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PPP exposure models for 3-D orchards considering spraying technologies in Southern Europe

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Abstract

Tree orchards like citrus, olives, apricot, peach and nuts, also known as 3D orchards, are typical crops of southern Europe (SEU) and present different vegetation characteristics (tree size, tree shape, foliar density, etc) and distinctive training systems and row and tree spacing in comparison with the ones used in apple and pear orchards in Central and Northern Europe, which are 3D orchards more typical of these zones. Furthermore, plant protection products (PPP) application techniques and their setting up are different as well. Moreover, the climatic conditions between North and South of Europe are pretty dissimilar. This could result in very different PPP exposure scenarios to those currently applied for risk assessment of pesticides where models developed for agro-climatic conditions typical of northern Europe are used. The multidisciplinarity and the specificity of the topic, in one hand related to registration but also to pesticide application equipment and training system of crops, have been addressed by a consortium with the appropriate expertise in the related fields. The present project characterised distribution of 3-D crops in Europe, addressing the ones present just in SEU and gathered information on equipment use, training system of crops and pesticide practices through dedicated surveys to farmers, sprayer inspection stations and manufacturers. A literature search was also performed to check whether studies specifically designed for 3-D orchards, in agro-climatic conditions of Southern Europe about drift and exposure models, are available in the public literature. From the few articles assessed as relevant to this project, some discrepancies between what is currently used and what is measured in those 3-D orchards of Southern use were identified, tackling the "worst-case" approach. The other key point raised by the literature search, which can greatly impact risk assessment procedures, is the importance of measuring not just sedimenting drift but also airborne spray drift: several studies report higher values for airborne drift compared to those found at ground level for the same downwind sampling distance.

3-D orchards

Overall, the results of this project provide valuable information to better address risk assessment of PPP in 3-D orchards, identifying major data gaps for exposure assessment that require further work and areas that require harmonisation.

Key words: drift, spray technology, citrus, olives, vineyard, fruit orchards, air blast sprayer, risk assessment.

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Summary

3-dimensional (3D) crops are defined as those that do not grow covering the ground, but consist of a volume of vegetation growing upwards, with non-negligible height, which requires that pesticides are applied sidewise, to cover the whole canopy. 3-D crops of southern Europe (SEU), like peaches, apricots, cherries and kiwi, nuts, citrus, olives, vines, etc, present different vegetation characteristics (tree size, tree shape, foliar density, etc) and very different training systems and row and tree spacing in comparison with apple and pear orchards, present also in Central and Northern Europe. Furthermore, pesticides' application techniques and their setting up is also different and the climatic conditions between North and South of Europe are pretty different.

Currently, in the procedure for the registration of pesticides, the risk assessment is based on drift and exposure models obtained in the agro-climatic conditions of Northern-Central Europe, that do not take into account the Southern scenarios. Therefore, registration of pesticides for these crops mainly present in SEU would need an exposure assessment characterised by a "Southern approach", still not available, to be considered reliable: this update requires information coming from Southern countries because, until now, just data obtained from the Central - Northern countries have been used.

For these reasons, there is a need to generate, collect and synthesise information about the current crop protection management and spray technology (sprayer`s type, spray drift reduction techniques, …) in SEU.

The collection of data and information of 3-D orchards like vines, citrus, olive, and fruit crops in EU in terms of localization and extension of cultivated surface has been performed using census data collected from international databases while the major national areas of production of the selected orchards were identified with the contribution of national census data (collected for the year 2019, to be consistent with the European data available during collection).

A comparison was performed among the area of SEU cultivated with a specific crop with respect to the European Union area cultivated with the same one, by calculating the percentage that the area cultivated with each crop in SEU represented respect the total area cultivated in Europe, in order to identify which crops deserve investigation in Southern Europe. As a cut-off criteria, crops representing an area lower than 50.000 ha were excluded by further investigation, since they were considered minor with respect to all the crops cultivated in Europe.

Furthermore, the representativeness of the three Member States involved in this project (Italy, Greece and Spain) was tackled for each 3-D crop identified.

When the total area cultivated with a specific 3-D crop in Italy, Spain and Greece represented more than 50% of the area cultivated in the European Union (27) and more than 80% in Southern Europe, this orchard was considered well represented and suitable to be addressed by this project.

For each crop, the statistical data have been reported at province level, just for regions where the cultivated area represents at least 10% of the national cultivated area.

Therefore, considering the results from this analysis and taking into account the crop and the training system, the following list of crops was considered the most of SEU:

3-D orchards

- Grapes (to be considered also for the two different types of cultivation: table grape and wine grape)
- Apricots
- Cherries
- Lemons and limes
- Oranges
- Peaches and nectarines
- Tangerines, clementine, satsumas
- Olives (to be investigated also for the possible difference occurring in treatments for intensive vs. traditional training system)
- Nuts (sum of almond, walnuts, chestnuts, hazelnuts and pistachio).

These crops, after the analysis of their distribution in the different countries, were grouped into 5 major classes: citrus, olive, grapes, fruit trees (other than apple and pear), and nuts.

From national census data, in Spain 8 regions out of 17 (Cantabria, Galicia, Islas Baleares, Islas Canarias, La Rioja, Madrid, Navarra, Principado de Asturias and País Vasco) could be excluded from further investigations, since the 3-D crops identified, if present, are cultivated in very minor areas. For the same reason, in Greece, 5 regions out of 13 (Eastern Macedonia and Thrace, Western Macedonia, Ionian Islands, Northern Aegean and Southern Aegean) were excluded from further assessment as well as, in Italy, 8 regions out of 20 (Valle d'Aosta, Liguria, Friuli Venezia Giulia, Trentino Alto Adige, Marche, Umbria, and Molise) were no more investigated.

Information on crops, spray equipment and pesticide application practices were collected through surveys. Three different questionnaires were developed:

- The first questionnaire was submitted to the workshops making inspection of sprayers in use.
- The second questionnaire was submitted to sprayer manufacturers.
- The third questionnaire was submitted to farmers and field technicians.

The questionnaire for the sprayer inspection stations and for the manufacturers included information related to:

- The characteristics of equipment inspected/sold
- The most widespread equipment
- The trend of machine characteristics in marketing over the last 10-15 years

The questionnaire proposed to farmers and field technicians, collected information on:

- the 3-D crops cultivated (e.g. species, training system, variety, etc..)
- the spraying equipment used (e.g. type and model, age of sprayer)
- the spray application technique (e.g. parameters used to apply PPP like spray pressure, volume applied, forward speed, airflow rate)
- use of Spray Drift Reducing Techniques –SDRT - (e.g. drift-reducing nozzles, closure of airflow on one side when the row-edges are sprayed)
- adoption of buffer zones (e.g. free crop buffer zone or cropped-buffer zone)
- presence/absence of surface water bodies
- distance from the field and surface water bodies
- bees protection system adopted

- pesticide mixing and loading system used
- time of PPP mixing and loading
- time of application
- the presence of financial support from EU or regional government for the adoption of SDRT or for buying new environmental-friendly sprayers (e.g. tunnel recycling sprayer)
- the number of spray application per year (how many insecticide treatments and how many fungicide treatments)
- Personal Protection Equipment (PPE) used

The three questionnaires were developed by specialists using a simple language to facilitate understanding and to collect as much information as possible.

For this project, the sample size for each target population was calculated with a tool available on the Creative Research Systems website (available at https://www.surveysystem.com/sscalc.htm), where software related to conducting surveys is offered. The tool can be used to determine how many people need to be interviewed in order to get results that reflect the target population as precisely as needed. It can also provide the level of precision in an existing sample.

Taking into account a confidence limit of 95%, with 30 surveys, a confidence interval of 16.2% would be obtained, which is considered an acceptable interval for this study.

Therefore, the consortium decided to carry out 30 surveys in each target population. Regarding the farmer case, it was decided to conduct 30 surveys for each 3D crop on which the project focuses: citrus, olive, grapes, fruit (other than apple and pear), and nuts.

Results from the surveys were structured into three main topics:

- Topic A Growers, crop, PPP application practices
- Topic B: State of spraying equipment and the habits of equipment owners
- Topic C: Spray Drift and Use of Techniques for its Reduction

Topic A

Considering growers, repartition between professional and part-time farmers follows a similar trend for all the southern European (SEU) countries and the five crops object of the survey: in almost all the crop types (excluding olives), more than 80% of the farmers are professionals. In all the SEU most of the farms are located in plain land, independently of the crop. In some cases, the farms are situated in intermediate conditions, for example they have some terrain in plain and some in hilly areas. Regarding nuts, in general more farms are in hilly areas. Considering the cultivated surface area, the trend is slightly different between the states and the crop types. In general, the farms in Greece are smaller when compared to the other states, independently of the crop considered.

The training system adopted, excluding vineyard, can be divided into three macro-categories: traditional, extensive and intensive. Traditional means intended fields with low density (large inter-row distance and plant widely spaced on the rows), canopy developed in volume and non-continuous vegetative wall. Extensive system has a slightly higher density, with lower inter-row and inter-plant distance, resulting in a more continuous vegetative wall. The intensive system is quite different from the previous two since the higher density results in a continuous vegetative wall along the rows, and also with a lower width of the crop across the row. The main advantages of this type of training system, other than the increase of the yield and the possibility to mechanise the operation, is the reduction of hours of labour required. The training systems differ for each crop, but their occurrence is similar in SEU. Vineyard is peculiar: in this crop, the training system influences the shape of the canopy more, when compared to the other target crops of this survey. In the vineyard case, the training system also influences the type of pesticide application equipment (PAE) adopted. Independent of the country considered, the trellised vineyard is widely the most common. This may depend on the fact that with this training system all the operations are fully mechanised. Super-intensive category was not included because currently its use is scarce and mainly referred to olive and almond orchards. In other crops, like citrus, they are under research.

In all the SEU countries, the Integrated Pest Management (IPM) system is by far the most adopted, regardless the type of crop considered.

The airblast sprayer is the most common PAE, with the class from 5 to 10 years old resulting as the most frequent; from the surveys, the majority of the interviewees states that their PAE are certified.

The criteria considered most relevant by farmers when purchasing a new PAE are (in order of relevance): spray efficacy, precision application, operator safety, reduction of PPP usage, environmental protection and the selling price. The relevance obtained by these criteria puts evidence that farmers, nowadays, are starting to take care of the environment and human health.

For each crop type and country, the percentage of farmers that do not adjust any spraying parameter is always below 20%. Almost all of the growers report to modify the volume rate and the spray pressure along the vegetative season and almost the totality of the interviewees stated that they try to maintain a constant forward speed during the spray application. According to the growers, the parameters related to the airflow characteristics (fan speed and air direction) are on a secondary level of importance. According to the interviewees, the spray application timing is decided by taking into account the advice of plant scientists or based on the personal experience of the growers themselves.

In every crop type considered in the survey, most of the farmers declare to spend between 0.5 hour to 1 hour to spray one hectare. It is relevant to point out that in this question there is no distinction between different PAE, which directly affects the operative time.

An important portion of the surveyed farmers states to spray one hectare or less per day, while the majority declares to spray between 1 ha to 5 ha per day.

Almost the totality of the interviewees states that they read the labels on the PPPs, and almost all the interviewees report to be aware of the fact that the dose in the labels could be expressed in terms of kg or L/ha or as a concentration (e.g. kg or L of PPP / 100 L of water).

Regarding the observance of the dosage reported on the labels, almost all the growers comply with it, this trend is representative of the SEU for all the crops. In all the crops, few growers state that they apply more PPPs than what is reported on the labels. The vineyard case is slightly different; few Italian farmers reported to apply less product than the dose reported on the label. Among these farmers, some use tunnel recycling sprayer, therefore they consider to reduce the dosage since they have much lower dispersion of the product.

Concerning handling of PPP remnants after the spray application, based on the data obtained, the most common practice is to spray it on the crops (with or without pre-dilution). Some of the surveyed growers reported that they don't have any exceeding mixture. Especially in citrus, olive and vineyard, the practice of remediation systems (intended as both bio-remediation and evaporation systems) is adopted by growers.

Regarding the frequency of the PAE internal cleaning, for every crop at least 60% of farmers report to clean the equipment at the end of every spray application. The most common practice is to drain the water waste over the ground (point pollution). A limited percentage report to address the remnants to the sewer system or over draining channels. Depending on the crop, between 15 to 25% states to convey the water on adequate substrate.

Considering operator safety during PPP application, the PPE most used by farmers are gloves, masks with filters and coveralls. The less adopted were the common mask (intended as a mask without filter) and the hat. Most of the farmers use cab-less tractors or tractors with cab with filters.

Topic B

State of spraying equipment and the habits of equipment owners were addressed through the answers of the surveys from sprayer dealers and manufacturers and the answers of the surveys from the inspection stations in the three SEU countries.

Regarding the types of spraying equipment mostly sold and inspected, the vast majority of both sold and inspected equipment concerns airblast sprayers in all three countries.

Considering the inspections of spraying equipment, Greece has smaller inspection stations with the majority of them inspecting less than 10 equipment per month, while something similar holds for Italy, where, of course, there are also some larger inspection centres which control dozens of equipment per month. On the other hand, the majority of inspection stations in Spain are larger, with 10-20 inspections per month, while a remarkable percentage of them inspect more than 80 sprayers per month. Moreover, it seems that inspection stations in Spain apply stricter criteria since they present lower approval rates than those observed in Italy and particularly in Greece.

Both inspection stations, dealers and manufacturers report that, among the trends in equipment characteristics preferences, the efficacy of the equipment stands out, followed by user safety and endurance.

From the surveys, it seems that in Spain spraying equipment is more regularly maintained than in Italy and Greece. When it comes to technical services for repair, a similar overall picture can be observed; however, the situation in Greece is slightly shifted towards that of Spain. Regarding third party certification, the situation is very similar for all three countries: the vast majority of dealers and manufacturers (around 80%) reported that less than 25% of the sprayers than they sell have been certified by some 3rd party.

During maintenance and repair, it seems that the most problematic parts are the pump, the nozzles, the measurement, control and calibration systems, and the filters, with evidence of high consistency between the 3 countries. However, in the case of inspection stations, with the exception of Greece, there seems to be a high differentiation in the answers regarding the most frequent problematic parts, particularly with the tank (gauge indicator) in the case of Italy, and with the power transmission parts in the case of Spain. This leads to the conclusion that in several cases, these kinds of problems do not force the owners to bring their sprayer for repair, and that maintenance is not performed regularly.

