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Organic versus conventional systems in viticulture: comparative effects on

spiders and carabids in vineyards and adjacent forests

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Abstract

Farming systems and management regimes of vineyards may affect local biodiversity of plants and invertebrates. While most studies have focused on the overall biodiversity of vineyards, there has been little consideration of the response of different ecological guilds to vineyard management, nor to how vineyard management affects communities of adjacent semi-natural habitats.

We study here two functional guilds of carabids and five of spiders in Langa Astigiana (NW-Italy) with the following aims: *i)* to assess the comparative effects of organic and conventional farming systems, along with associated habitat and landscape variables, on species richness and abundance in vineyards; and *ii)* to compare the same within forest patches *surrounding* organic and conventional vineyards.

The different guilds exhibited distinct preferences for habitat characteristics (i.e. grass cover), landscape context and farming systems. Generalized Linear Mixed Models showed that spider preferences mostly depended upon habitat variables, while carabid preferences depended on small-scale landscape variables. In general, organic farming increased biodiversity and abundance of arthropod predators, even though different guilds of carabids and spiders responded differently. Brachypterous carabids, ambush spiders, ground-hunter spiders and other hunters preferred organic vineyards, whereas macropterous carabids, specialist spiders (mostly ant-eating spiders) and sheet web weavers selected conventional vineyards. The research we report here shows that preferences for vineyards with different farming systems has been driven by farming systems *per se* (i.e. omission of synthetic pesticides), but also by habitat characteristics and small-scale landscape structure. Arthropod diversity was greater in the forest patches adjacent to organic vineyards than to conventional ones. This suggests that organic systems may sustain a higher diversity of carabids and spiders both in vineyards and in the adjacent forest patches as well. We conclude that although conventional systems may promote the diversity of some guilds, organic systems should take priority.

Keywords

Biodiversity, carabids, spiders, organic farming, vineyards, forest patches.

1. Introduction

Agroecosystems are characterized by diverse inputs, such as human labour and petrochemical energy and products, which replace and supplement the functioning of many ecosystems. While such substitutions may buffer some of these functions, they also run the risk of damaging others. For instance, the use of pesticides may control diseases that have negative impact on crops, but these may also kill non-target organisms with other positive functions such as pollination or soil fertility enhancement (Swift and van Noordwijk, 2004; Power, 2010).

The current intensification of agriculture is leading to growing concern about the sustainability of farming systems, since farmland biodiversity has severely declined (Vickery et al., 2004; Kleijn et al., 2011). Biodiversity is certainly important to the functioning of ecosystems: insights from Biodiversity and Ecosystem Function (BEF) experiments are likely to underestimate, rather than overestimate, the importance of biodiversity to ecosystem functioning and the provision of ecosystem services (Duffy, 2009). One of the major threats to farmland biodiversity is the simplification of landscape structure, with diminution of non-crop habitat deriving from the expansion of intensive arable crops (Stoate et al., 2001; Benton et al., 2003). Organisms at higher trophic levels seem to be more vulnerable to disturbance than those at the lower trophic levels (Kruess and Tscharntke, 1994), suffering decreases both in their diversity and abundance. Disturbance affects predatory arthropods both directly and indirectly through reduced densities of their prey and hosts. This process in turn decreases the *natural* control of important crop pests (Riechert and Lawrence, 1997; Schmidt et al., 2003). Considering that many ecosystem services of particular importance for agriculture such as pollination and natural pest control often depend on the number of species in an ecosystem (Tilman et al., 2002; Cardinale et al., 2012), the impoverishment of natural communities by agriculture should be minimized to avoid negative feedbacks on production (Diaz et al., 2007).

Organic systems have been shown to support higher biodiversity than conventional ones across many different taxa (Fuller et al., 2005; Bengtsson et al., 2005). These systems aim to promote beneficial organisms by prohibiting the use of synthetic pesticides, herbicides and mineral fertilizers. Moreover, they minimize tillage in order to reduce soil erosion. Studies on organic farming in vineyards are particularly prominent because these agroecosystems are important not just for agriculture, but for conservation as well. In temperate Europe, vineyards (which typically occupy sites with particularly warm and dry climates) may host rare and endangered species of plants and invertebrates. General biodiversity is also typically high (Costello and Daane, 1998; Gliessman, 2000; Isaia et al., 2006).

Vineyards are an ancient crop of Mediterranean mountain environments, cultivated on steep slopes or terraces probably since the early middle ages (Wicherek, 1991; Aldighieri et al., 2006; Cots-Folch et al., 2006). Predicted northward shifts in the climate of European viticultural regions over the coming decades (Kenny and Shao, 1992; Maracchi et al., 2005) may alter both the spectrum and the distribution of grape varieties currently used (Schultz, 2000; Metzger et al., 2008). Several studies have shown that farming systems and regimes of vineyards are important factors determining biodiversity of plants and invertebrates (Di Giulio et al., 2001; Costello and Daane, 2003; Thomson and Hoffman, 2007; Bruggisser et al., 2010; Trivellone at al., 2012). Carabids and spiders are important components of the vineyards. They are potentially important natural agents of pest-control because of their predatory polyphagous habits, and they may be helpful to maintain ecosystem functions and services and promote sustainable agriculture (Kromp, 1999).

Vineyard landscapes of north-western Italy represent peculiar agroecosystems which deserve high conservation priority because of ecological, historical and economic importance (high quality wine production). The research we report here investigated how species richness and abundance of spiders and carabids respond to organic and conventional farming systems in the context of habitat and landscape variables. We also studied the effects of these systems on spider and carabid diversity in the forest patches surrounding the vineyards because, to our knowledge, little attention has been addressed to study the effect of management on surrounding habitats while more consideration has been addressed to analyze how landscape context influences arthropod communities in organic and conventional farms.

Furthermore, while most studies have focused on the overall biodiversity of vineyards, less attention has addressed the effect of organic versus conventional systems on the different ecological guilds (Krauss et al., 2011). Accordingly, we considered functional guild identity of carabids and spiders instead of the overall community, since species with varying ecological requirements may respond differently to different farming systems.

