber *et al.* (2013).

III – Challenges for summer farming

1. Polarization of land use: intensification and abandonment

There is a close link between the home farms in the valley and the mountain summer farms. Because of a general increase of the forage area on the valley farms, the need for additional fodder from summer pastures is decreasing. As a consequence, the numbers of animals on summer farms decreases, 24 km^2 of marginal summer pastures are abandoned every year and forest is expanding. Also, modern high performing cows tend to be too heavy for the alpine terrain (erosion) and too demanding with respect to fodder quality. A survey showed that almost half of the 856 farmers which were interviewed are indeed seeking to expand the forage area of the valley farm and consequently consider to give up summering livestock (Fischer *et al*., 2012).

2. Economic aspects

The income of summer farms depends considerably on the size of the herd (Fig. 2). A decrease in production (milk, cheese, butter, meat) has a stronger impact on profitability than the decrease in working hours and salary. Therefore, securing enough animals is crucial for the profitability and therefore for the future of a summer farm.

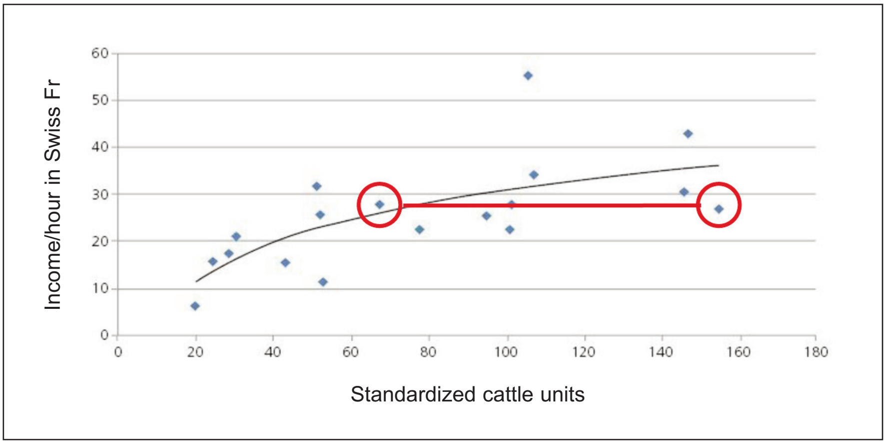

Fig. 2. The income per hour increases with the number of standardized cattle units ("Normalstösse") (R^2 = 0.37). Still, some small alpine summer farms that are well organised and make good use of their capacities achieve the same income per hour as farms that are about three times bigger (thick line) (© Fig. 6.5 in Lauber *et al.,* 2013).

3. Herders and cheese makers

An AlpFUTUR survey revealed the importance of well trained, experienced and reliable personnel, especially because the number of family members involved in summer farming is decreasing. 38 percent of the summer farms depend on temporarily hired personnel. Ideally, the same team returns to the same summer farm every season, but often this is not the case. AlpFUTUR interviewed 120 employees of summer farms and identified three key factors which make a summer farm attractive: Recognition of the hard work and effort, minimum level of infrastructure and the possibility to take responsibility for at least certain domains. For employers, knowing the motivations and expectations of their herdsmen is a key factor to make them come back the following year.

IV – Opportunities

1. Consumers trends

In a comprehensive survey consumers indicated their preference for regional products (76.4%), natural products (70.2%) and taste (66.9%) as main reasons to buy cheese from summer farms. These findings are in line with European food trends (Bosshart *et al.*, 2010). Especially in the urban centers, AlpFUTUR surveys showed that consumers are ready to pay up to 30 percent more for summer farm products. Another representative survey by Junge and Hunziker (2013) confirmed that the Swiss population perceives summer farming as an integral part of Swiss identity. The abandonment of summer farming would be regretted by both, the inhabitants of the mountain regions and by the Swiss population at large.

2. Support by agricultural policy

Since 1980 summer farming is supported with direct payments. As long as the stocking rate is within 75 to 110 percent of the carrying capacity of a summer farm, full contributions for alpine summer farming are paid. These contributions aim at avoiding reforestation as well as intensification of alpine summer pastures. The contributions were increased with the beginning of 2014 (Bundesrat, 2014), mainly to counteract the abandonment of marginal pastures. Additional direct payments were introduced for pastures with high biodiversity and to enhance landscape quality. These contributions aim at maintaining labour-intensive practices, such as removing fern, shrubs and trees from pasture land and are expected to counteract the undesired trends of abandonment because of missing manpower. The promotion of summer farming products is indirectly supported by official labels for cheeses from summer farms. In the near future a specific “summer farm label” should facilitate the distinction of summer farms products from alpine mountain products in general. There is, however, no centrally organized support for the temporary employment.

V – Conclusions

At the national level, policy reacted to land use polarization in summer pasture areas with increased direct payments. They should motivate farmers to continue the tradition of summer farming. However, the trend of increasing size of home farms is a strong antagonist to the new payments and future evaluations will have to prove their effectiveness. At the summer farm level, where reliable personnel was shown to be the key factor for economic success, we recommend that employers invest in the motivation of their employees and produce alpine products of high quality standards. Alpine summer farming will then persist as a living mountain tradition.

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