Specific problems related to the nozzles are quite common, without any differentiation between maintenance, repair and inspection. Regarding specific problems related to the pump, it seems that there is a general agreement among the answers from all three countries that this kind of problems are occasional in the case of maintenance and repair, with pressure problems being the most common in Italy and Greece, and leakage from the pump being the most common in Spain. Concerning the frequency of other equipment problems in specific parts of the sprayers during maintenance and repair and during inspection, there is an absolute agreement between all three countries regarding the occurrence: pressure gauge problems are the ones more frequently detected.

Topic C

Generally, the majority of farmers and technicians declared to know what drift is: from the surveys, it results that more than 90% of farmers growing nuts, stone fruits and orange know drift, in olives the percentage is a little bit smaller (around 85%) and in vineyards the percentage is the lowest, around 80%. The drift concern is high among farmers (80-90%) although a little bit lower than its knowledge. The percentage of farmers/technicians familiar with spray drift reduction techniques (SDRT) is between 65% and 90% in the 3 countries. Comparing this point in each crop, the vineyard farmers in general result less familiar with SDRT. In general, the range of importance for using SDRT were similar between farmers/technicians of different crops and between 3 SEU countries: the most important reasons declared were the reduction of human risk and the protection to the environment followed by the reduction of PPP consumption, the reduction of PPP residues on products and the protection to the neighbours. Generally, between 55% and 70% of farmers declared to use drift reduction nozzles (DRN) in their sprayers while air deflectors of airblast sprayer are used by around 70% of farmers. More than 80% of farmers/technicians declared to switch off nozzles in specific situations (e.g. U turns to pass from one row to the adjacent one) to reduce spray drift independent from the crop and country.

According to the manufacturers and the sprayer inspection stations, DRN is the spray SDRT most demanded/used by the customers for the 3 SEU countries, followed by the air deflectors or adjustable air spouts. The third SDRT more demanded differs among countries: in Greece it is the precision spraying, meanwhile in Italy and Spain it is the automatic variable application rate based on forward speed.

Regarding the questions about the use of other management practices that help in reducing spray drift, 50% of farmers reported that they use spray additives, and this results more frequent in citrus and in fruit trees and less in vineyards.

More than 50% of Spanish farmers, independent of the crop, allow vegetation to grow on the field boundaries to reduce spray drift; Italian farmers do that but in lower percentage and with differences among crops, with olives, vineyards and nuts around 50%, while citrus around 40% and fruit trees around 30%. On the contrary, Greek farmers do not allow vegetation to grow on the field boundaries in citrus, the practice is very scarce in olives, vineyards and fruit trees but in nuts it is around 45%. The presence of windbreaks on field boundaries is generally occasional, on average less than 15%. The presence of hail nets over the orchards is low, more than 95% of orchards are not covered by hail nets except in the case of fruit trees, where around 25% of orchards are covered.

Since the weather conditions highly influence spray drift, farmers were asked about what meteorological conditions they take into account before PPP application: for all crops and countries, rain and wind speed were the parameters more considered while temperature was the third in importance.

A literature search was performed to check whether studies about pesticide drift and exposure specifically designed for 3-D orchards under the agro-climatic conditions of Southern Europe are available in the public literature. Since the topic is quite peculiar, no limitation of time was considered for the search. Major attention was put onto olives, citrus and vines. After a first selection through the title and the abstract, the articles retrieved were analysed with the full paper and the ones referring to the three main crops under assessment (vines, olives and citrus) were selected. After this check, the articles considered suitable for further assessment were 21. Then, the articles were assessed with respect to ISO 22866 requirements (the reference methodology for drift test in the field). After this last screening, 6 articles were identified as relevant: 1 for olive, 3 for vines and 2 for citrus.

The literature search did not provide enough information to produce new drift tables to possibly substitute the curves currently used in risk assessment. Nevertheless, even in the absence of such quantitative data, a lot of qualitative information is available to show how 3-D orchards in Southern Europe present peculiarities which are not typical of 3-D orchards in Central and Northern Europe, as well as the agro-climatic conditions differ from those used to develop the models of pesticide drift and exposure in orchards.

From the studies considered acceptable for this project, the vineyard late-growth-stage reference curve currently used for risk assessment does not fit the worst case for the South Europe conditions, since the 90th percentile curve obtained from experimental data is higher than those obtained by Rautmann *et al*. (2001) at all downwind distances from the applied area (up to 30m). This fact may be considered a sort of "warning": if spray drift in vineyard for SEU is assessed providing an underestimated exposure, being the same type of crop assessed on Rautmann's curves, what may be the situation of other 3-D crops, like citrus and olives, which were never, or scarcely, assessed with experimental data?

The other key point raised by the literature search, which can greatly impact on risk assessment procedures, is the airborne spray drift. The reference curves used for modelling provide values just referred to spray drift sediments measured on the ground, while new studies report higher values for airborne drift compared to those found at ground level for the same sampling distance. Since the droplets remain suspended in the air, they have the potential to travel long distances and few information is available on how long they can remain airborne and how much they can travel.

A comprehensive overview of spray drift phenomenon in relation to both the weather conditions and spray application technology is needed to update what is currently used for risk assessment. Considering the quick and high development of PAE used in agriculture, it has to be considered whether data collected more than 20 years ago might still be considered reliable or need some integration to check whether improvement in application techniques might have changed the phenomenon of drift.

Last but not least, the increasing interest in precision farming and spraying drones is opening new scenarios of exposure which might need a complete revision of what has been considered a standard situation up to now.

Considering the high variability in crop cultivations and training, in pesticide application techniques, in equipment and in new evolution of agriculture, it is clear that risk assessment cannot pretend anymore to exclude agronomists from the process. Even if models in different compartments and risk assessment of different organisms/populations need specific experts, the global vision of what is reliable in field, e.g. which application makes sense, which mitigation measures may be applied, what the behaviour of farmers might be in specific situation etc. are information that just people with expertise in agronomy might have and share.

Table of contents

1 Introduction

The use of chemical plant protection products (PPP) in agriculture contributes, together with other stressors, to soil, water and air pollution and to biodiversity loss and can affect non-target species, including humans. In order to reduce these risks, the EU Commission through the Sustainable Use of Pesticides Directive, imposes the use of integrated pest management (IPM), promoting greater use of safer alternative ways to protect harvests from weeds, pests and diseases. The latter include the use of biological control, physical methods like mechanical weeding, etc. In fact, recently, through the strategy farm to fork included in the Green Deal, the European Commission intends to reduce within 2030 the use of chemical pesticides by 50%, and that of more hazardous pesticides in particular. Therefore, in the next few years, agricultural practices that reduce the use of pesticides through the common agricultural policy (CAP) will be of paramount importance; moreover, the Commission will also facilitate the placing on the market of bio-PPP containing biological active substances and reinforce the environmental risk assessment (RA) of chemical pesticides.

The current evaluation of environmental risk assessment, described in Regulation 1107 for the authorisation of PPP, is based on a combination model/scenarios that has been obtained in the agro-climatic conditions of Central and Northern Europe. Therefore, both scenarios and models need to be updated to fix bugs, to include new conditions, to solve problems identified during their application and to take into account new scientific evidence.

Technology is evolving at such a rapid pace that annual predictions of trends may become out-of-date before they even go live. As technology evolves, it enables even faster change and progress, causing an acceleration of the rate of change. Computer science allows the use of mathematical models of increasing complexity in a short time and in a friendly way. This development allowed the revisions of the FOCUS models used in the pesticide arena, increasing the number of parameters to be considered for pesticide distribution (e.g. foliar wash-off, root uptake, etc.), in order to provide more realistic and detailed representation of the environmental fate and behaviour of a substance.

Nevertheless, the key agronomic factors producing an environmental/operator exposure of pesticide, such as agronomical practices, equipment used, and way of cultivating and managing crops, have been often disregarded and hardly updated in recent years. Nowadays, spraying equipment used for PPP applications, training system of crops, orchards and vines in particular, are very different from the ones used twenty years ago.

This combination of new techniques and cultivating systems strongly modifies the "scenario" of application.

On the other hand, it is well known that agriculture is strongly related to climatic conditions. In fact, Regulation 1107 introduced the zonal registration for PPP, to take into account the different needs related to different climatic areas. Southern Europe (SEU) has a large part of its agriculture devoted to 3D orchards: citrus, olives and vines are typical products of SEU, as well as fruit crops like peach, apricot, cherries and kiwi.

These crops present different vegetation characteristics (tree size, tree shape, foliar density, etc) and very different training systems and row and tree spacing in comparison with apple and pear orchards that are widely spread also in Central and Northern Europe. Furthermore, pesticides' application techniques and their setting up is also different, and the climatic conditions between North and South of Europe are pretty distinctive as well. This could result in very different drift values with respect to those currently applied for risk assessment of pesticides, which consider the drift curves derived for apple and pear grown in Central-Northern Europe to address all orchards. The actual values obtained for apple and pear, implemented in FOCUS models for pesticides or used in human risk assessment for bystanders and residents, and ecotoxicology risk assessment for non-target arthropods or plants, may not be appropriate for all orchards and all agro-climatic scenarios, particularly those related to SEU.

Pesticides are applied to crops to protect them against pests: the knowledge on how this application occurs, the specific needs of different crops, the best way for controlling a disease/pest/weed is a typical cultural heritage of agronomists.

On the other hand, the way of calculating exposure, the use of models, the key elements to be used for RA are part of the knowledge of the assessors involved in the registration process of active substances and PPP. Unfortunately, the world of agriculture and the world of pesticide risk assessment hardly communicate and often the risk assessment of a pesticide is strictly performed according to current guidance but is very detached from reality in the field.

The present consortium is composed of four organisations from three different SEU countries: Italy, Spain and Greece. Three organisations have recognised experience in crop protection equipment, spray technology mainly related to the optimization of pesticide applications in high crops, certifications and supervision of mobile or stationary Pesticide Application Equipment Inspection Stations. One organisation is involved in the registration process of professional PPP, at zonal and EU level, participates in the discussion on active substances in expert consultation in EFSA and commonly uses the exposure model for RA in the environment and for operators, workers, bystanders and residents.

The purpose of this consortium is to address the characteristics of southern 3-D crops, other than apple and pear, to possibly tailor and update the exposure models used to perform risk assessment for 3-D crops, with particular attention to those typical of SEU.

Through three surveys addressed to manufacturers, sprayer inspection stations, and growers, the key agronomic factors (equipment used, and way of cultivating and managing crops, training system of crops, pesticides and type of treatments) that influence drift when pesticides are applied, were collected. Data was processed and information obtained was used to propose an updating of the parameters implemented in exposure models or to provide useful background for any further revision or update of exposure models.

The structure of the project was articulated into four work-packages. The first three work packages addressed an agro technical background and are closely related to each other:

(1) the characterisation of 3-D orchards (vineyards, citrus, olive and fruit crops) in EU,

(2) the full description of sprayers' types and spraying practices currently used in SEU, and

(3) the collection of available spray drift experimental data for these types of crops.

An analysis of parameters used in different models used in risk assessment, and a comparison with the figures coming from the three activities described above, was the fourth action suggested in the proposal.

1.1 Background and terms of reference as provided by the requestor

This project was awarded by EFSA to: Università degli Studi di Milano (UMIL), Department of Biomedical and Clinical Sciences, Italy – Università degli Studi di Torino (UNITO), Italy - Agroengineering Center of Valencian Institute of Agricultural Research (IVIA) Spain - Hellenic Agricultural Organization "DIMITRA" / Institute of Soil & Water Resources / Dept. of Agricultural Engineering (ELGO_DIMITRA), Greece.

Coordinator / Project Leader: Università di Milano

Grant title: PPP exposure models for 3D orchards considering spraying technologies in Southern Europe.

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2 Data and Methodologies

2.1 Data

2.1.1 Relevant 3-D orchards at EU level

The collection of data and information about 3-D orchards like vines, citrus, olive, and fruit crops in the EU in terms of localization and extension of cultivated surfaces has been performed using census data collected from international databases. The latest release of FAOSTAT was considered as the reference one for a European overview of the crop distribution (FAOSTAT, 2019). Since the scope of this project is to address drift data for 3-D crops in SEU versus the drift values currently used in the European Union for pesticide risk assessment, FAOSTAT data were collected for all member states belonging to the European Union. Therefore, throughout the report, any reference to Europe means EU 27.

The following parameters were selected to download the data at European level:

- Domain: "Production" ---> "Crops and livestock products"
- Element: "area harvested"
- Special Group: "European Union (27) + total"
- Items: "Crop Primary (list)" selecting almonds with shell, apricots, cherries, cherries sour, chestnut, fruit (citrus nes), grapes, hazelnuts with shell, kiwi fruit, lemons and limes, olives, oranges, peaches and nectarine, tangerines, mandarins, clementine, satsumas, and walnuts with shell.
- Year: 2019

2.1.2 Major areas of production in Italy, Spain and Greece

The major national areas of production of the selected orchards were identified with the contribution of national census data (collected for the year 2019, to be consistent with the European data).

Data were collected from the National Institute of Statistics of Italy (ISTAT), from the Ministry of Agriculture, Fisheries and Food of Spain (MAPA) and from the Hellenic Statistical Authority (ELSTAT) in Greece.

2.1.3 Surveys

Three different questionnaires were developed to collect information on spray equipment / crops / application practices in Italy, Spain and Greece.

- The first questionnaire was addressed to inspection stations of sprayers.
- The second questionnaire was submitted to sprayer manufacturers.
- The third questionnaire was addressed to farmers and field technicians.

2.2 Methodologies

2.2.1 CENSUS analysis

A comparison was performed among the area of SEU cultivated with a specific crop with respect to the EU area cultivated with the same one, in order to identify which crops deserve an investigation in SEU. As a cut-off criteria, crops representing an area lower than 50.000 ha were excluded by further investigation, since they were considered minor with respect to all the crops cultivated in Europe.

The area covered by each 3-D crop identified was also represented as surface cultivated in SEU with respect to the one cultivated in EU (27).

Furthermore, the representativeness of the three Member States involved in this project (Italy, Greece and Spain) was tackled for each 3-D crop identified.

When the total area cultivated with a specific 3-D crop in Italy, Spain and Greece represented more than 50% of the area cultivated in the EU (27) and more than 80% in SEU, this orchard was considered well represented and suitable to be addressed by this project.

For each crop, the statistical data have been reported at province level, just for regions where the cultivated area represents at least 10% of the national cultivated area.

2.2.2 GIS elaboration

CENSUS data were also reported on maps to help the identification of major areas. The use of statistical national data, collected at province level, together with the comparison of maps allowed the identification of clusters of each crop cultivation in the 3 MS. These clusters were used to identify areas where to carry out the survey.