2. Material and methods

2.1. Study area and sampling design

The study was carried out in the Langa Astigiana (NW Italy which ranges for about 28.000 ha), a rural region where vineyards cover 19% of the territory (5343 ha). The present landscape is the result of centuries of historically documented activities. Other main land uses include oak (*Quercus robur*), chestnut (*Castanea sativa*) and black locust (*Robinia pseudoacacia*) groves/forests (28%, 7873 ha), hazelnut orchard areas and other fruit crops (21%, 5905 ha), arable lands (16%, 4499 ha), grasslands and pastures (9.5%, 2671 ha), shrub lands (3%, 843 ha), urban areas (3%, 843 ha), and uncultivated lands (0.11%, 31 ha). The climate belongs to type Cfa (temperate, without dry season and with hot summer), in terms of Köppen-Geiger‘s classification (Peel et al., 2007). During the last five years, annual precipitation ranged from 567 to 894 mm with minimum values in July, January and February and with a maximum peak in April and November. Total annual rainfall averaged 757.4 mm, while the mean annual temperature was 11.9°C (Loazzolo climatic station, 600 m a.s.l.). We investigated 12 vineyards, of which 6 were certified for organic production whereby no chemical treatments except sulphur and copper sulfate spraying were used. In some cases pyrethrum was sprayed against the principal vector (*Scaphoideus titanus*) of flavescence dorèe (*Candidatus*

Phytoplasma vitis IRPCM 2004) which is a bacterial disease of the vine. The other 6 vineyards were cultivated according to conventional production methods. These involved chemical treatments with pre- and post-emergence herbicides, insecticides (mostly against flavescence dorèe), anti-rot compounds, sulphur, copper and zinc spraying, products with esaconazol and copper oxiclorur sulphate against oidium and rots, carbamate pesticides and fungicide, and the use of mineral fertilizers with average concentration of P, K and N at 6.5 q/ha. In particular, during the study period, conventional vineyards were treated with 1.5 l/ha of chlorpyrifos-ethyl and 1.5 l/ha of chlorpyrifos-methyl against bacterial infection (flavescence dorèe) in the months of June and July respectively. Treatment against downy mildew consisted of three treatments of copper oxychloride (40%) and Dimetomorf 6% (3.5 kg/ha) in June and three treatments of Bordeaux mixture (6 kg/ha). Treatment against Oidium consisted of powdered sulphur (50 kg/ha), one treatment of Trifloxystrobin (125 g/ha), and two treatments of wettable sulphur powder (3 kg/ha) in June and two in July.

We placed five pitfall traps in the core of each vineyard and five in the last row of the vines at the edge of the vineyards. For each vineyard, we selected the closest, possibly adjacent, broad leaved forest patch (mixed black locust-oak forest in each site), where we placed five traps as well. Traps were arranged 10 m apart along line transects. Pitfall traps were 7.5 cm in diameter and 9 cm deep, filled with 150 ml of a standard mixture of wine vinegar and saturated sodium chloride solution, designed to preserve individuals. They were placed at the beginning of July 2009 and emptied three times at two-week intervals. Trapped arthropods were sorted and identified, whenever possible, to the species level using updated standard keys or specialist works. For spiders, only adults were considered. Nomenclature follows Platnick, 2014 for spiders and Vigna Taglianti, 2005 for carabids.

Three habitat variables were recorded in vineyards around each pitfall in a circular area of 5 meter radius: the percentage of grass cover, leaf litter cover (estimated by eye), and the mean grass height (ten random measurements, in centimeters). Five habitat variables were recorded in the forests close to the vineyards around each pitfall in a circular area of 5 meter radius: the percentage of grass cover, leaf litter cover, bare ground cover and dead wood cover (estimated by eye), and the mean grass height (ten random measurements, in centimeters).

2.2. Data analysis

We used land cover data digitized from 1:10000 aerial photographs to describe the landscape composition and structure. We considered a small scale (focused on the vineyard and forest patches) and a large scale (focused on the landscape, i.e. vineyard and adjacent land uses). At the small scale, we created a buffer of 200 m of radius with the center coincident with the third trap (i.e. in the middle of the transect) of each transect. At the large scale, we created a buffer of 1500 m of radius with the center coincident with the centroid of the triangle whose vertices coincided with the third trap of each of the three transects (two in the vineyard and one in the forest patch).

Thirteen local landscape variables were measured using Geographical Information System (ESRI, 2006): the area of forests, grasslands, shrubs, vineyards, croplands, hazelnut orchards, urban and uncultivated patches, total number of patches, Shannon diversity index of patches, total mean area of patches, the distance from the closest patch of forest (in meters) and the largest patch index (LPI). LPI corresponds to the area of the largest patch (m^2) of the corresponding patch type divided by total landscape area (m^2), and multiplied by 100. In other words, LPI equals the percentage of the landscape comprised within the largest patch. The number of collinear variables was reduced by applying a Principal Component Analysis (PCA) with a Varimax rotation (Kaiser 1958). At large scale we considered the areas of forests, grasslands, shrubs, vineyards, croplands, hazelnut orchards, urban and uncultivated patches.

Differences in landscape and habitat between conventional and organic systems were tested using a Kruskal-Wallis test due to evidence of a non- Normal distribution.

The diversity of carabid and spider assemblages was described in terms of species richness and total abundance. Two functional guilds were considered for carabids: the macropterous and the brachypterous. We identified seven functional guilds for spiders according to the recent classification provided by Cardoso et al., 2011. Specifically, we considered: ambush hunters (namely Thomisids), ground hunters (dominated by Gnaphosids and Lycosids), sheet web weavers (mostly Agelenids), space web weavers (Theridiids), specialists (mostly Zodariids - ant-eating spiders), sensing web weavers (Atypids) and the mixed group of other hunters either runners and stalkers (Philodromids and Salticids) or small ballooners (Erigonids).

The relative contribution of vineyard systems (conventional or organic), transect location (core or edge of the vineyard), habitat variables (grass cover, grass height, leaf litter cover) and landscape variables on species richness and abundance *in the vineyards* were tested using generalized linear mixed models, GLMMs (Zuur et al., 2009). Vineyards (N=12) and pitfalls inside each transect (N=5) were considered as random factors. The fixed factors were represented by: farming systems (organic or conventional), transect location (core or edge of the vineyard), sampling period, habitat variables and landscape variables. Conditioning scatter plots were used to evaluate possible interactions among these variables. The significance of factor levels in the models was tested through maximum likelihood methods, and model simplification was undertaken. Akaike's information criteria (AIC) was used to test the goodness of fit of the estimated statistical models, and a model with a lower AIC was preferred to one with a higher AIC. Likelihood ratios were used for testing the explanatory power of the models and, using the *drop1* function, we selected the minimum adequate model best explaining the data (Crawley, 2002). A Poisson distribution of errors was specified since variables were based on count data. All models were checked for overdispersion via the ratio between Pearson residuals of the model and the degrees of freedom. Observation level was treated as a random factor when models showed overdispersion (Elston et al., 2001).