2.2.3 Development of the surveys

2.2.3.1 Surveys for the inspection of sprayers and the sprayer manufacturers

The surveys made among sprayer inspection workshops and sprayer manufacturers collected information related to:

- The characteristics of equipment inspected/sold
- The most widespread equipment
- The trend of machine characteristics in marketing over the last 10-15 years

Appendix C.1 reports the proposed questionnaire for sprayer manufacturers.

Appendix C.2 reports the proposed questionnaire for inspection stations of sprayers.

The proposed questionnaires were drafted in English, Greek, Italian and Spanish languages.

2.2.3.2 SURVEY FOR FARMERS AND FIELD TECHNICIANS

The survey targeted to farmers and field technicians collected information about:

- the 3-D crops cultivated (e.g. species, training system, variety, etc.)
- the spraying equipment used (e.g. type and model, age of sprayer)
- the spray application technique (e.g. parameters used to apply PPP like spray pressure, volume applied, forward speed, airflow rate)
- the use of SDRT (e.g. DRN, closure of airflow on one side when the row-edges are sprayed)
- the adoption of buffer zones (e.g. free crop buffer zone or cropped-buffer zone)
- the presence/absence of surface water bodies close to sprayed fields
- the distance between the field and surface water bodies
- any bees protection system adopted
- the PPP mixing and loading system used
- the time of mixing and loading
- the time of application
- the presence of financial support from EU or regional government for the adoption of SDRT or for buying new environmentally-friendly sprayers (e.g. tunnel recycling sprayer)
- the number of spray applications per year (how many insecticide treatments and how many fungicide treatments)
- the personal protection equipment used

Appendix C.3 reports the proposed questionnaire for farmers and field technicians.

The proposed questionnaires were drafted in English, Greek, Italian and Spanish languages.

2.2.4 Population samples

2.2.4.1 SAMPLE SIZE

The major problem in defining the sample size is to answer the question: how many interviews are enough? In order to answer this question, a brief literature review was performed.

Mason (2020) comments that while there are other factors that affect sample size in qualitative studies, however, the guiding principle should be the concept of saturation.

Guest *et al.* (2006) reported that based on the data set, they found that saturation occurred within the first twelve interviews, although basic elements for meta-themes were present as early as six interviews. Variability within the data followed a similar pattern. A systematic review of empirical tests, addressing the sample size saturation in qualitative research (Hennink and Kaiser, 2022), shows that studies using empirical data reached saturation within a narrow range of interviews (9–17) or focus group discussions (4–8), particularly those with relatively homogenous study populations and narrowly defined. Results of this review show that across 16 tests using various approaches to saturation, the sample size for saturation ranges between 5 and 24 interviews. The lowest sample size for saturation was 5 interviews, in a study with a homogenous study population that was intended to support survey findings and where saturation was sought in broad categories. The highest sample sizes for saturation were 20–40. Most datasets reached saturation between 9 and 17 interviews, with a mean of 12–13 interviews, despite using different approaches to assess saturation. Most of these studies had a relatively homogeneous study population.

The review reports that in all 16 tests of saturation with data from in-depth interviews, saturation was reached in under 25 interviews, more specifically between 9 and 17 interviews excluding outliers. Despite using different approaches to assess saturation, different datasets, varying saturation goals (codes vs categories), and homogeneous and heterogeneous study populations, studies still reached saturation within a narrow range of interviews. This demonstrates strong external reliability across the different approaches. Across all tests, an average of 12–13 interviews reached saturation, which is remarkably similar to findings from Guest *et al*. (2006).

In another study (Malterud *et al*., 2016), it is reported that qualitative interview studies may benefit from sampling strategies by shifting attention from numerical input of participants to the contribution of new knowledge from the analysis. Information power indicates that the more information the sample holds, relevant for the actual study, the lower number of participants is needed. An initial approximation of sample size is necessary for planning, while the adequacy of the final sample size must be evaluated continuously during the research process.

Van Rijnsoever (2017), explored the sample size that is required to reach theoretical saturation in various scenarios and used these insights to formulate guidelines about purposive sampling. Following a simulation approach, he assessed experimentally the effects of different population parameters on the minimum sample size.

For this project, the sample size for each target population was calculated with a tool available on the Creative Research Systems website (available at https://www.surveysystem.com/sscalc.htm), where software related to conducting surveys is offered. The Survey System is an extremely versatile collection of software packages. The Basic Edition of The Survey System is designed to appeal to all users. This tool is used, for example, by the Italian Institute of Health to carry out epidemiological studies.

The tool can be used to determine how many people need to be interviewed in order to get results that reflect the target population as precisely as needed. It can also provide the level of precision in an existing sample.

Taking into account a confidence limit of 95%, with 30 surveys, a confidence interval of 16.2% would be obtained, which is considered an acceptable interval for this study.

Finally, the consortium decided to carry out 30 surveys in each target population. Regarding the farmer case, it was decided to conduct 30 surveys for each 3D crop on which the project focuses: citrus, olive, grapes, fruit (other than apple and pear), and nuts.

2.2.5 Selection of the sample subjects

2.2.5.1 SPRAYER INSPECTION STATIONS

2.2.5.1.1 SPAIN

In Spain, there are 159 sprayer inspection stations authorised by the Ministry of Agriculture, Fisheries and Food, as of July 2022 (Table 1). It should be noted that the regions where the weight of plant production is greater, such as Andalucía, Castilla-La Mancha, Castilla y León and the Comunidad Valenciana, are the ones with the largest number of inspection stations.

Table 1. Inspection stations authorised in each region in Spain (Source: https://www.mapa.gob.es/es/agricultura/temas/medios-de-produccion/iteafautorizadasjulio2022_tcm30-623493.PDF).

Region	# Inspection Stations
Andalucía	41
Aragón	5
Asturias	1
Cantabria	0
Comunidad Valenciana	17
Islas Baleares	1
Islas Canarias	4
Castilla-La Mancha	30
Castilla y León	18
Cataluña	4
Extremadura	10
Galicia	9
La Rioja	1
Madrid	7
Murcia	7
Navarra	2
País Vasco	2
TOTAL	**159**

30 surveys were conducted randomly among the inspection stations authorised in Spain. Therefore, the sample represents 18.9% of all those available in the country.

2.2.5.1.2 GREECE

In Greece, there are 75 active sprayer inspection stations authorised by the Ministry of Rural Development and Food, as of December 2022 (Table 2). 30 surveys were randomly done, so the sample represents e 40% of total.

Table 2. Inspection stations authorised in each region of Greece.

Region	Inspection station
Eastern Macedonia and Thrace	16
Central Macedonia	21
Western Macedonia	5
Epirus	1
Thessaly	10
Central Greece	7
Ionian Islands	0
Western Greece	2
Peloponnese	10
Attica	1
Northern Aegean	0
Southern Aegean	0
Crete	2
TOTAL	**75**

2.2.5.1.3 ITALY

As shown in Table 3, in Italy, in 2023, there are 341 authorised inspection stations. The distribution of the stations is uneven among the regions, the greater concentration is in the northern regions. Indeed, Veneto, Piedmont and Lombardy have 43% of the total number of inspection stations in Italy. To reach at least 10% of the total inspection station, 10 more questionnaires that the number initially scheduled (30) were submitted. In total, 41 questionnaires were randomly collected in different inspection stations, therefore the sample represents 12% of total.

Table 3. Sprayer inspection stations authorised in each region of Italy (Source: https://www.laboratorio-cpt.to.it/centri-prova/)

Region	# Inspection Stations
Abruzzo	30
Basilicata	7
Calabria	8
Campania	18
Emilia-Romagna	19
Friuli-Venezia Giulia	10
Lazio	7
Liguria	6
Lombardy	47
Marche	11
Molise	2
Piedmont	49
Bolzano e Trento	6
Apulia	16
Valle d'Aosta	2
Sardinia	9
Sicily	19
Tuscany	12
Umbria	8
Veneto	55
TOTAL	**341**

2.2.5.2 Sprayer manufacturers and dealers

2.2.5.2.1 Spain

First of all, an internet search was carried out for finding the contact details of sprayer dealers and manufacturers throughout Spain and a database was prepared with the name of the company, its location and the contact information available (phone, email,…). Those who did not provide their telephone number were contacted by email to request it. Subsequently, they were randomly contacted to find out their availability and willingness to carry out the survey until the total of 30 respondents were reached. To achieve that number of surveys, a total of 170 manufacturers/dealers were contacted.

2.2.5.2.2 Greece

The initial goal was to find a total of 30 dealers/manufacturers to answer the survey. However, due to the relatively small number of manufacturers in Greece, 15 manufacturers were reached and interviewed.

2.2.5.2.3 Italy

Previously to the survey's submission, a dataset with all the dealers/manufacturers information was created; for the ones where the phone contact was not available it was requested via email. From this dataset the interviewer randomly contacted (through phone) the sprayer manufacturers listed until the target of 30 surveys was reached.

2.2.5.3 Growers and field technicians

2.2.5.3.1 Spain

Taking into account the previous tasks performed in the framework of the project, for each type of crop (citrus, olive, grapes, fruit (other than apple and pear), and nuts), the different regions were arranged in descending order of surface (ha). Based on the relative % of surface of each region, the regions that added up to at least 75% were taken into account for the surveys. Then, the total 30 surveys were distributed among the resulting regions, proportionally to their relative surface. (Table 4).

Table 4. Questionnaires distribution for each crop on the different regions of Spain for the surveys to growers and field technicians.

Crop	Region	Surface (ha)	Relative surface (%)	# surveys/ region
CITRUS	C. VALENCIANA	157190	53.79	20
	ANDALUCÍA	84019	28.75	10
GRAPES	CASTILLA-LA MANCHA	441423	47.12	17
	CASTILLA Y LEÓN	82083	8.76	3
	EXTREMADURA	78982	8.43	3
	C. VALENCIANA	64151	6.85	2
	CATALUÑA	56612	6.04	2
	LA RIOJA*	47451	5.06	2
OLIVES	ANDALUCÍA	1633215	62.77	24
	CASTILLA-LA MANCHA	373849	14.37	6
FRUITS	ARAGÓN	32152	25.35	10
	CATALUÑA	25553	20.14	8
	MURCIA	22852	18.01	7
	EXTREMADURA	16760	13.21	5

3-D orchards

Crop	Region	Surface (ha)	Relative surface (%)	# surveys/ region
NUTS	ANDALUCÍA	226810	28.77	11
	CASTILLA-LA MANCHA	164786	20.90	8
	C. VALENCIANA	94960	12.05	4
	MURCIA	80976	10.27	4
	ARAGÓN	79172	10.04	4

* La Rioja was taken into account although the previous regions already added up more than 75% of the grape surface of Spain, because it is the best known wine area from Spain around the world

2.2.5.3.2 GREECE

The questionnaires for farmers were distributed within the various regions of the country based on the relative cultivation areas per region for each crop type of interest (olives, vines, citrus, fruits (except apples and pears) and nuts). For each crop type, the basic representative regions are included, and these are the regions that the questionnaires were focused on (the percentage of the total cultivation areas of each crop category that these regions represent is shown in the last column). Based on the cultivation area percentages per region for each crop category and on the fact that 30 questionnaires per crop type are sufficient for the statistical analysis, the final regional distribution of the questionnaire per crop category was estimated (presented in Table 5).

Table 5. Cultivation areas of each crop category in most important (for each category) regions and relevant percentages of cultivations areas per crop among these regions.

Crop	Region	Surface (ha)	Relative surface (%)	# surveys/ region
CITRUS	Peloponnese	21493	52%	18
	W. Greece	8423	20%	7
	Epirus	6054	15%	5
GRAPES	Peloponnese	18725	22%	8
	Crete	17358	20%	8
	W. Greece	12488	14%	6
	C. Greece	5470	6%	2
	Attica	5745	7%	3
	Thessaly	3938	5%	2
	C. Macedonia	4144	5%	1
OLIVES	Peloponnese	220704	28%	12
	Crete	189666	24%	10
	W. Greece	83272	10%	4
	C. Greece	80655	10%	4
FRUITS	Peloponnese	3559	6%	2
	Thessaly	4172	7%	2
	C. Macedonia	50415	80%	26
NUTS	Peloponnese	4488	10%	4
	C. Greece	5539	13%	5
	Thessaly	15091	35%	13
	C. Macedonia	8435	19%	8

2.2.5.3.3 ITALY

Table 6 reports the questionnaire distribution for each crop in the different regions. For each crop, regions are listed in descending order of surface (ha). Based on the relative percentage of surface of each region, the ones that added up to at least 75% of the total national surface, per each crop type, were considered for the surveys.

The questionnaires were distributed among regions according to their surface contributing to reach the 75% of total national surface. In total 30 questionnaires, per each crop case, were submitted across the selected regions.

Table 6. Distribution of the questionnaire submitted to growers and field technicians for each crop in the different regions of Italy (source: ISTAT, 2019).

Crop	Region	Surface (ha)	Relative surface (%)	# surveys/ region
CITRUS	Sicily	84929	59.43	21
	Calabria	35910	25.13	9
GRAPES	Sicily	120262	17.95	7
	Veneto	89288	13.33	5
	Apulia	88109	13.15	5
	Tuscany	59213	8.84	3
	Latium	53385	7.97	3
	Piedmont	42961	6.41	3
	Abruzzo	32529	4.86	2
	Sardinia	26619	3.97	2
OLIVES	Apulia	384300	32.99	13
	Calabria	184529	15.84	6
	Sicily	157891	13.55	5
	Tuscany	89929	7.72	3
	Latium	82931	7.12	3
FRUITS	Campania	27623	24.62	10
	Apulia	23974	24.62	8
	Emilia-Romagna	19514	17.39	7
	Sicily	8910	7.94	3
	Basilicata	6814	6.07	2
NUTS	Sicily	49307	34.31	13
	Campania	24613	17.13	6
	Piedmont	24557	17.09	6
	Apulia	19836	13.80	5

2.2.6 Conduction of surveys

The first task was to find out contact information from as many subjects from the different target populations as possible. Subjects were first contacted by phone and depending on their availability and preference, an appointment was scheduled to carry out the interview. All the surveys were performed through direct interviews, both by telephone or in-person. All pollsters that conducted the surveys had expertise in spray technology used in 3-D crops.

3-D orchards

The data collected from the different surveys were filled in excel files, for each target of the surveys. Excel files are provided separately, as raw data (https://zenodo.org/records/10478363).

2.2.6.1 Survey to sprayer dealers and manufactures

After the tabulation of the data obtained by the survey, all the data were verified to avoid potential error. In case of error, the pollsters contacted the manufacturer again to correct the mistake.

Concerning the open-ended questions (e.g., number of sales per month and type of sprayer equipment sold), a descriptive analysis of the frequency has been conducted. The ranges have been selected based on the answers collected.

In the questions related to the type and characteristics of the sprayers checked and repaired (e.g., use of drift reduction technology), and the issues that are usually found (e.g., problems related to the air system), when the interviewee answered with a rating from 1 to 5 (1 infrequent or no important, and 5 very frequent or important), the data analysis has been based on a descriptive analysis. Different types of graphs were used to discuss the answers.

2.2.6.2 Survey to workshops in charge of the inspection of sprayers in use

After conducting the surveys, the data were tabulated and a preliminary analysis was conducted to detect potential erroneous data.

In the questions related to the number of sprayer inspections per month, those approved in the first inspection and the type of equipment inspected, a descriptive analysis of the frequency has been conducted based on ranges that have been established on the basis of the answers obtained.

In the questions related to the type and characteristics of equipment inspected i (e.g., use of drift reduction technology) and the problems that are usually found, where the interviewee had to answer with a rating from 1 to 5 (1 being infrequent or not important and 5 very frequent or important), the data analysis has been based on a descriptive analysis. Different types of graphs were used to discuss the answers.

2.2.6.3 Survey to growers and field technicians

After conducting the surveys, the data were tabulated and a preliminary analysis was conducted to detect potential erroneous data.

In the questions related to the type and characteristics of the sprayers, advice on its use and aspects that the respondent considers important for the reduction of drift, where the interviewee had to answer with a rating from 1 to 5 (being 1 infrequent or not important and 5 very frequent or important), the data were assessed through a descriptive analysis using different type of graphs.

A descriptive analysis was also performed to assess the number of applications of PPP per year carried out in the farm, distinguishing between insecticides and fungicides.

For the rest of the questions, a descriptive analysis of the frequency has been conducted based on ranges that have been established on the basis of the answers obtained.

2.2.7 Literature search

A literature search was performed to check whether studies about pesticide spray drift and exposure specifically designed for 3-D orchards different to apples and pears are available in the public literature. Since the topic is quite peculiar, no limitations of time were considered for the search. Major attention was put onto olives, citrus and vines.

Results of search queries in a public link to a working space for EFSA supported projects in the JRC TIM-tool were considered (https://custom.timanalytics.eu/TimTechnology2/main.jsp?dataset=s_1709)

The following keywords were used in March 2022:

- topic:(("pesticide drift"~2 OR "pesticide exposure" OR "pesticide loss" OR "pesticide runoff" OR "pesticide efficient"~3) AND ("airblast sprayer" OR "mist blower" OR airblaster OR "axial fan sprayer" OR "nozzle" OR "droplet size" OR "Spray Drift Reduction Techniques")AND (citrus OR vine OR olive OR vineyard OR peach OR apricot OR cherry OR kiwi OR almond OR "3d crop" OR "mediterranean fruits" OR "mediterranean orchard"~3))
- topic:(("pesticide drift"~2 OR "pesticide exposure" OR "pesticide loss" OR "pesticide efficient"~3 OR "pesticide runoff") AND (citrus OR vine OR olive OR vineyard OR peach OR apricot OR cherry OR kiwi OR almond OR "3d crop" OR "mediterranean fruits" OR "mediterranean orchard"~3))
- topic:(("pesticide drift"~2 OR "pesticide exposure" OR "pesticide loss" OR "pesticide runoff" OR "pesticide efficient"~3) AND ("airblast sprayer" OR "mist blower" OR airblaster OR "axial fan sprayer" OR "nozzle" OR "droplet size" OR "Spray Drift Reduction Techniques"))

Further search was performed by partners considering the following list of keywords:

- **Citrus/drift/pesticide** (this combination could be also for: Olive, vineyard, orchard, trees)
- **Citrus/drift/exposure** (this combination could be also for: Olive, vineyard, orchard, trees)
- **Airblast sprayer/drift/pesticide** (airblast sprayer could be found as: airblaster, or axial fan sprayer)
- **Airblast sprayer/drift/exposure** (airblast sprayer could be found as: airblaster, or axial fan sprayer)
- **Nozzle/drift/citrus** (this combination could be also for: Olive, vineyard, orchard, trees)
- **Droplet size/ drift / vineyard** (this combination could be also for: Olive, citrus, orchard, trees)
- **Drift / airblast sprayer / tracer** (airblast sprayer could be found as: airblaster, or axial fan sprayer)
- **SDRT = (Spray Drift Reduction Techniques) / Pesticide / Vineyard** (this combination could be also for: Olive, citrus, orchard, trees)

Furthermore, the partners consolidated experience in the subject allowed them to identify works not falling in the keywords highlighted above.

A first selection of articles was made considering mainly European studies, excluding therefore all the Asiatic ones. A second screening was made through the title/abstract assessment: all studies not directly addressing spray drift in 3-D orchards were excluded.

3-D orchards

Finally, since the literature search was performed to identify the possibility to develop new drift curves for 3-D orchards different from apple and pear, reference was made to ISO 22866 requirements. Therefore, each article was assessed with respect to the following list of parameters

Orchard characteristics	Crop	
	Cultivar	
	Row direction	
	Row x Tree spacing (m)	
	Total height (m)	
	Skirt (m)	
	Tree height (m)	
	Diameter 1 (m)	
	Diameter 2 (m)	
	Canopy volume (m3) (indicate calculation used)	
	TRW (m3 TRV/ha)	
	LWA (m2 LWA/ha)	
	BBCH (vineyard)	
	Foliar density/LAI….	
Meteo	Distance/Position of sensors respect the orchard	
	Height 1 (m)=	Frequency (Hz)
		Horizontal wind speed (m/s)
		Horizontal wind direction (º)
		Vertical wind speed (m/s)
		Temperature (ºC)
		Relative humidity (%)
		% of measures ≥30º
		% of measures ≥45º
	Height 2 (m) (in case there is)=	Frequency (Hz)
		Horizontal wind speed (m/s)
		Horizontal wind direction (º)
		Vertical wind speed (m/s)
		Temperature (ºC)
		Relative humidity (%)
		% of measures ≥30º
		% of measures ≥45º
	Stability	
Trial layout	Length of passes (row length) (m)	
	Rows treated (number of rows/ width treated area)	
	Spray application in the 1st row	
	Substance applied (tracer, PPP,…)	Substance
		Concentration/Dose
Treatment/s	Treatment 1	Volume rate (L/ha)
		Forward speed (km/h)
		Airflow (m3/h)
		Working pressure (MPa)
		Type of nozzles
		Liquid flow rate (L/min)
	Treatment 2 (in case)	Volume rate (L/ha)
		Forward speed (km/h)
		Airflow (m3/h)
		Working pressure (MPa)

		Type of nozzles
		Liquid flow rate (L/min)
	Treatment 3 (in case)	Volume rate (L/ha)
		Forward speed (km/h)
		Airflow (m3/h)
		Working pressure (MPa)
		Type of nozzles
		Liquid flow rate (L/min)
Response variables	Airborne drift	Collector (if lines, vertical/horizontal)
		Height range (max-min measured height) (m)
		Precision (0.5 m/ 1 m…)
		Distance/s to the first row (m)
		Replicates/distance
	Sedimenting drift	Collector
		Distance range (max-min measured distance) (m)
		Precision (1 m…)
		Distance/s to the first row (m)
		Replicates/distance

2.2.8 3D orchards and spraying technologies versus exposure models

The models used for risk assessment in Europe were addressed to check in which operative conditions drift data used for the estimation of the exposure were collected. Furthermore, information on 3-D orchards and on the equipment used to apply pesticides were collected in order to tackle the real need of refinement for drift curves.

The updated version of guidance documents currently used for pesticide registration in Europe were considered, with a specific attention on models used for exposure assessment in the environment and for humans.

2.2.8.1 Environmental models and drift

In the registration process for pesticides, drift values are used just for Surface Water exposure assessment where different values at different steps are considered.

2.2.8.1.1 FOCUS Step1

At Step 1, inputs of spray drift, run-off, erosion and/or drainage are assessed as a single loading to the water body and "worst-case" surface water and sediment concentrations are calculated. The assumptions are very conservative and are essentially based on drift values

Table 7. Step 1: input into surface water via spray drift (90th percentile).

Crop	**Distance crop-water (m)*** *natural buffer	**Drift (% of application)**
citrus	3	15.7
olives	3	15.7
pome / stone fruit, early applications	3	29.2
pome / stone fruit, late applications	3	15.7
vines, early applications	3	2.7
vines, late applications	3	8.0

3-D orchards

2.2.8.1.2 FOCUS Step 2

At Step 2, inputs of spray drift, run-off, erosion and/or drainage are evaluated as a series of individual loadings including drift events (number and timing as defined in step 1 followed by a loading representing a run-off, erosion and/or drainage event four days after the final application).

Table 8. Step 2: input into surface water via spray drift (90th percentile)

Crop	Distance crop-water (m)	Number of application per season							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**>7**
citrus	3	15.7	12.1	11.0	10.1	9.7	9.2	9.1	8.7
olives	3	15.7	12.1	11.0	10.1	9.7	9.2	9.1	8.7
pome / stone fruit, (early)	3	29.2	25.5	24.0	23.6	23.1	22.8	22.7	22.2
pome / stone fruit (late)	3	15.7	12.1	11.0	10.1	9.7	9.2	9.1	8.7
vines, early applications	3	2.7	2.5	2.5	2.5	2.4	2.3	2.3	2.3
vines, late applications	3	8.0	7.1	6.9	6.6	6.6	6.4	6.2	6.2

2.2.8.1.3 FOCUS Step 3

For Step 3 calculations, drift losses are calculated using the drift calculator in SWASH. The mean areic drift rate for the relevant surface area is used as input to TOXSWA. The spray drift data were obtained from the BBA (2000) data and were calculated based on a single application rate, the number of applications and default distances between various types of crops (arable crops, fruit crops (orchards), grapevines, hops and vegetables/ ornamentals/ small fruit) and adjacent surface water. In addition, the drift loadings were integrated across the width of the water body to provide a mean drift loading for a specific type of water body.

Crop	Distance crop-water (m)	Areic mean drift % * *single application as worst case		
		Ditch	Pond	Stream
citrus	FOCUS value	11.1339	1.6485	9.6236
olives	FOCUS value	11.1339	1.6485	9.6236
pome / stone fruit, early applications	FOCUS value	23.5988	4.7297	21.5827
pome / stone fruit, late applications	FOCUS value	11.1339	1.6485	9.6236
vines, early applications	FOCUS value	1.7184	0.1933	1.4186
vines, late applications	FOCUS value	5.1730	0.6121	4.2930

Main parameters related to drift and used by environmental fate exposure models are:

- Application rate
- Number of application per season
- Crop type (i.e. citrus, grapes, pome/stone fruits, vegetables etc.)
- Phenological stage of crop (i.e. leaf cover)
- Water body type (ditch, pond, stream)
- Distance between crop and water body.

Application equipment, weather conditions such as wind speed are not considered by the models.

2.2.8.2 DRIFT VALUES USED IN ECOTOXICOLOGY

2.2.8.2.1 BIRDS AND MAMMALS

The exposure for birds and mammals is evaluated through diet and contaminated water. No specific drift values are considered. For secondary poisoning, values from surface water are used and reference to the e-fate section is made. Spray drift values used for the exposure assessment of mammals in the off-crop environment are aligned to those for other non-target organisms, making reference to the new guidance not yet in place, as reported in the table below.

Table I.1: Spray drift technique and spray drift value from Rautmann et al. (2001)

Spray drift category from Rautmann et al., 2001	Spray technique and conditions for which the Rautman category is being used to represent
Field crops	Standard horizontal boom sprayer
Fruit crops, early (= orchards with lower crop intercept(1))	Air-blast equipment to plants with lower crop intercept(1)
Fruit crops, late (= orchards with higher crop intercept(2))	Air-blast equipment to plants with a higher crop intercept(2)
Vine, late(3)	Sideward sprayer
Hops	Hop sideward sprayer

(1): Deciduous trees at BBCH 0–69 and 97–99.
(2): Evergreen trees and deciduous trees at BBCH 71–95.
(3): EFSA (2020) excluded drift values for 'vines, early' in the exposure assessment as these drift values were based on non-standard application techniques for early vines.

2.2.8.2.2 AQUATIC ORGANISMS

For the exposure of surface water reference is made to drift values at different steps used in the models for exposure assessment (see §2.2.8.1)

2.2.8.2.3 BEES

Considering bees, different guidelines are used, with the new one (EFSA 2023) not yet adopted, the previous one (EFSA 2013) never entered into force and the oldest one (SANCO) still in place.

In these three different guidelines, drift is considered as follows:

- the SANCO guidance does not require drift values (in field);
- the EFSA guidance (2013), not in force but used sometimes as a reference, requires further exposure scenarios for field margins and adjacent crops (with specific drift values) and contact exposure with drift data very close to the ones used for non-target arthropods (NTA) as reported in the table below.

Table H1: Conservative default deposition percentages for spray drift and dust drift to be used for the different combinations of application technique and types of plants.

Application type	Crop	Default deposition (%) to be used for		
		concentrations in nectar and pollen entering the hive		contact exposure assessment
		field margins	adjacent crops	field margins
Spray applications (spray drift)	Field crops	0.92	0.33	2.8
	Early fruit	9.7	6.6	29.2
	Late fruit	5.2	3.1	15.7
	Early grapevine	0.90	0.47	2.7
	Late grapevine	2.7	1.43	8.0
	Hops	6.4	4.1	19.3
Granule applications (dust drift)	All crops	3.2	1.5	9.6

Source: EFSA Journal 2013;11(7):3295

- the EFSA guidance (2023), not yet adopted, did not revise the deposition factors with the exception of some amendments for spray: the category 'vine early' was eliminated and the early and late stage for orchard crops had been better defined (linked to BBCH categories). Apart from those small amendments the deposition factors will be considered in the same way as in EFSA (2013).

2.2.8.2.4 NON TARGET ARTHROPODS AND PLANTS

Drift values for spray application depend on the number of applications: the percentile varies from the worst case value (90%) for a single application to lower percentile for multiple applications, as reported in the table below.

No. applications	percentile
1	90
2	82
3	77
4	74
5	72
6	70
7	69
8 or more	67

As an example, the next table provides the drift values, for a single application, at different distances in various crops.