The effects of farming systems, habitat and landscape structure *on the adjacent forest patches* were also tested on the abundance and species richness of carabids and spiders using univariate GLMMs.

The farming system, habitat and landscape variables were set as fixed factors, while the vineyards (N=12) and the pitfalls inside each transect (N=5) as random effects.

In all GLMM analyses, the pitfall was the basic sampling unit, and the number of species and the abundance of arthropods per trap was measured.

All statistical analyses were run using R package (R Core Team, 2013; Roberts, 2012).

3. Results

3.1. Assemblage composition

A total of 1541 carabids and 1204 adult spiders were collected, corresponding to 49 and 95 species respectively (Table. 1). Juveniles of spiders (261) were also collected; however, they were excluded from the analyses because they could not be identified at the species level.

In organic systems, the average number of individuals per pitfall was 3.73±6.09 in vineyards and 5.62±7.5 in forest patches. In conventional systems, the average number of individuals was 5.59±14.69 in vineyards versus 1.33±2.54 in forest patches.

Most of the arthropods were collected inside the vineyards (85% of individuals and 74% of species), because the sampling effort was twice as high in vineyards (two transects, ten pitfall traps) than in adjacent forest patches (one transect, five traps). Macropterous carabids were the most abundant guild in vineyards with 64% of sampled individuals. *Calathus fuscipes graecus* and *Brachinus crepitans* were the predominant brachypterous species, while *Harpalus dimidiatus* was the most abundant macropterous species.

Spiders were dominated by the ground hunters guild with 58% of sampled individuals, followed by specialists (14.7%), space web weavers (8.8%), ambush hunters (8.3%), other hunters (5.8%) and sheet web weavers (4.6%). Sensing web weavers were very poorly represented (only one individual found in a conventional vineyard) and were therefore discarded from analyses. *Zodarion rubidum*, an ant-eating specialist, and the ground hunter, *Haplodrassus dalmatensis*, were the predominant spider species. The lists of carabid and spider species are given in supplementary material Appendix A and B, respectively.

3.2. Landscape and habitat characterization of vineyards

On a large scale within the 1.5 km radius buffer, landscape variables did not differ significantly between organic and conventional systems. On the contrary, on a small scale within a 200 m radius buffer, the area of vineyards was smaller (Kruskal-Wallis chi-squared = 4.20, df = 1, residual df=26, p-value = 0.04), while the area of adjacent forests (Kruskal-Wallis chi-squared = 10.17, df = 1, residual df=26, p-value = 0.001), and Shannon- Wiener diversity index (Kruskal-Wallis chi-squared = 3.84, df = 1, residual df=26, p-value = 0.05) were greater in organic than in conventional landscapes.

Since organic and conventional vineyards were located in the same contexts, as shown by landscape analysis on a large scale, only small scale variables were used to identify landscape factors affecting species richness and total abundance/trap in vineyards. The first four principal components (PC1, PC2, PC3, PC4) accounted for 81.8% of the total variation in the landscape structure matrix, with eigenvalues > 1 (Table. 2). The Shannon diversity index along with grassland, crop and shrubland areas were positively correlated with PC1 while vineyards areas and largest patch index (LPI) were negatively correlated with PC1. This shows a gradient from landscapes dominated by vineyards to more diverse and rich landscapes. PC2 was correlated negatively with woodland areas and positively with the distance from woodland. PC3 was positively correlated with patch richness, urban and uncultivated areas, and PC4 was positively correlated with hazelnut orchards.

Habitat analyses showed that grass height (Kruskal-Wallis chi-squared = 12.27, df = 1, residual df=26, p-value = 0.0005) and the percentage of leaf cover (Kruskal-Wallis chi-squared = 13.98, df = 1, residual df=26, p-value = 0.0002) were significantly higher in organic than in conventional vineyards.

3.3. Factors affecting diversity in vineyards

GLMM models regarding the richness and abundance of carabid and spider species are shown in Table 3a-3b. Sampling period was included in most of the models (with the exception of those relative to spider specialists and sheet web weavers), with total abundance and species richness higher in the first than in the second and third periods. Carabid species richness and abundance were higher in the core transect (fig. 1) and were negatively correlated with PC2, increasing therefore when forests were larger and closer to the vineyards. Spider species richness was lower in conventional vineyards, and increased according to grass cover and PC3. That is, it increased with urban and uncultivated areas and patch richness. Spider abundance responded in the same way as the species richness (fig. 2), in addition to being greater in the core transect.

Carabid functional guilds

Species richness and abundance of brachypterous species were negatively correlated with PC2, increasing therefore when forests were larger and closer to the vineyards. Also, the abundance was significantly lower in the core than in the edge transect.

The number of macropterous species was higher in the core than in the edge transects. Abundance of macropterous species was higher in conventional than organic vineyards and in core than in edge transects; it also increased with taller grass and a lower percentage of grass cover. Finally, abundance was positively correlated with PC1 and negatively correlated with PC4, meaning that it increased with larger grassland, shrubland and crop areas and smaller hazelnut areas (Table. 3a).

Spider functional guilds

Species richness of ground hunters, ambush hunters and other hunters was greater in organic than in conventional vineyards as well as the abundance of ground and other hunters.

The abundance of ambush and other hunters increased with larger grass cover. Ambush hunters showed also a significant interaction _grass cover * farming system‘, suggesting a negative effect of grass cover in conventional vineyards. Species richness of ground hunters also increased with taller grass.

Species richness and abundance of specialists (namely ant-eating spiders) were higher in conventional than in organic vineyards, while species richness and abundance of sheet web weavers were associated with grass height only, decreasing significantly with taller grasses (Table. 3b).