3-D orchards

Basic drift values for one application Ground sediment in % of the application rate (90[th] percentiles)				
Distance	**Fruit crops**		**Grapevine**	
[m]	**early**	**late**	**early**	**late**
3	29.20	15.73	2.70	8.02
5	19.89	8.41	1.18	3.62
10	11.81	3.60	0.39	1.23
15	5.55	1.81	0.20	0.65
20	2.77	1.09	0.13	0.42
30	1.04	0.54	0.07	0.22
40	0.52	0.32	0.04	0.14
50	0.30	0.22	0.03	0.10
75	0.11	0.11	0.015	0.05
100	0.06	0.06	0.009	0.03
125	0.03	0.04	0.007	0.024
150	0.021	0.03	0.005	0.018
175	0.015	0.024	0.004	0.014
200	0.011	0.019	0.003	0.011
225	0.008	0.016	0.003	0.010
250	0.006	0.013	0.002	0.008

According to the EFSA guidance (2013b), the deposition to plants at the field margin or to crops at the adjacent field is related to the drifted amount of pesticides from the treated area to the off-field areas (spray drift or dust drift). The Working Group did not revise these deposition factors in EFSA GD (2023) with the exceptions of some amendments for spray application for orchard crops and vines (i.e. the spray drift values have been selected to cover the conditions which will lead to the highest drift between early/late applications).

Table I.2: Crop groups used for the Tier 1 exposure assessment for sprays together with the spray drift value to be used for Tier 1 exposure assessment

Name for GD	EPPO name	Spray drift category to be used for Tier 1 (in the first instance)	Considerations for more specific spray drift category (and proposed by applicant)
Citrus fruit crops	citrus fruit crops (3CITC)	Air-blast equipment to plants with a higher crop intercept[2]	–
Nut crops	nut crops (3NUTC)	Air-blast equipment to plants with lower crop intercept[1] or Air-blast equipment to plants with a higher crop intercept[2]	Lower crop intercept = Deciduous trees at BBCH 0–69 and 97–99 Higher crop intercept = Evergreen trees and deciduous trees at BBCH 71–95 Sideward sprayer may be used pending on the application technique.
Olives	*Olea europaea* (OLVEU)	Air-blast equipment to plants with a higher crop intercept[2]	
Stone fruit crop	stone fruit crops (3STFC)	Air-blast equipment to plants with lower crop intercept[1] or Air-blast equipment to plants with a higher crop intercept[2]	Lower crop intercept = Deciduous trees at BBCH 0–69 and 97–99 Higher crop intercept = Evergreen trees and deciduous trees at BBCH 71–95 Sideward sprayer may be used pending on the application technique.

3-D orchards

Table I.5: Drift values for air-blast equipment to plants with lower crop intercept for single and multiple applications

Air-blast equipment to plants with lower crop intercept								
Distance [m]	No of applications							
	1	2	3	4	5	6	7	8 and more
	90th centile	82nd centile	77th centile	74th centile	72nd centile	70th centile	69th centile	67th centile
3	29.20	25.53	23.96	23.61	23.12	22.76	22.69	22.24
5	19.89	16.87	15.79	15.42	15.06	14.64	14.45	14.09
10	11.81	9.61	8.96	8.66	8.42	8.04	7.83	7.58
15	5.55	5.61	5.23	4.91	4.61	4.51	4.40	4.21
20	2.77	2.59	2.36	2.21	2.09	2.04	1.99	1.91
30	1.04	0.87	0.77	0.72	0.69	0.66	0.65	0.62
40	0.52	0.40	0.35	0.32	00.31	0.30	0.29	0.28
50	0.30	0.22	0.19	0.17	0.17	0.16	0.16	0.15

Table I.6: Drift values for air-blast equipment to plants with higher crop intercept for single and multiple applications

Air-blast equipment to plants with higher crop intercept								
Distance [m]	No of applications							
	1	2	3	4	5	6	7	8 and more
	90th centile	82nd centile	77th centile	74th centile	72nd centile	70th centile	69th centile	67th centile
3	15.73	12.13	11.01	10.12	9.74	9.21	9.10	8.66
5	8.41	6.81	6.04	5.60	5.41	5.18	5.11	4.92
10	3.60	3.11	2.67	2.50	2.43	2.38	2.33	2.29
15	1.81	1.58	1.39	1.28	1.24	1.20	1.20	1.14
20	1.09	0.90	0.80	0.75	0.72	0.68	0.67	0.65
30	0.54	0.40	0.36	0.35	0.34	0.31	0.30	0.29
40	0.32	0.23	0.21	0.20	0.20	0.17	0.17	0.16
50	0.22	0.15	0.13	0.13	0.13	0.11	0.11	0.11

Table I.4: Drift values for sideward sprayers for single and multiple applications

Sideward sprayers								
Distance [m]	No of applications							
	1	2	3	4	5	6	7	8 and more
	90th centile	82nd centile	77th centile	74th centile	72nd centile	70th centile	69th centile	67th centile
3	8.02	7.23	6.90	6.71	6.59	6.41	6.33	6.26
5	3.62	3.22	3.07	2.99	2.93	2.85	2.81	2.78
10	1.23	1.07	1.02	0.99	0.9	0.95	0.94	0.93
15	0.65	0.56	0.54	0.52	0.51	0.50	0.49	0.49
20	0.42	0.36	0.34	0.33	0.33	0.32	0.31	0.31
30	0.22	0.19	0.18	0.17	0.17	0.17	0.16	0.16
40	0.14	0.12	0.11	0.11	0.11	0.11	0.10	0.10
50	0.10	0.08	0.08	0.08	0.08	0.07	0.07	0.07

2.2.8.3 HUMAN EXPOSURE MODELS

In the exposure assessment for humans, drift values are considered just for the exposure of residents and bystanders according the new EFSA model 2022[1] .

2.2.8.3.1 SPRAY DRIFT – RESIDENTS EXPOSURE

The exposures of residents caused by spray drift should be calculated according to the following equation:

Spray drift resident exposure = Dermal exposure × dermal absorption percentage + inhalation exposure.

[1] (EFSA (European Food Safety Authority), Charistou A, Coja T, Craig P, Hamey P,Martin S, Sanvido O, Chiusolo A, Colas M and Istace F, 2022. Guidance on the assessment of exposureof operators, workers, residents and bystanders in risk assessment of plant protection products. EFSAJournal 2022;20(1):7032, 134 pp. https://doi.org/10.2903/j.efsa.2022.7032);

3-D orchards

Table 9. Ground sediments based on drift as a percentage of the application rate

Distance	Fruit crops, early stages [(a), (b)]		Fruit crops, late stages [(a), (b)]		Grapes [(a)]	
	Median	P77	Median	P77	Median	P77
2-3 m	18.96	23.96	6.96	11.01	5.25	6.90
5 m	11.69	15.79	6.04	6.04	2.32	3.07
10 m	6.07	8.96	2.67	2.67	0.77	1.02

P77: 77th percentile.
(a): From Ganzelmeier/Rautmann (the 75th percentile is not published)[2].
(b): Early/late season (stage) is a parameter only relevant for bystanders and residents and is based upon measured drift deposits (Ganzelmeier/Rautmann), in which the values for orchards were displayed separately for early and late stages (without leaves and with leaves). This differentiation applies also to cane fruit/high berries (outdoor) but does not apply to oil fruits or citrus crops, which are not directly comparable to orchards since these crops are evergreen plants. For oil fruits and citrus crops only, late season is considered relevant and realistic as regards exposure of bystanders and residents by deposits based on drift.

2.2.8.3.2 Spray drift - Bystanders exposure

The exposure of bystanders caused by spray drift should be calculated using the following equation:

Dermal exposure × dermal absorption percentage) + inhalation exposure.

Table 10. Ground sediments as a percentage of the application rate

Distance	Fruit crops, early stages [(a), (b)]	Fruit crops, late stages [(a), (b)]	Grapes [(a)]
	90th percentile	90th percentile	90th percentile
2-3 m	29.20	15.73	8.02
5 m	19.89	8.41	3.62
10 m	11.81	3.60	1.23

(a): From Ganzelmeier/Rautmann[2]
(b): Early/late season (stage) is a parameter only relevant for bystanders and residents and is based upon measured drift deposits (Ganzelmeier/Rautmann), in which the values for orchards were displayed separately for early and late stages (without leaves and with leaves). This differentiation applies also to cane fruit/high berries (outdoor) but does not apply to oil fruits or citrus crops, which are not directly comparable to orchards since these crops are evergreen plants. For oil fruits and citrus crops only late season is considered relevant and realistic as regards exposure of bystanders and residents by drift.

The main drift parameters considered in bystanders and residents exposure model are:

- Crop type (i.e. pome/stone fruits, citrus, grapes etc.)
- Substance properties:
  - Formulation type (powder, granules, soluble concentrates, emulsifiable concentrate, etc.)
  - Application rate
- Scenario:
  - Indoor (not considered for orchards, grapes and citrus) or outdoor

[2]Rautmann D, Streloke M, Winkler R, 2001. New drift values in the authorisation procedure for plant protection products. Mitteilungen aus der Biologischen Bundesanstalt f¨ur Land-und Forstwirtschaft (Federal Biological Research Center for Agriculture and Forestry). 383, Berlin, Germany, 133–141

3-D orchards

- Application method (down spraying or upward spraying)
- Application equipment (Vehicle-mounted, Vehicle-mounted with 50% drift reduction, Manual-Hand held, Manual-Knapsack)
- Number of application
- Season (early-no leaves or late-with leaves)

3 Assessment/Results

3.1 Identification of relevant 3-D orchards

In Table 11, data on area devoted to 3-D crops referred to each Southern Member State are reported together with the total area cultivated in the whole EU (27).

Table 11. Data on area (ha) devoted to 3-D orchards in EU (27) and in all MSs of SEU

3-D orchards	**Area in ha**									
	BG	**HR**	**CY**	**FR**	**EL**	**IT**	**MT**	**PT**	**ES**	**EU (27)**
Almonds, with shell	1010	620	2710	1180	15130	52040		39640	687230	799870
Apricots	2910	260	180	12280	8350	17910		560	20240	73240
Cherries	10840	680		7260	16100	29210		6060	27470	121870
Cherries, sour	1330	2170		770	140	0		90	130	53990
Chestnut		180		8570	8410	36280		38870	37120	129730
Figs	10	420	160	440	3990	2150		4130	14600	25920
Fruit, citrus nes					950	1560			1300	3810
Fruit, stone nes			30	2200	730			210	460	3940
Grapefruit (inc. pomelos)			410	390	150	280		20	2430	3680
Grapes	30050	19820	6670	755470	101850	697910	420	178780	936890	3160500
Hazelnuts with shell	1270	5530	20	5190	520	79350		350	13020	110420
Kiwi fruit	10			3810	10290	25080		2740	1550	43510
Lemons and limes		40	450	1070	3830	23130		1070	46840	76430
Nuts nes			50		4590	3840		65170	39600	113250
Olives		18610	11060	17720	903080	1139470		359950	2601900	5053160
Oranges		50	1260	1050	30320	81850		17470	140310	272310
Peaches and nectarines	3220	890	320	9040	41410	60430		3740	77700	206990
Plums and sloes	8020	4460	380	14830	2180	11940		1800	14850	154500
Tangerines, mandarins, clementines, satsumas		2110	1090	2100	8980	33920		2510	105580	156290
Walnuts, with shell	6360	7210	210	25880	14820	4670		3850	11440	86100
NUT*	8640	13540	2990	40820	43470	176180	0	147880	788410	1239370

* Sum of almonds, chestnut, hazelnut, nut nes and walnut

The area covered by each 3-D crop identified was also represented as surface cultivated in SEU with respect to the one cultivated in EU 27. Appendix A collects original data from the national statistics centres.

Furthermore, the representativeness of the three Member States involved in this project (Italy, Greece and Spain) was tackled for each 3-D crop identified. In the following table (Table 12), for each 3-D crop, the total area in SEU versus the area in the European Union is reported together with the total area represented by Italy (IT), Spain (ES) and Greece (EL) versus the area in the European Union.

To better represent the selection of relevant crops addressed in this project, the 3-D crops excluded for their limited extension are highlighted in grey (cultivated area lower than 50.000 ha) while the 3-D crops excluded due to the limited representativeness of SEU with respect to the whole European Union are highlighted in yellow. The crops grouped in a single larger category (NUTS) are highlighted in green

Table 12. Area (ha) and percentage represented by SEU vs EU (27) and by 3 MS vs. EU (27)

3D- Orchards	EL+ES+IT	SEU	EU (27)	SEU vs EU (27)	3MS vs. EU (27)
Fruit. citrus nes	3810	3810	3810	100%	100.00%
Lemons and limes	73800	76430	76430	100%	96.56%
Tangerines, clementine, satsumas	148480	156290	156290	100%	95.00%
Oranges	252480	272310	272310	100%	92.72%
Grapefruit (inc. pomelos)	2860	3680	3680	100%	77.72%
Nuts nes	48030	113250	113250	100%	42.41%
Olives	4644450	5051790	5053160	99.97%	91.91%
Almonds with shell	754400	799560	799870	99.96%	94.32%
Kiwi fruit	36920	43480	43510	99.93%	84.85%
Figs	20740	25900	25920	99.92%	80.02%
Chestnut	81810	129430	129730	99.77%	63.06%
Hazelnuts with shell	92890	105250	110420	95.32%	84.12%
Peaches and nectarines	179540	196750	206990	95.05%	86.74%
Fruit stone nes	1190	3630	3940	92.13%	30.20%
Walnuts with shell	30930	74440	86100	86.46%	35.92%
Grapes	1736650	2727860	3160500	86.31%	54.95%
Apricots	46500	62690	73240	85.60%	63.49%
Cherries	72780	97620	121870	80.10%	59.72%
Plums and sloes	28970	58460	154500	37.84%	18.75%
Cherries sour	270	4630	53990	8.58%	0.50%
NUT	1008060	1221930	1239370	98.59%	81.34%

Grey: Crop excluded for their limited extension
Yellow: crops excluded for the limited representativeness of SEU vs EU
Green: crops grouped in a single larger category (NUTS)

It has to be underlined that crops may also be grouped according to the crop training system and treatment equipment used for application.