3.4. Differences between organic and conventional forest patches

Univariate GLMMs showed that diversity parameters of the overall carabid community (species richness and abundance of individuals), macropterous (species richness) and brachypterous carabids (species richness and abundance) were lower in the forest patches adjacent to conventional than in the patches close to organic vineyards, and their values increased along with the size of the forest patch (supplementary material Appendix C). Carabid species richness was also positively correlated with leaf litter and dead wood cover and negatively correlated with grass cover and mean grass height. Macropterous carabids were also positively correlated with bare ground and dead wood cover, shrub areas and heterogeneous landscape. Brachypterous species richness was also positively correlated with the size of the forest patch, litter and dead wood cover, and negatively correlated with grass cover and grass height.

Concerning spiders, the overall community (abundance and species richness), ambush hunters (abundance) and specialists (abundance and species richness) increased significantly in forest patches adjacent to organic vineyards compared to those adjacent to conventional vineyards (supplementary material Appendix D). The diversity parameters of the overall community (abundance and species richness) were also positively correlated with grassland area, forest patch area, heterogeneous landscape, and negatively correlated with LPI and vineyard area. Also, the abundance of spiders significantly increased with shrubland area.

Species richness of ground hunters responded positively to bare ground cover, forest patch and grassland area, while their abundance was positively correlated with bare ground, grassland and shrubland area, grass cover and Shannon patch diversity index. Abundance was also negatively correlated with the area of the vineyards, LPI and grass height. Ambush hunters (species richness and abundance) were positively correlated with bare ground, grass height, the area of shrubs and heterogeneous landscape. Sheetweb weavers (species richness and abundance) were positively correlated with grassland and shrub area and heterogeneous landscape. The diversity parameters of the specialist guild showed a positive correlation with litter and dead wood cover and a negative correlation with grassland cover, grass height and homogenous landscapes (i.e. LPI).

4. Discussion

In our study, we considered carabid and spider functional guilds to monitor the effects of two farming systems in addition to habitat characteristics and landscape context. Our approach allowed us to take into account the heterogeneity of the ecological requirements of distinct functional groups within carabid and spider assemblages (Cole et al., 2002, Clough et al., 2007, Negro et al., 2009, Batáry et al., 2012). Our results confirmed the robustness of this approach, because different guilds of carabids and spiders responded in different ways to habitat, landscape and farming systems. Considering all the species of carabids or spiders together may be misleading in two ways: the ecological preference of the dominant guild may become representative of the overall assemblage; or the ecological preferences of different groups may mask a potential trend in the community response to a possible disturbance. As a caveat, we acknowledge that, by using pitfall traps, sampling was not exhaustive for spiders, as we mainly detected ground dwelling spiders.

4.1. Habitat variables

Habitat variables appeared to have minimal influence on carabids. Only the abundance of macropterous species were linked to grass cover and grass height. On the contrary, spiders seemed to be more dependent on habitat structure. In particular, species richness and abundance of ambush, ground and other hunters were positively linked to grass cover and/or grass height, while species richness and abundance of sheet web weavers were negatively correlated with grass height. Higher grass height and grass cover may provide protection and favorable thermal conditions for prey, which may attract a large number of spider species in turn. In particular, the preference of ambush hunters for higher grass cover accords with their hunting strategy, since they typically lie motionless in ambush for prey. Ambush hunters were mainly represented by *Xysticus kochi* (Thomisidae) whose abundance has also been shown to increase with higher litter and grass cover in other studies (Clark et al. 1994, Zrubecz et al. 2008). Ground hunters are dominated by species such as *Haplodrassus dalmatensis* and *Pardosa hortensis* belonging to the Gnaphosidae and Lycosidae families, respectively, while other hunters are mainly represented by *Thanatus arenarius* (Philodromidae). This species is known to select typically open and dry habitats. The negative correlation of sheet web weavers with grass height seems to be related to their preference to construct webs at low heights (Janetos, 1982).

4.2. Landscape structure

On a large scale, conventional and organic vineyards did not differ with respect to landscape structure variables, suggesting that they were located in the same general landscape context. Nonetheless, small scale analysis showed that *landscape structure* in organic farms differed significantly from the conventional ones: the former were characterized by smaller vineyards, larger forest areas and greater landscape heterogeneity. Moreover, organic systems favored the maintenance of bushes, trees and small forest patches. In this framework, carabids appeared to depend on landscape structure, while no guild of spiders seemed to be affected by the small scale landscape. This result seems to contrast with Isaia et al., 2006, in which landscape heterogeneity and distance from forest patches affected significantly the composition of the spider assemblage, both on the ground (pitfall trapped) and on the vines (visual standardized search).

Species richness and abundance of brachypterous carabids increased with large forest patches close to the vineyards; while abundance of macropterous carabids was linked to large grassland, shrubland and crop areas and to small hazelnut areas. Brachypterous species are mainly predators. They are medium-large body size species, either wingless or with reduced wings, and hence incapable of long movements or dispersal by flight (den Boer, 1970; Negro et al. 2009). It is sensible that they are mainly associated with less managed sites (Ribera et al., 2001). Large forests represented a potential source habitat for this functional guild. A greater proximity of the forests to vineyards allowed them to disperse with short movements and reach areas with high availability of prey. On the contrary, macropterous species are small body sized, flying, pioneer species which prefer open and disturbed areas and are able to colonize new habitats (Negro et al., 2009, Ribera et al., 2001)

4.3. Farming systems

In general, organic farming exhibited greater biodiversity and abundance of arthropod predators, allowing us to assume a better top-down control of insect pests. However, it need to be considered that generalist predators like several species of carabids and spiders may strongly reduce pest insects, but they may also act as an intraguild predator, reducing the control by other specialist predators or parasitoids (Snyder et al., 2001). The different guilds of carabids and spiders showed different preferences according to farming system.

For example, macropterous carabids were more abundant in conventional vineyards than the organic ones. On the contrary, brachypterous species richness and abundance were explained mainly by landscape context in the models instead of farming system (Table. 3a), suggesting that the main driver influencing brachypterous carabids was the small scale landscape structure surrounding the vineyards. Conventional vineyards which cover larger areas and have less ground cover were selected by macropterous species. These commonly prefer disturbed habitat (Ribera et al., 2001). Apart from differences in farming system, macropterous and brachytpterous species showed different patterns of abundance according to its location: the former were more abundant in the core transect, while the latter in the edge transect. The vineyard cores are probably the most disturbed habitat in terms of natural vegetation development. For this reason they might be more attractive to macropterous species. Conversely, field edges may have benefitted from lower farming intensities and from edge effects from the forest patches close to the vineyards (Rand et al., 2006). Our results showed that field edges and field cores may often contain communities that vary in diversity and abundance according to functional group, with consequent provisioning of ecosystem service varying in the edge compared to the core. Brachypterous species are indeed predators, while most of phytophagous carabids belong to macropterous species.(Brandmayr et al., 2005). Moreover, the surrounding landscape matrix, and specifically the distance of forests to the vineyard edges, may act as a source for farmland brachypterous carabids in that they provide refuges and corridors for beetles dispersing between and across fields.

The effect of farming system in addition to habitat variables was particularly evident in spiders since variations in the community indices were explained in most of the models by organic versus conventional systems (Table. 3b). The influence of farming system on spider communities implies that some unmeasured factor such as pesticides may affect spiders. Omitting pesticides would both directly reduce spider mortality, and increase food availability through a reduction in the mortality of spider prey (Schmidt et al., 2005). However, the different guilds of spiders exhibited opposite preferences in relation to farming system. In particular, organic farming enhanced predators like ground, ambush and other hunters, relevant for ecosystem services. In contrast to our expectations, specialists (mostly ant eating spiders) appeared to prefer conventional vineyards. However such a trend appears unclear: considering the negative effect of conventional management on ants (Lobry de Bryuyn 1999, Dauber 2001), a positive effect on ant spiders would have been expected. On the other hand, conventional farming may favor ant nesting for two reasons: (1) the use of herbicides in conventional vineyards may determine more open soil surface that is favorable for ants, strongly depending on high soil temperatures; (2) mechanical treatments for the weed control in organic vineyards may increase soil disturbance. Less soil disturbance in conventional vineyards because of the use of herbicides could favor the ground-nests of ants.

The different farming systems, chemical treatments and habitats did not affect ambush hunter abundance, but only species richness. This was probably due to the higher diversification of microhabitats found in organic vineyards and to the high sensitivity of spiders to pesticides (Ripper 1956, Mansour 1987, Mansour & Nentwig 1988, Pekar 1998, Fountain et al. 2007). A similar explanation can be given concerning ground hunters (both diurnal and nocturnal spiders) and for the mixed guild of other hunters (foliage dwellers and stalkers).

Ecosystem services provided by the increasing abundance and number of functional guilds in organic fields may benefit farmers due to better top-down control of pest species (Krauss et al., 2011).

The preference patterns of spiders for farming systems is strongly linked to the habitat features characterizing organic and conventional vineyards. Organic vineyards, for instance, were characterized by higher grass height and leaf cover which provide higher structural complexity and hence refuges at the soil surface, and may potentially increase the availability of herbivore prey (Zrubecz et al., 2008; Purtauf et al., 2005).

The functional guild of the specialists showed a preference for conventional vineyards. Since most of the specialists are ant-eating spiders (Zodariidae) (Pekar, 2004), we hypothesize that the conventional vineyards might have higher availability of specialist prey.

A rather surprising result of this study was that species richness and abundance of carabids and spiders were higher in forest patches adjacent to organic than in patches close to conventional vineyards, irrespective of functional guilds. It should be noted that forest patches were usually located below the vineyards. This result could be determined by a possible leaching of chemicals and fertilizers coming from conventional systems and/or smaller forest patch areas surrounding conventional vineyards. The possible leaching of chemicals may have caused arthropod mortality and/or a decrease of food availability for predators such as spiders and carabids in forest patches adjacent to conventional vineyards. Other drivers influencing the arthropod community in the forest patches were characterized by habitat and landscape variables. In carabids, the flying macropterous are strongly influenced by landscape features such as presence of bushes and patch richness, showing the importance of the hedges for the maintenance of good disperses in the agricultural landscape (Fischer et al., 2013), which may enhance the biological pest control for adjacent agricultural crops via carabids‘ colonisation potential (Niemelä, 2001). Conversely, brachypterous which have a limited dispersal abilities are mainly influenced by habitat variables and by the size of forest patches (Pearce et al., 2005). However, the models ranked based on the AIC value showed that in most cases species richness in carabids was mainly influenced by the farming system while abundance of individuals responded to habitat/landscape variables. Moreover, our results showed that spiders are strongly influenced by landscape heterogeneity and in particular by the presence of grasslands (Lacasella et al., 2014).

Many studies have considered how landscape context in organic and conventional farms influences arthropod communities (Schimdt et al., 2005; Purtauf et al., 2005), but much less consideration has been devoted to evaluating the effects of farming systems on the communities of the surrounding habitats and the spillover in the managed to natural direction (Blitzer et al., 2011).

Here, we evaluated both the effect of landscape context on arthropods sampled inside the vineyards, and the effect of vineyard systems on the arthropod communities sampled outside the vineyards. The preservation of forest patches surrounding the farmland is likely to be useful for biodiversity conservation in all types of agro-ecosystems. In crop ecosystems, for instance, forest patches, field margins and grasslands are important refuges for shelter, breeding and dispersal, as well as for hibernation, especially for spring breeding carabids (Holland & Luff, 2000; Wamser et al., 2011; Jonason et al., 2013).

5. Conclusions

Vineyard landscapes of north-western Italy (Langhe, Roero and Monferrato, in Piedmont region) are included among World Heritage Sites listed by UNESCO. These areas form a spectacular expanse of rolling hills where the various combinations of climate, cultivation techniques, type of graft and grape variety determine the development of a wide range of agro-ecosystems. Our results showed that organic farming systems enhance arthropod predators belonging to several functional guilds, and influence the diversity of carabids and spiders in adjacent forest patches as well. Therefore, although conventional systems may promote the diversity of macropterous carabids and specialist spiders, we suggest organic systems should take priority. Our conclusions are also supported by several general considerations. The presence of predator carabids and spiders in crops is particularly important because the control of herbivores depends on high predator densities (Landis et al., 2000; Symondson et al., 2002; Schmidt et al., 2003). The increase, or even the mere preservation of species richness and abundance of spider and carabid predator guilds through organic farming may improve natural pest control, contributing thereby to enhanced agricultural productivity (Östman et al., 2003). Furthermore, conventional farming systems can severely reduce the economic value of some ecosystem services in agriculture (supporting and regulating services, explained in Millennium Ecosystem Assessment, 2005), whereas organic practices may enhance their value (Sandhu et al., 2010). Finally, several studies have shown that organic agriculture enhances the nutritional value of plant foods themselves, the dry matter, the minerals and anti-oxidant micronutrients such as phenols and salicylic acid (Brandt and Mølgaard, 2001; Lairon, 2010).