Therefore, considering the results from the analysis reported in Table 12 and taking into account the crop training system, the following list of crops is considered the one mainly representative for the 3-D crops, typical of Southern Europe:

- Grapes (to be considered also for the two different types of cultivation: table grape and wine grape)
- Apricots
- Cherries
- Lemons and limes
- Oranges
- Peaches and Nectarines
- Tangerines, clementine, satsumas
- Olives (to be investigated also for the possible difference occurring in treatments for intensive vs. traditional training system)
- Nuts (sum of Almond, Walnuts, Chestnuts, Hazelnuts and Pistachio).

All these crops were addressed in the next paragraph, moving from official data collected at European level to official data collected at national level.

3.2 Analysis of National data

Statistical data related to 3D orchards cultivation were reported on maps to help the identification of major areas. The use of statistical national data, collected at province level, allowed the identification of clusters of crop cultivations on the 3 MSs.

In the next three tables, the regional percentages of the crops for Greece, Italy and Spain are reported. The crops have been addressed with official data collected at national level.

These data were also reported on maps through a GIS system. All maps are reported in Appendix B.

Table 13. Regional percentage - Greece

	Apricot	Cherry	Vines for wine	Vines for table grapes	Vines for raisins	Lemon	Almond	Walnut	Chestnut	Hazelnut & pistachio	Olive trees	Orange	Peaches - Nectarine	Tangerines clementines, satsumas
			Grapes				NUTS							
Greece Total (ha)	**8.102**	**15.736**	**49.504**	**9.886**	**27.624**	**4.102**	**15.207**	**13.881**	**8.873**	**5.471**	**793.092**	**29.451**	**39.404**	**8.179**
Regions	**% vs total**													
Eastern Macedonia and Thrace	2.33%	4.18%	4.56%	28.85%	0.00%	0.00%	7.98%	8.22%	0.61%	1.11%	1.88%	0.00%	0.57%	0.00%
Central Macedonia	52.65%	79.32%	8.37%	18.93%	0.05%	0.02%	23.86%	15.99%	23.65%	8.92%	5.05%	0.01%	85.44%	0.01%
Western Macedonia	0.38%	4.82%	3.19%	1.66%	0.00%	0.00%	5.66%	10.97%	4.14%	1.74%	0.04%	0.00%	5.63%	0.00%
Epirus	0.20%	0.08%	1.48%	0.11%	0.00%	3.49%	0.32%	2.43%	1.91%	0.95%	2.44%	10.73%	0.07%	35.15%
Thessally	9.18%	5.93%	7.95%	12.33%	0.00%	0.15%	50.74%	23.43%	31.58%	24.15%	3.38%	0.03%	6.33%	0.06%
Central Greece	0.37%	2.15%	11.05%	1.22%	0.10%	1.07%	5.79%	13.52%	4.31%	43.85%	10.17%	0.34%	0.33%	0.20%
Ionian Islands	0.06%	0.03%	3.37%	0.22%	4.19%	1.71%	0.27%	0.12%	0.00%	0.00%	4.25%	0.28%	0.01%	0.31%
Western Greece	0.35%	0.83%	10.63%	1.66%	25.57%	48.68%	1.72%	5.04%	2.73%	0.26%	10.50%	18.91%	0.12%	10.49%
Peloponnese	33.71%	2.21%	15.26%	7.04%	37.93%	27.06%	2.17%	18.26%	17.86%	0.69%	27.83%	57.42%	1.22%	42.46%
Attica	0.05%	0.04%	11.61%	0.54%	0.00%	3.44%	0.28%	0.06%	0.01%	17.35%	1.99%	0.14%	0.01%	0.23%
Northern Aegean	0.11%	0.18%	4.45%	1.28%	0.00%	2.10%	0.84%	0.19%	10.46%	0.00%	6.69%	1.22%	0.02%	3.66%
Southern Aegean	0.22%	0.02%	5.92%	1.34%	0.00%	2.93%	0.23%	0.03%	0.00%	0.79%	1.86%	0.98%	0.17%	1.77%
Crete	0.38%	0.22%	12.17%	24.82%	32.15%	9.36%	0.15%	1.74%	2.75%	0.22%	23.91%	9.95%	0.08%	5.67%

Table 14. Regional percentage - Italy

	Apricot	Cherry	Wine grapes	Table grapes	Lemons	Table and oil olives	Oranges	Peach	Nectarine	Almond	Hazelnut	Pistachio	Clementine	Tangerine
			Grapes							NUTS			Tangerines, clementines, satsumas	
Italy (ha)	**20089**	**30011**	**669827**	**47416**	**25812**	**1164568**	**82729**	**42835**	**19267**	**53076**	**86725**	**3922**	**25762**	**8594**
Regions	**% vs total**													
Piemonte	3.51%	1.18%	6.41%	0.43%	0	0.01%	0	3.76%	11.00%	0	28.32%	0	0	0
Lombardia	0.51%	0.63%	3.73%	0	0	0.21%	0	0.74%	0.44%	0.01%	0.30%	0	0	0
Veneto	1.94%	7.01%	13.33%	0.15%	0	0.44%	0	3.11%	3.82%	0	0.62%	0	0	0
Liguria	0.32%	0.08%	0.24%	0	0.10%	1.45%	0.02%	0.25%	0.03%	0	0.03%	0	0.01%	0.08%
Trentino Alto Adige / Südtirol	0.47%	1.30%	2.35%	0.19%	0	0.03%	0	0.01%	0.01%	0	0	0	0	0
Friuli-Venezia Giulia	0.05%	0.08%	3.59%	0	0	0.05%	0	0.38%	0.07%	0	0.01%	0	0	0
Emilia-Romagna	31.38%	7.14%	7.97%	0.05%	0	0.36%	0	9.96%	35.30%	0.01%	0.16%	0	0	0
Toscana	0.95%	0.49%	8.84%	0.15%	0.01%	7.72%	0	1.11%	0.62%	0.12%	0.54%	0	0.01%	0
Lazio	0.73%	2.87%	3.04%	2.08%	0.25%	7.12%	0.51%	3.91%	1.63%	0.07%	28.34%	0	0.34%	0.26%
Campania	23.68%	10.60%	3.83%	0.15%	4.78%	6.51%	1.20%	36.30%	21.46%	0.02%	24.74%	0.89%	1.10%	5.10%
Puglia	5.75%	62.34%	13.15%	52.69%	1.10%	33.00%	4.70%	7.59%	4.46%	37.35%	0.01%	0.03%	19.39%	1.49%
Calabria	3.12%	1.29%	1.32%	0.69%	3.95%	15.85%	19.80%	4.06%	5.62%	0.35%	0.35%	0	62.48%	28.07%
Sicilia	4.96%	2.48%	17.95%	39.60%	89.14%	13.56%	66.44%	14.60%	4.75%	59.57%	15.92%	98.95%	8.64%	55.05%
Sardegna	0.69%	0.96%	3.97%	1.18%	0.47%	3.49%	2.68%	3.61%	0.91%	1.93%	0.17%	0	3.08%	2.33%
Umbria	0.12%	0.07%	1.84%	0.02%	0	2.32%	0	0.27%	0.11%	0.01%	0.17%	0	0	0
Marche	0.90%	0.28%	2.37%	0.03%	0	0.82%	0	1.25%	1.31%	0.03%	0.02%	0	0	0
Abruzzo	1.49%	0.61%	4.86%	1.42%	0	3.60%	0.01%	4.25%	2.70%	0.26%	0.15%	0	0	0
Molise	0.70%	0.03%	0.83%	0.13%	0	1.23%	0.01%	0.49%	0.49%	0.11%	0.09%	0	0	0
Basilicata	18.74%	0.59%	0.30%	1.03%	0.19%	2.24%	4.63%	4.35%	5.25%	0.15%	0.05%	0.13%	4.95%	7.63%
Valle d'Aosta / Vallée d'Aoste	0	0	0.07%	0	0	0	0	0	0	0	0	0	0	0

Table 15. Regional percentage - Spain

	Apricot	Cherry	Wine grape	Table & raisin grape	Lemon	Nuts (almond. walnut. hazelnut. chestnut. pistachio)	Orange	Oil & table olive	Table olive	Oil olive	Peach & nectarine	Tangerines clementines, satsumas
			Grapes					Olive				
Spain total	**20235**	**27604**	**920525**	**16363**	**46684**	**788266**	**139971**	**2601901**	**166774**	**2435127**	**77464**	**105583**
Region	**% vs total**											
Andalucía	2.56%	6.86%	2.78%	18.75%	14.01%	28.77%	41.09%	62.77%	56.93%	63.17%	6.00%	18.91%
Aragón	13.14%	32.47%	3.78%	1.11%	0	10.04%	0	1.79%	0	1.91%	26.43%	0
C. Valenciana	18.61%	9.70%	6.38%	33.39%	29.51%	12.05%	50.26%	3.60%	0.28%	3.83%	5.70%	69.20%
Cantabria	0	0	0.01%	0	0.02%	0	0	0	0	0	0	0
Castilla la Mancha	7.70%	1.01%	47.95%	0.40%	0	20.90%	0	14.37%	0.14%	15.34%	2.92%	0
Castilla y León	0.01%	5.78%	8.92%	0.06%	0	0.75%	0	0.31%	0.33%	0.31%	0.07%	0
Cataluña	9.20%	10.05%	6.15%	0.11%	0.06%	6.68%	1.56%	4.22%	0.25%	4.49%	26.95%	6.19%
Extremadura	3.23%	27.26%	8.55%	1.83%	0	2.06%	0.04%	10.16%	41.35%	8.02%	11.06%	0.01%
Galicia	0.43%	2.46%	2.62%	0	0.41%	3.22%	0.06%	0.01%	0	0.01%	1.31%	0
Islas Baleares	2.10%	0.11%	0.24%	0.31%	0.40%	3.05%	1.20%	0.33%	0.06%	0.35%	0.19%	0.25%
Islas Canarias	0.33%	0.02%	0.68%	0.56%	0.56%	0.03%	0.68%	0.02%	0.06%	0.01%	0.18%	0.09%
La Rioja	0.15%	1.65%	5.15%	0.02%	0	1.33%	0	0.22%	0	0.23%	0.62%	0
Madrid	0	0.01%	0.89%	0	0	0.26%	0	1.03%	0.07%	1.09%	0	0
Navarra	0.08%	1.23%	1.95%	0	0	0.54%	0	0.30%	0	0.32%	0.61%	0
P. de Asturias	0	0	0.01%	0	0	0	0	0	0	0	0	0
País Vasco	0	0.06%	1.54%	0	0	0.05%	0	0.01%	0	0.01%	0.02%	0
R. de Murcia	42.44%	1.35%	2.40%	43.48%	55.03%	10.27%	5.12%	0.87%	0.53%	0.90%	17.93%	5.34%

3.2.1 Identification of the major areas of production in Italy, Spain and Greece

The major national areas of production of the selected orchards were identified with the contribution of national census data. The data related to the identified crops were collected at regional and province level. In the next tables, the regional data for Greece, Italy and Spain are presented. The number of inspection stations for each region was also represented.

The major areas of production in the different MS, were coloured to highlight the major and medium area of cultivation, where further investigation is needed.

Two tables are available for each MS: the first one reporting the extension (ha) of the selected crop for each region and the second one the percentage of the crops in each region versus the total amount in the nation.

Considering Greece (Table 16 and Table 17), 5 regions out of 13 (Eastern Macedonia and Thrace, Western Macedonia, Ionian Islands, Northern Aegean and Southern Aegean) can be excluded from further investigations, since the 3-D crops identified, if present, are cultivated in very minor areas.

Cherries and peaches/nectarines are cultivated mostly in the region of Central Macedonia (around 80% of the national production is cultivated in this region).

Apricot and lemon are both present mainly in just two Greek regions. Central Macedonia and Peloponnese cover more than 85% of the national production of apricot while Western Greece and Peloponnese represent around 75% of the national production of lemon.

Orange and the group "tangerine, clementine and satsumas" are cultivated mainly in Peloponnese, Western Greece and Epirus. These 3 regions represent more than 85% of the national production for both orange and the group "tangerine, clementine and satsumas".

Grapes and olives are mainly cultivated in Peloponnese and Crete but also other regions cannot be excluded from further analysis.

Considering Italy (Table 18 and Table 19), 8 regions out of 20 (Valle d'Aosta, Liguria, Friuli Venezia Giulia, Trentino Alto Adige, Marche, Umbria, and Molise) may be excluded from further investigations, since the 3-D crops identified, if present, are cultivated in very minor areas.

Three regions in Southern Italy are of reference for citrus: Sicilia alone cover more than 89% of the production of lemons, with Calabria they represent more than 86% of the production of oranges and with Puglia the group "tangerine, clementine and satsumas" is represented at a level higher than 88% of the national production.

Sicilia and Puglia also represent more than 92% of the national production of table grapes.

Apricot is cultivated mainly in three different regions, Emilia Romagna, Campania and Basilicata, which represent more than 70% of the national production.

Peach and nectarine are cultivated mainly in Campania, but also Sicilia, Emilia.-Romagna and Puglia are characterised by quite a good number of hectares of these crops.

Sicilia, Puglia and Calabria are also of reference for the olive production but other regions like Toscana, Lazio and Campania cannot be disregarded.

3-D orchards

Finally, wine grapes and nuts are mainly cultivated in three regions (Sicilia, Puglia and Veneto for wine grapes and Sicilia, Lazio and Piemonte for nuts) but other regions are quite important for both crops.

Considering Spain (Table 20 and Table 21) 8 regions out of 17 (Cantabria, Galicia, Islas Baleares, Islas Canarias, La Rioja, Madrid, Navarra, Principado de Asturias and País Vasco) can be excluded from further investigations, since the 3-D crops identified, if present, are cultivated in very minor areas.

Orange and the group "tangerine, clementine and satsumas" are cultivated mainly in Andalucía and Comunidad Valenciana: these two regions represent more than 90% of the national production of oranges and more than 85% of the one of tangerine, clementine and satsumas.

The cultivation of lemon, apricot, table & raisin grape and olives are each represented by 3 regions: Andalucía, Comunidad Valenciana and Región de Murcia for lemon (more than 90% of national production); Aragón, Comunidad Valenciana and Región de Murcia for apricot (more than 70% of national production); Andalucía, Comunidad Valenciana, and Región de Murcia for table & raisin grape (more than 90% of national production); Andalucía, Castilla la Mancha and Extremadura for olives (more than 85% of national production)

Moreover, Castilla la Mancha is the major producer of wine grapes but other regions cannot be disregarded.

Cherries, peaches/nectarines and nuts are mainly cultivated in two regions (Aragón and Extremadura for cherries; Aragón and Cataluña for peaches/nectarines; Andalucía and Castilla la Mancha for nuts) but other regions are quite important for the three crops.