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Fig. 1. Average number of individuals of carabids sampled per pitfall, in each transect. Bars stand for standard errors. OF: Forest patch transect close to organic vineyards; OE: Edges transect in organic vineyards; OC: Core transect in organic vineyards; CF: Forest patch transect close to conventional vineyards; CE: Edges transect in conventional vineyards; CC: Core transect in conventional vineyards.

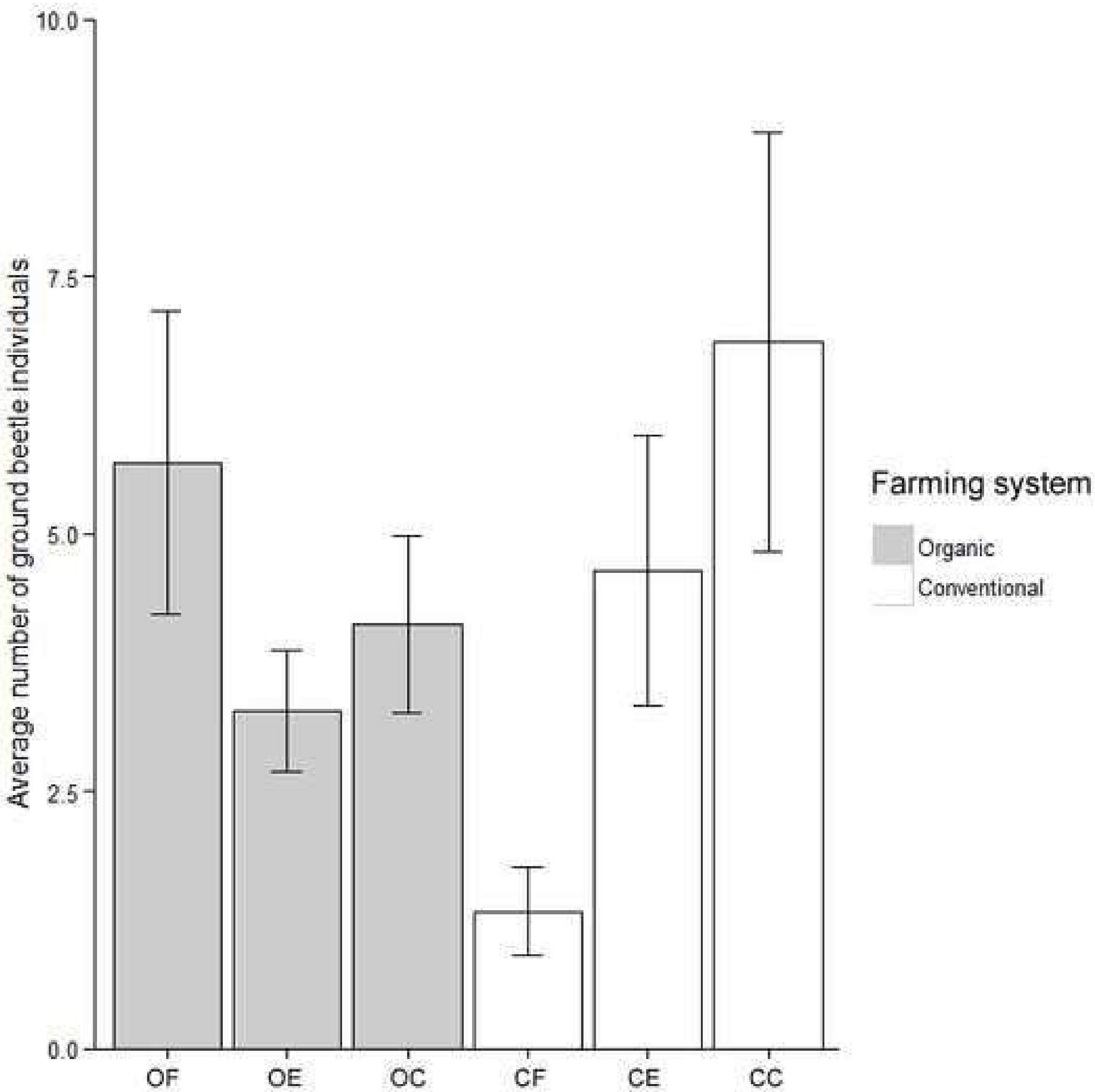

Fig. 2. Average number of individuals of spiders sampled per pitfall, in each transect. Bars stand for standard errors. OF: Forest patch transect close to organic vineyards; OE: Edges transect in organic vineyards; OC: Core transect in organic vineyards; CF: Forest patch transect close to conventional vineyards; CE: Edges transect in conventional vineyards; CC: Core transect in conventional vineyards.

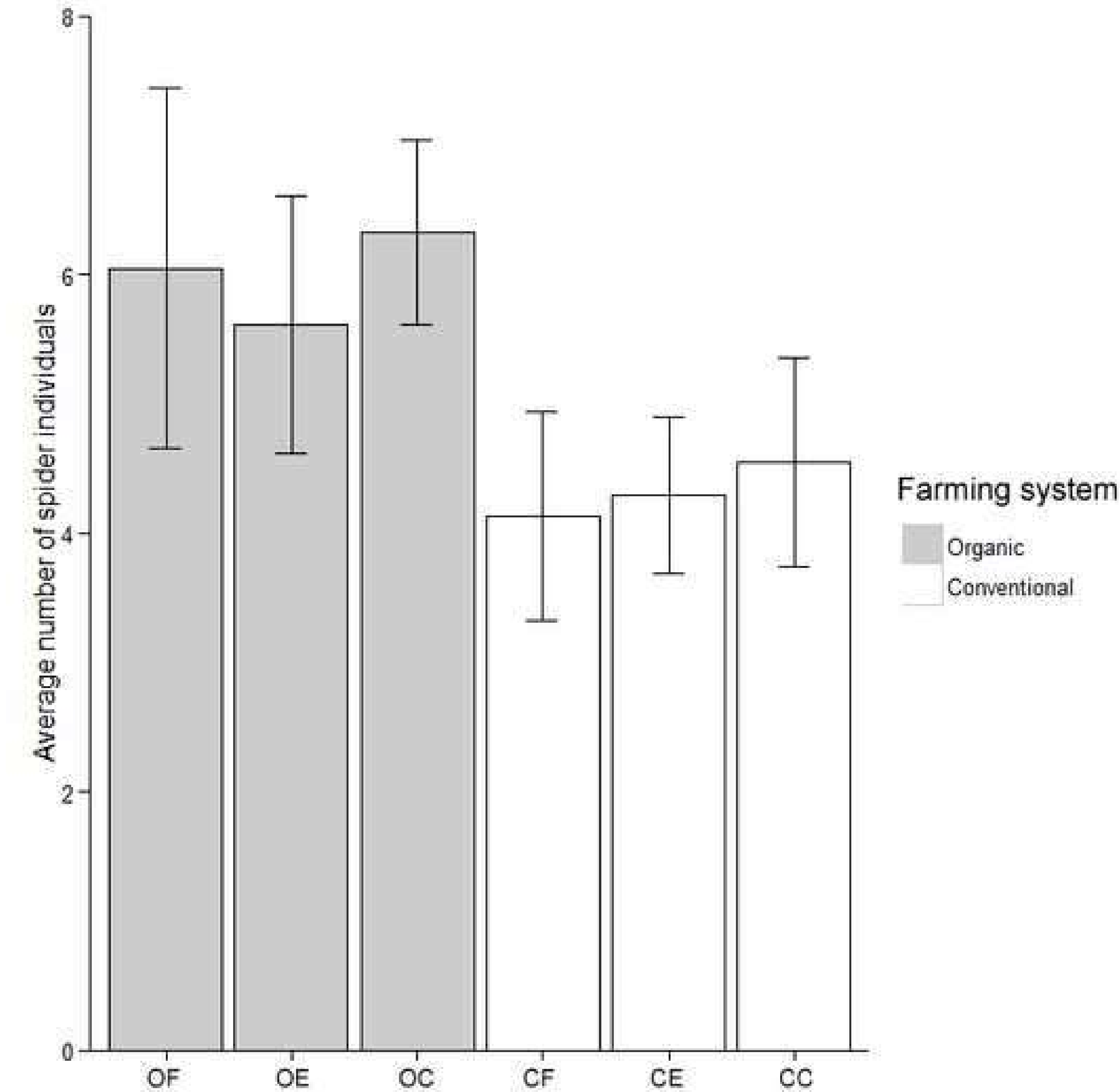

Table 1. Number of individuals and number of species (in brackets) of carabid and spider functional guilds in organic and conventional vineyards, and in forest patches close to organic and conventional vineyards.

Table 2. Results of Principal Component Analysis carried out on small scale landscape variables. The highest loadings are given in bold type.

Table 3a. GLMM results of carabid species richness and abundance, in organic and conventional vineyards. PC: principal component; SP: sampling period.

Table 3b. GLMM results of spider species richness and abundance, in organic and conventional vineyards. PC: principal component; SP: sampling period.

Appendix A List of carabid species collected in each transect (core, edge, forest) of organic and conventional vineyards. OF: Forest patch transect close to organic vineyards; OE: Edges transect in organic vineyards; OC: Core transect in organic vineyards; CF: Forest patch transect close to conventional vineyards; CE: Edges transect in conventional vineyards; CC: Core transect in conventional vineyards. The functional guild of each species is specified (B: Brachypterous, M: Macropterous).

Appendix B: List of spider species collected in each transect (core, edge, forest) of organic and conventional vineyards. OF: Forest patch transect close to organic vineyards; OE: Edges transect in organic vineyards; OC: Core transect in organic vineyards; CF: Forest patch transect close to conventional vineyards; CE: Edges transect in conventional vineyards; CC: Core transect in conventional vineyards. The functional guild of each species is specified (AH: Ambush hunters, GH: Ground hunters, OH: Other hunters, SEW: Sensing web weavers, SHW: Sheet web weavers, SP: Specialists, SPW: Space web weavers).

Appendix C: Univariate GLMM results of carabid species richness and abundance in forest patches close to organic and conventional vineyards. PC: principal component; SP: sampling period.

Appendix D: Univariate GLMM results of spider species richness and abundance in forest patches close to organic and conventional vineyards. PC: principal component; SP: sampling period.

Table 1. Number of individuals and number of species (in brackets) of carabid and spider functional guilds in organic and conventional vineyards, and in forest patches close to organic and conventional vineyards.

Vineyards	ORGANIC VINEYARDS	CONVENTIONAL VINEYARDS	**Forest patches**	CLOSE TO ORGANIC	CLOSE TO CONVENTIONAL
Carabids			**Ground beetles**		
Brachypterous	292 (11)	194 (11)	Brachypterous	129 (7)	34 (5)
Macropterous	194 (36)	675 (27)	Macropterous	14 (6)	9 (6)
Spiders			**Spiders**		
Ambush hunters	57 (4)	25 (4)	Ambush hunters	6 (4)	3 (3)
Ground hunters	363 (36)	207 (37)	Ground hunters	60 (16)	54 (21)
Other hunters	45 (12)	12 (12)	Other hunters	13 (3)	7 (7)
Space web weavers	40 (4)	47 (7)	Space web weavers	2 (2)	13 (3)
Sheet web weavers	13 (2)	33 (2)	Sheet web weavers	15 (3)	14 (1)
Sensing web weavers	0	1 (1)	Sensing web weavers	0	0
Specialists	21 (2)	124 (3)	Specialists	25 (4)	4 (2)

Table 2. Results of Principal Component Analysis carried out on small scale landscape variables. The highest loadings are given in bold type.

LAND USE TYPE	PC1	PC2	PC3	PC4
Urban areas	0.351	0.502	**0.644**	0.014
Woodland areas	0.365	**-0.849**	-0.23	0.048
Uncultivated areas	0.028	-0.111	**0.894**	0.007
Hazelnut orchard areas	0.027	-0.06	0.028	**0.969**
Grassland areas	**0.757**	0.05	0.007	-0.05
Crops areas	**0.83**	0.292	-0.015	-0.213
Shrubland areas	**0.735**	-0.231	0.138	-0.291
Vineyard areas	**-0.908**	0.373	-0.01	-0.134
LPI	**-0.918**	0.256	-0.059	-0.169
Mean areas of patches	-0.74	-0.188	-0.203	-0.107
Patch Richness	0.699	0.013	**0.564**	0.051
Shannon Diversity Index	**0.92**	-0.167	0.279	0.118
Distance from woodland	0.053	**0.848**	-0.172	-0.031
Eigenvalues	5.612	2.116	1.757	1.15
Total variance %	43.166	16.281	13.514	8.847

Table 3a. GLMM results of carabid species richness and abundance, in organic and conventional vineyards.