3-D orchards

Table 16. Greece - Cultivation area (ha) and inspection stations (#)

Regions	Number of inspection stations	Type of crop (Area - ha)									
		Orange	Tangerine + clementine +satsumas	Lemon	Apricot	Cherry	Peaches - Nectarines	NUT*	Vines for wine	Table & Raisin grap	Olive trees
Greece Total	**103**	**29.451**	**8.179**	**4.102**	**8.102**	**15.736**	**39.404**	**43.432**	**49.504**	**37.509**	**793.092**
Eastern Macedonia and Thrace	**27**				189	658	225	2.469	2.257	2.853	14.899
Central Macedonia	**5**	2	1	1	4.266	12.482	33.667	8.435	4.144	1.886	40.043
Western Macedonia	**2**				31	759	2.220	2.845	1.577	164	321
Epirus	**8**	3.159	2.875	143	16	13	28	607	735	11	19.378
Thessally	**12**	9	5	6	744	933	2.495	15.091	3.938	1.220	26.815
Central Greece	**0**	101	16	44	30	339	129	5.539	5.470	149	80.655
Ionian Islands	**9**	82	25	70	5	5	5	57	1.670	1.180	33.707
Western Greece	**15**	5.568	858	1.997	28	130	46	1.217	5.260	7.228	83.272
Peloponnese	**2**	16.910	3.473	1.110	2.731	347	481	4.488	7.552	11.173	220.704
Attica	**0**	42	19	141	4	6	3	1.001	5.745	53	15.810
Northern Aegean	**0**	358	299	86	9	29	7	1.081	2.205	127	53.037
Southern Aegean	**7**	289	145	120	18	3	67	82	2.929	132	14.784
Crete	**16**	2.931	464	384	31	34	32	520	6.023	11.335	189.666

Green: major area of production
Yellow: medium area of production
*NUT: Almond, walnut, hazelnut, chestnut, pistachio

Table 17. Greece - Cultivation area (%)

Regions	Type of crop (%)									
	Orange	**Tangerine + clementine +satsumas**	**Lemon**	**Apricot**	**Cherry**	**Peaches - Nectarines**	**NUT***	**Vines for wine**	**Table & Raisin grapes**	**Olive trees**
Eastern Macedonia and Thrace				2.34	4.18	0.57	5.68	4.56	7.61	1.88
Central Macedonia	0.01	0.02	0.02	52.65	79.32	85.44	19.42	8.37	5.03	5.05
Western Macedonia				0.38	4.82	5.63	6.55	3.19	0.44	0.04
Epirus	10.73	35.14	3.48	0.20	0.08	0.07	1.40	1.48	0.03	2.44
Thessally	0.03	0.06	0.15	9.18	5.93	6.33	34.75	7.95	3.25	3.38
Central Greece	0.34	0.19	1.08	0.38	2.15	0.33	12.75	11.05	0.40	10.17
Ionian Islands	0.28	0.30	1.70	0.06	0.03	0.01	0.13	3.37	3.15	4.25
Western Greece	18.91	10.49	48.68	0.34	0.83	0.12	2.80	10.62	19.27	10.50
Peloponnese	57.42	42.46	27.06	33.70	2.20	1.22	10.33	15.26	29.79	27.83
Attica	0.14	0.24	3.44	0.05	0.04	0.01	2.31	11.61	0.14	1.99
Northern Aegean	1.22	3.66	2.10	0.11	0.18	0.02	2.49	4.45	0.34	6.69
Southern Aegean	0.98	1.77	2.91	0.22	0.02	0.17	0.19	5.92	0.35	1.86
Crete	9.95	5.68	9.37	0.38	0.21	0.08	1.20	12.17	30.22	23.91

Green: major area of production
Yellow: medium area of production
*NUT: Almond, walnut, hazelnut, chestnut, pistachio

Table 18. Italy - Cultivation area (ha) and sprayer inspection stations for 3D crop sprayers (#)

Regions	No of inspection stations	Type of crop (Area - ha)									
		Orange	Tangerine + clementine +satsumas	Lemon	Apricot	Cherry	Peach & Nectarine	NUT*	Wine grapes	Table grapes	Table and oil olives
Italy total	**289**	**82729**	**34356**	**25812**	**20089**	**30011**	**62102**	**143723**	**669827**	**47416**	**1164568**
Piemonte	39				706	353	3728	24557	42961	206	132
Lombardia	31			1	103	189	401	264	24962		2394
Veneto	53				390	2105	2069	541	89288	69	5160
Liguria	2	16	10	27	65	24	115	27	1624	2	16840
Trentino Alto Adige / Südtirol	11				94	389	7	4	15763	91	392
Friuli-Venezia Giulia	10				10	24	176	11	24052		625
Emilia-Romagna	16				6303	2142	11069	148	53385	26	4155
Toscana	11	4	2	3	191	146	595	531	59213	70	89929
Lazio	7	420	110	64	147	860	1990	24613	20347	984	82931
Campania	18	990	721	1235	4757	3181	19685	21500	25633	69	75763
Puglia	15	3890	5123	283	1155	18709	4110	19836	88109	24985	384300
Calabria	5	16382	18509	1019	626	386	2822	491	8831	328	184529
Sicilia	11	54964	6956	23009	996	744	7170	49307	120262	18776	157891
Sardegna	7	2215	993	121	138	289	1722	1170	26619	561	40604
Umbria	4				24	20	138	149	12300	11	27001
Marche	13				180	84	787	37	15859	16	9606
Abruzzo	26	6			299	182	2340	269	32529	673	41895
Molise	2	8	1	1	140	8	305	135	5593	60	14335
Basilicata	6	3834	1931	49	3765	176	2873	131	2027	489	26086
Valle d'Aosta	2							2	470		

Green: major area of production
Yellow: medium area of production
*NUT: Almonds. Hazelnut and Pistachio
Note: for limes, satsumas, chestnuts and walnuts no data are available for 2019

Table 19. Italy -Cultivation area (%).

Regions	Type of crop (%)									
	Orange	**Tangerine + clementine +satsumas**	**Lemon**	**Apricot**	**Cherry**	**Peach & Nectarine**	**NUT***	**Wine grapes**	**Table grapes**	**Table and oil olives**
Piemonte				3.51	1.18	6.00	17.09	6.41	0.43	0.01
Lombardia				0.51	0.63	0.65	0.18	3.73		0.21
Veneto				1.94	7.01	3.33	0.38	13.33	0.15	0.44
Liguria	0.02	0.03	0.10	0.32	0.08	0.19	0.02	0.24		1.45
Trentino Alto Adige / Südtirol				0.47	1.30	0.01	0.00	2.35	0.19	0.03
Friuli-Venezia Giulia				0.05	0.08	0.28	0.01	3.59		0.05
Emilia-Romagna				31.38	7.14	17.82	0.10	7.97	0.05	0.36
Toscana		0.01	0.01	0.95	0.49	0.96	0.37	8.84	0.15	7.72
Lazio	0.51	0.32	0.25	0.73	2.87	3.20	17.13	3.04	2.08	7.12
Campania	1.20	2.10	4.78	23.68	10.60	31.70	14.96	3.83	0.15	6.51
Puglia	4.70	14.91	1.10	5.75	62.34	6.62	13.80	13.15	52.69	33.00
Calabria	19.80	53.87	3.95	3.12	1.29	4.54	0.34	1.32	0.69	15.85
Sicilia	66.44	20.25	89.14	4.96	2.48	11.55	34.31	17.95	39.60	13.56
Sardegna	2.68	2.89	0.47	0.69	0.96	2.77	0.81	3.97	1.18	3.49
Umbria	0.00	0.00	0.00	0.12	0.07	0.22	0.10	1.84	0.02	2.32
Marche	0.00	0.00	0.00	0.90	0.28	1.27	0.03	2.37	0.03	0.82
Abruzzo	0.01	0.00	0.00	1.49	0.61	3.77	0.19	4.86	1.42	3.60
Molise	0.01	0.00	0.00	0.70	0.03	0.49	0.09	0.83	0.13	1.23
Basilicata	4.63	5.62	0.19	18.74	0.59	4.63	0.09	0.30	1.03	2.24
Valle d'Aosta / Vallée d'Aoste							0.00	0.07		

Green: major area of production
Yellow: medium area of production
*NUT: Almonds. Hazelnut and Pistachio
Note: for limes, satsumas, chestnuts and walnuts no data are available for 2019

Table 20. Spain -Cultivation area (ha) and inspection stations (#).

Regions	Number of inspection stations	Type of crop (Area - ha)									
		Orange	Tangerine + clementine +satsumas	Lemon	Apricot	Cherry	Peach & Nectarine	NUT	Wine Grape	Table & Raisin grape	Oil & Table olive
Spain Total	**158**	**139.971**	**105.583**	**46.684**	**20.235**	**27.604**	**77.464**	**788.266**	**920.525**	**16.363**	**2.601.901**
Andalucía	38	57.509	19.971	6.539	518	1.893	4.646	226.810	25.627	3.068	1.633.215
Aragón	4	-	-	-	2.659	8.962	20.475	79.172	34.833	181	46.534
C. Valenciana	18	70.344	73.068	13.778	3.766	2.678	4.417	94.960	58.688	5.463	93.741
Cantabria	0	-	-	8	-	1	1	10	119	-	-
Castilla la Mancha	30	-	-	-	1.559	278	2.264	164.786	441.357	66	373.849
Castilla y León	18	3	-	-	2	1.595	54	5.879	82.074	9	8.150
Cataluña	4	2.188	6.536	30	1.862	2.775	20.880	52.621	56.594	18	109.731
Extremadura	10	51	7	1	653	7.524	8.567	16.228	78.683	299	264.286
Galicia	10	84	-	192	88	678	1.015	25.412	24.134	-	275
Islas Baleares	1	1.677	261	185	425	29	148	24.043	2.237	50	8.524
Islas Canarias	5	952	97	260	67	5	138	245	6.244	91	425
La Rioja	1	-	-	-	30	456	483	10.472	47.447	4	5.651
Madrid	7	-	-	-	1	2	1	2.038	8.197	-	26.696
Navarra	8	-	-	-	17	339	471	4.257	17.950	-	7.752
P. de Asturias	2	-	-	-	-	-	-	-	114	-	-
País Vasco	1	-	-	1	-	16	13	357	14.143	-	365
R. de Murcia	1	7.161	5.643	25.690	8.588	373	13.891	80.976	22.084	7.114	22.707

Green: major area of production

Yellow: medium area of production

*NUT: Almond, walnut, hazelnut, chestnut, pistachio

Table 21. Spain -Cultivation area (%).

Regions	Type of crop (%)									
	Orange	**Tangerine + clementine +satsumas**	**Lemon**	**Apricot**	**Cherry**	**Peach & Nectarine**	**NUT**	**Wine Grape**	**Table & Raisin grape**	**Oil & Table olive**
Andalucía	41.09	18.91	14.01	2.56	6.86	6.00	28.77	2.78	18.75	62.77
Aragón	0.00	0.00	0.00	13.14	32.47	26.43	10.04	3.78	1.11	1.79
C. Valenciana	50.26	69.20	29.51	18.61	9.70	5.70	12.05	6.38	33.39	3.60
Cantabria	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Castilla la Mancha	0.00	0.00	0.00	7.70	1.01	2.92	20.90	47.95	0.40	14.37
Castilla y León	0.00	0.00	0.00	0.01	5.78	0.07	0.75	8.92	0.06	0.31
Cataluña	1.56	6.19	0.06	9.20	10.05	26.95	6.68	6.15	0.11	4.22
Extremadura	0.04	0.01	0.00	3.23	27.26	11.06	2.06	8.55	1.83	10.16
Galicia	0.06	0.00	0.41	0.43	2.46	1.31	3.22	2.62	0.00	0.01
Islas Baleares	1.20	0.25	0.40	2.10	0.11	0.19	3.05	0.24	0.31	0.33
Islas Canarias	0.68	0.09	0.56	0.33	0.02	0.18	0.03	0.68	0.56	0.02
La Rioja	0.00	0.00	0.00	0.15	1.65	0.62	1.33	5.15	0.02	0.22
Madrid	0.00	0.00	0.00	0.00	0.01	0.00	0.26	0.89	0.00	1.03
Navarra	0.00	0.00	0.00	0.08	1.23	0.61	0.54	1.95	0.00	0.30
P. de Asturias	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
País Vasco	0.00	0.00	0.00	0.00	0.06	0.02	0.05	1.54	0.00	0.01
R. de Murcia	5.12	5.34	55.03	42.44	1.35	17.93	10.27	2.40	43.48	0.87

Green: major area of production
Yellow: medium area of production
*NUT: Almond, walnut, hazelnut, chestnut, pistachio

3.2.2 Identification of cluster of 3-D orchards cultivation in Italy, Spain and Greece

3.2.2.1 Apricots

3 regions in Greece represent more than 95% of the Greek production of apricots (Table 22); 3 regions in Italy represent more than 70% of the Italian production of apricots (Table 23); and 5 regions in Spain represent more than 90% of the Spanish production of apricots (Table 24).

Table 22. Distribution of apricots at province level: EL. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Greece Total	**8102**	
Region of Central Macedonia	**4266**	**52.65**
Imathia	413	9.69
Pella	2109	49.44
Chalkidiki	1447	33.93
Region of Thessally	**744**	**9.18**
Larissa	708	95.12
Region of Peloponnese	**2731**	**33.71**
Argolida	1469	53.80
Korinthia	1085	39.73

Table 23. Distribution of apricots at province level: IT. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Italy total	**20089**	
Emilia-Romagna	**6303**	**31.38**
Ravenna	2600	41.25
Bologna	1255	19.91
Forlì-Cesena	1782	28.27
Campania	**4757**	**23.68**
Caserta	1923	40.42
Napoli	2369	49.80
Basilicata	**3765**	**18.74**
Matera	3700	88.40

4

Table 24. Distribution of apricots at province level: ES. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	**ha**	**%**
Spain total	**20235**	
Aragón	**2659**	**13.14**
Huesca	722	27.15
Zaragoza	1773	66.68
Cataluña	**1862**	**9.20**
Lleida	1564	84.00
Tarragona	212	11.39
Castilla la Mancha	**1559**	**7.70**
Albacete	1545	99.10
C. Valenciana	**3766**	**18.61**
Alicante	606	16.09
Valencia	2970	78.86
R. de Murcia	**8588**	**42.44**

In Appendix B, the distribution of apricot is reported as distribution in EU (27) at MS level (B.1.) and in EL, IT and ES at province level (B.2.).