PC: principal component; SP: sampling period.

CARABIDS				
Overall community species richness				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	0.689	0.171	4.018	***
Transect location-Core	0.246	0.098	2.491	*
PC2	-0.201	0.082	-2.503	*
SP 2	-1.257	0.131	-9.565	***
SP 3	-0.991	0.118	-8.356	***
Overall community abundance of individuals				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	1.183	0.268	4.42	***
Transect location-Core	0.355	0.175	2.025	*
PC2	-0.316	0.129	-2.45	*
SP 2	-1.857	0.211	-8.792	***
SP 3	-1.736	0.206	-8.422	***
Brachypterous				
Species richness				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-0.375	0.182	-2.065	*
PC2	-0.209	0.091	-2.281	*
SP 2	-0.803	0.204	-3.944	***
SP 3	-0.772	0.202	-3.823	***
Abundance				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-0.00142	0.324	0	0.997
PC2	-0.336	0.159	-2.11	*
Gradient-Core	-0.981	0.1743	5.627	***
SP 2	-1.359	0.266	-5.12	***
SP 3	-1.631	0.274	-3.823	***
Macropterous				
Species richness				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	0.115	0.215	0.54	0.591
Transect Location-Core	0.376	0.187	2.9	**
SP 2	-1.557	0.187	-8.33	***
SP 3	-1.101	0.155	-7.12	***
Abundance				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-0.899	0.647	-1.39	0.165
System-Conventional	1.273	0.747	1.7	*
Transect Location-Core	0.549	0.229	2.39	*
Grass %	-0.01	0.007	-1.55	**
Grass height	0.063	0.0089	7.12	***
PC1	0.421	0.148	2.84	**
PC4	-0.655	0.111	-5.88	***
SP 2	-2.461	0.29	-8.48	***
SP 3	-1.782	0.233	-7.65	***

Table 3b. GLMM results of spider species richness and abundance, in organic and conventional vineyards.

PC: principal component; SP: sampling period.

SPIDERS				
Overall community specie richness				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	0.899	0.172	5.22	***
System-Conventional	-0.203	0.098	-2.07	*
Grass %	0.008	0.002	3.52	***
PC 3	0.114	0.054	2.11	*
SP 2	-0.43	0.117	-3.66	***
SP 3	-0.187	0.094	-1.98	*
Overall community abundance				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	1.5731	0.18	8.73	***
System-Conventional	-0.203	0.098	-2.07	*
Transect location-Core	0.138974	0.069813	3.52	*
Grass%	0.007301	0.001812	2.11	**
PC3	0.067	0.012	2.373	*
SP 2	-0.68	0.166	-4.11	***
SP 3	-0.19	0.13	-1.42	NS
Ambush hunters				
Species Richness				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-0.694	0.254	-2.734	**
System-Conventional	-0.894	0.294	-3.042	**
SP 2	-1.7675	0.607	-2.909	**
SP 3	0.15	0.279	0.57	NS
Abundance				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-1.579	0.552	-2.859	**
System-Conventional	0.451	0.673	0.67	NS
Grass %	0.018	0.008	2.422	*
Grass %: Systems (Conventional)	-0.025	0.01	-2.511	*
SP 2	-2.036	0.606	-3.359	***
SP 3	-0.025	0.01	-2.365	.
Ground hunters				
Species Richness				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	0.796	0.242	3.285	**
System-Conventional	-0.449	0.113	-3.972	***
Hgrass	0.027147	0.007	3.626	***
SP 2	-1.019	0.146	-6.989	***
SP 3	-1.056	0.141	-7.474	***
Abundance				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	0.952	0.294	3.238	**
System-Conventional	-0.615	0.149	-4.126	***
Hgrass	0.032	0.009	3.351	***
SP 2	-1.226	0.185	-6.624	***
SP 3	-1.206	0.174	-6.895	***
Other hunters				
Species Richness				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-0.537	0.26	-2.066	*

System-Conventional	-0.512	0.25	-2.04	*
SP 2	-1.02	0.3697	-2.76	**
SP 3	-0.561	0.292	-1.922	NS
Abundance				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-1.646	0.53	-3.105	**
System-Conventional	-0.626	0.317	-1.979	*
Grass%	0.014	0.0064	2.28	*
SP 2	-1.031	0.445	-2.319	*
SP 3	-0.669	0.37	-1.81	NS
Sheet Web Weavers				
Species Richness				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-2.29413	1.2525	-1.832	0.067
Hgrass	-0.06292	0.02755	-2.284	*
Abundance				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-2.20571	1.25809	-1.753	0.0796
Hgrass	-0.06319	0.02705	-2.336	*
Specialists				
Species Richness				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-1.8954	0.4193	-4.521	***
System-Conventional	0.7933	0.2749	2.885	***
Abundance				
Fixed Factors	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	-2.718	0.583	-4.663	***
System-Conventional	1.258	0.37	3.399	***

Table 4. Indicator Values for functional guilds in organic and conventional vineyards and in forest patches close to organic and conventional vineyards.

	Functional Guilds	**Organic vineyards**	**Conventional vineyards**	**pval**	**Forest patches - Organic**	**Forest patches - Conventional**	**pval**
Carabids	Brachypterous	**42.15**	**28.36**	**	**65.46**	**23.91**	**
	Macropterous	33.48	41.21	NS	5.31	26.72	NS
Spiders	Ambush Hunters	**28.02**	**4.56**	***	11.03	4.11	NS
	Ground Hunters	**57.76**	**23.12**	***	45.95	37.18	NS
	Other Hunters	20.96	8.52	NS	21.29	19.19	NS
	Sensing Web Spiders	0	1.09	NS	NA	NA	NA
	Sheet Web Weavers	2.52	9.72	NS	16.94	16.85	NS
	Space Web Weavers	14.08	16.15	NS	1.59	23.15	NS
	Specialists	**2.87**	**29.06**	***	**36.81**	**1.72**	*