3.2.2.2 Cherries

2 regions in Greece represent more than 80% of the Greek production of cherries (Table 25); 4 regions in Italy represent more than 85% of the Italian production of cherries (Table 26); and 5 regions in Spain represent more than 85% of the Spanish production of cherries (Table 27).

Table 25. Distribution of cherries at province level: EL. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	**ha**	**%**
Greece Total	**15736**	
Region of Central Macedonia	**12482**	**79.32**
Imathia	1083	8.68
Pella	10174	81.51
Region of Thessally	**933**	**5.93**
Larissa	755	80.95
Magnesia	116	12.44

Table 26. Distribution of cherries at province level: IT. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Italy total	**30011**	
Puglia	**18709**	**62.34**
Bari	17200	91.92
Emilia-Romagna	**2142**	**7.13**
Modena	890	44.55
Bologna	290	13.54
Forlì-Cesena	540	25.21
Campania	**3181**	**10.60**
Caserta	1948	61.24
Benevento	460	14.46
Veneto	**2105**	**7.01**
Verona	1621	77.01
Vicenza	268	12.73

Table 27. Distribution of cherries at province level: ES. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Spain total	**27604**	
Aragón	**8962**	**32.47**
Huesca	890	9.93
Zaragoza	7920	88.37
Cataluña	**2775**	**10.05**
Barcelona	285	10.27
Lleida	817	29.44
Tarragona	1571	56.61
Extremadura	**7524**	**27.26**
Cáceres	7490	99.55
C. Valenciana	**2678**	**9.70**
Alicante	2029	75.77
Castellón	562	20.99
Andalucía	**1893**	**6.86**
Valencia	690	36.45
Jaén	1041	54.99

In Appendix B, the distribution of cherries is reported as distribution in EU (27) at MS level (B.3.) and in EL, IT and ES at province level (B.4.).

3.2.2.3 Grapes

3.2.2.3.1 Table grapes

2 regions in Greece represent more than 86% of the Greek production of table grapes (Table 28); 2 regions in Italy represent more than 90% of the Italian production of table grapes (Table 29); and 3 regions in Spain represent more than 95% of the Spanish production of table grapes (Table 30).

Table 28. Distribution of table grapes at province level: EL. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Greece Total	**37509**	
Region of Eastern Macedonia and Thrace	**2853**	**7.61**
Kavala	2519	88.29
Region of Western Greece	**7228**	**19.27**
Achaia	4664	64.53
Ilia	2553	35.32
Region of Peloponnese	**11173**	**29.79**
Korinthia	9459	84.66
Mesinia	1541	13.79
Region of Crete	**11335**	**30.22**
Heraklion	10796	95.24

Table 29. Distribution of table grapes at province level: IT. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Italy total	**47416**	
Puglia	**24985**	**52.69**
Bari	11000	44.03
Taranto	8100	32.42
Barletta-Andria-Trani	4200	16.81
Sicilia	**18776**	**39.60**
Agrigento	5560	29.61
Caltanissetta	3000	15.98
Catania	4000	21.30
Palermo	3280	17.47
Ragusa	2700	14.38

Table 30. Distribution of table grapes at province level: ES. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Spain total	**16363**	
R. de Murcia	**7114**	**43.48**
Andalucía	**3068**	**18.75**
Cádiz	246	8.02
Málaga	2194	71.51
Sevilla	256	8.34
C. Valenciana	**5463**	**33.39**
Alicante	5284	96.72

3.2.2.3.2 Wine grapes

7 regions in Greece represent more than 77% of the Greek production of wine grapes (Table 31); 6 regions in Italy represent more than 65% of the Italian production of wine grapes (Table 32); and 6 regions in Spain represent more than 80% of the Spanish production of wine grapes (Table 33).

Table 31. Distribution of wine grapes at province level: EL. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Greece Total	**49504**	
Region of Central Macedonia	**4144**	**8.37**
Thessaloniki	1018	24.56
Imathia	535	12.92
Kilkis	555	13.38
Pella	461	11.13
Pieria	297	7.17
Serres	512	12.36
Chalkidiki	766	18.48
Region of Thessally	**3938**	**7.95**
Larissa	2206	56.02
Karditsa	916	23.25
Magnesia	364	9.24
Trikala	445	11.29
Region of Central Greece	**5470**	**11.05**
Pthiotida	1005	18.37
Viotia	2904	53.10
Evia	1410	25.77
Region of Western Greece	**5260**	**10.62**
Achaia	2992	56.88
Etolia and Akarnania	735	13.96
Ilia	1533	29.15
Region of Peloponnese	**7552**	**15.26**
Arkadia	1429	18.92
Argolida	882	11.68
Korinthia	3273	43.33
Lakonia	726	9.62
Mesinia	1243	16.46
Region of Attica	**5745**	**11.61**
Athens East Section	4918	85.61
West Attica	748	13.03
Region of Crete	**6023**	**12.17**
Heraklion	2925	48.56
Lasithi	768	12.75
Rethymno	810	13.45
Chania	1520	25.23

Table 32. Distribution of wine grapes at province level: IT. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Italy total	**669827**	
Puglia (the entire region)	**88109**	**13.15**
Emilia Romagna	**53385**	**7.97**
Ravenna	15900	29.78
Reggio Emilia	8600	16.11
Modena	8489	15.90
Bologna	6177	11.57
Forlì-Cesena	6145	11.51
Sicilia	**120262**	**17.95**
Agrigento	38076	32.20
Trapani	54000	45.66
Palermo	15295	12.93
Toscana	**59213**	**8.84**
Arezzo	6330	10.69
Firenze	16800	28.37
Grosseto	7500	12.67
Siena	20872	35.25
Veneto	**89288**	**13.30**
Treviso	39013	43.69
Verona	16800	39.44
Venezia	8548	9.57
Piemonte	**42961**	**6.41**
Alessandria	10865	25.29
Asti	14631	34.06
Cuneo	15400	35.83

Table 33. Distribution of wine grapes at province level: ES. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Spain total	**920525**	
La Rioja	**47447**	**5.15**
Cataluña	**56594**	**6.15**
Barcelona	22389	39.56
Tarragona	27298	48.23
Castilla y León	**82074**	**8.92**
Burgos	18578	22.64
León	11206	13.65
Valladolid	29082	35.43
Zamora	12148	14.80
Castilla la Mancha	**441357**	**47.95**
Albacete	86388	19.57
Ciudad Real	159512	36.14
Cuenca	84209	19.08
Toledo	109553	24.82
C. Valenciana	**58688**	**6.38**
Alicante	10516	17.92
Valencia	47402	80.77
Extremadura	**78683**	**8.55**
Badajoz	75888	96.45

In Appendix B, the distribution of grapes is reported as distribution in EU (27) at MS level (B.5.) and in EL, IT and ES at province level, divided in table grapes and wine grapes (B.6. and B.7. respectively).

3.2.2.4 Lemons

3 regions in Greece represent more than 80% of the Greek production of lemons (Table 34); 1 region in Italy represents more than 89% of the Italian production of lemons (Table 35); and 3 regions in Spain represent more than 98% of the Spanish production of lemons (Table 36).

Table 34. Distribution of lemons at province level: EL. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Greece Total	**4102**	
Region of Western Greece	**1997**	**48.68**
Achaia	1511	75.66
Etolia and Akarnania	311	15.55
Ilia	176	8.79
Region of Peloponnese	**1110**	**27.06**
Argolida	182	16.41
Korinthia	705	63.47
Lakonia	159	14.34
Region of Crete	**384**	**9.37**
Heraklion	105	27.29
Rethymno	33	8.45
Chania	239	62.25

Table 35. Distribution of lemons at province level: IT. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Italy total	**25812**	
Sicilia	**23009**	**89.60**
Catania	4500	19.56
Messina	8500	36.94
Palermo	4020	17.47
Siracusa	5500	23.90

Table 36. Distribution of lemons at province level: ES. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Spain total	**46684**	
R. de Murcia	**25690**	**55.03**
Andalucía	**6539**	**14.01**
Almería	1695	25.92
Málaga	4526	69.22
C. Valenciana	**13778**	**29.51**
Alicante	13584	98.59

In Appendix B, the distribution of lemons is reported as distribution in EU (27) at MS level (B.8.) and in EL, IT and ES at province level (B.9.).

3.2.2.5 NUTS (Almonds. Chestnuts. Hazelnuts & Walnuts)

5 regions in Greece represent more than 80% of the Greek production of nuts (Table 37); 5 regions in Italy represent more than 95% of the Italian production of nuts (Table 38); and 6 regions in Spain represent more than 85% of the Spanish production of nuts (Table 39).

Table 37. Distribution of NUTS at province level: EL. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Greece Total	**43432**	
Region of Central Macedonia	**8435**	**19.42**
Thessaloniki	777	9.21
Kilkis	1109	13.15
Pella	1625	19.26
Pieria	1292	15.31
Serres	2759	32.71
Region of Western Macedonia	**2845**	**6.55**
Kozani	1290	45.35
Grevena	645	22.66
Florina	602	21.14
Region of Thessally	**15091**	**34.75**
Larissa	10592	70.19
Magnesia	3091	20.48
Region of Central Greece	**5539**	**12.75**
Pthiotida	3868	69.84
Evia	770	13.90
Region of Peloponnese	**4488**	**10.33**
Arkadia	2661	59.29
Korinthia	820	18.28
Lakonia	686	15.28

Table 38. Distribution of NUTS at province level: IT. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Italy total	**143723**	
Lazio	**24613**	**17.13**
Viterbo	23600	95.88
Sicilia	**49307**	**34.31**
Agrigento	10280	20.85
Caltanissetta	5202	10.55
Catania	6930	14.05
Messina	12904	26.17
Siracusa	5300	10.75
Campania	**21465**	**14.93**
Avellino	8313	38.69
Napoli	6041	26.16
Caserta	3731	17.39
Salerno	3300	15.38
Puglia	**19836**	**13.80**
Bari	13000	65.54
Brindisi	3900	19.66
Piemonte	**24557**	**17.09**
Alessandria	2782	11.33
Asti	5535	22.54
Cuneo	15400	62.71

Table 39. Distribution of NUTS at province level: ES. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Spain total	**788266**	
Aragón	**79172**	**10.04**
Huesca	15196	19.19
Teruel	22158	27.99
Zaragoza	41818	52.82
Cataluña	**52621**	**6.68**
Lleida	19827	37.68
Tarragona	30770	58.47
Castilla la Mancha	**164786**	**20.90**
Albacete	79830	48.44
Ciudad Real	26009	15.78
Cuenca	29146	17.69
Toledo	29182	17.71
C. Valenciana	**94960**	**12.05**
Alicante	22672	23.88
Castellón	37966	39.98
Valencia	34322	36.14
R. de Murcia	**80976**	**10.27**
Andalucía	**226810**	**28.77**
Almería	57411	25.31
Granada	113752	50.15
Málaga	22771	10.04
Sevilla	11924	5.26

In Appendix B, the distribution of NUTS is reported as distribution in EU (27) at MS level (B.10.) and in EL, IT and ES at province level (B.11.).

3.2.2.6 Olives

5 regions in Greece represent about 79% of the Greek production of olives (Table 40); 5 regions in Italy represent about 77% of the Italian production of olives (Table 41); and 3 regions in Spain represent more than 85% of the Spanish production of olives (Table 42).

Table 40. Distribution of olives at province level: EL. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Greece Total	**793092**	
Region of Central Greece	**80655**	**10.17**
Pthiotida	33473	41.50
Viotia	12929	16.03
Evia	26938	33.40
Fokida	6630	8.22
Region of Western Greece	**83272**	**10.50**
Achaia	18127	21.77
Etolia and Akarnania	24070	28.91
Ilia	41075	49.33
Region of Peloponnese	**220704**	**27.83**
Arkadia	17941	8.13
Argolida	27236	12.34
Korinthia	19740	8.94
Lakonia	69832	31.64
Mesinia	85956	38.95
Region of Northern Aegean	**53037**	**6.69**
Lesbos	41573	78.39
Samos	5122	9.66
Chios	3957	7.46
Region of Crete	**189666**	**23.91**
Heraklion	90300	47.61
Lasithi	27589	14.55
Rethymno	28116	14.82
Chania	43661	23.02

Table 41. Distribution of olives at province level: IT. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Italy total	**1164568**	
Puglia (all the region)	**384300**	**33.00**
Calabria (all the region)	**184529**	**15.85**
Sicilia (all region but Ragusa and Caltanissetta)	**157891**	**13.56**
Toscana	**89929**	**7.72**
Arezzo	11000	12.23
Firenze	21008	23.36
Grosseto	18500	20.57
Siena	15100	16.79
Lazio (all the region)	**82931**	**7.12**

4

Table 42. Distribution of olives at province level: ES. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Spain total	2601901	
Andalucía	**1633215**	**62.77**
Córdoba	364898	22.34
Granada	203157	12.44
Jaén	586921	35.94
Málaga	138512	8.48
Sevilla	253278	15.51
Castilla la Mancha	**373849**	**14.37**
Albacete	38160	10.21
Ciudad Real	159103	42.56
Cuenca	26994	7.22
Guadalajara	28200	7.54
Toledo	121392	32.47
Extremadura	**264286**	**10.16**
Badajoz	196288	74.27
Cáceres	67998	25.73

In Appendix B, the distribution of olives is reported as distribution in EU (27) at MS level (B.12.) and in EL, IT and ES at province level (B.13.).

3.2.2.7 ORANGES

4 regions in Greece represent more than 95% of the Greek production of oranges (Table 43); 2 regions in Italy represent more than 85% of the Italian production of oranges (Table 44); and 2 regions in Spain represent more than 90% of the Spanish production of oranges (Table 45).

Table 43. Distribution of oranges at province level: EL. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Greece Total	**29451**	
Region of Epirus	**3159**	**10.73**
Arta	2684	84.97
Thesprotia	296	9.38
Preveza	178	5.63
Region of Western Greece	**5568**	**18.91**
Etolia and Akarnania	2931	52.64
Ilia	2478	44.50
Region of Peloponnese	**16910**	**57.42**
Argolida	9266	54.79
Lakonia	6993	41.35
Region of Crete	**2931**	**9.95**
Chania	2623	89.49

Table 44. Distribution of oranges at province level: IT. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Italy total	**82729**	
Calabria	**16382**	**19.80**
Reggio Calabria	9000	54.94
Cosenza	2562	15.64
Catanzaro	2435	14.86
Sicilia	**54964**	**66.44**
Agrigento	5500	10.10
Catania	25000	45.48
Siracusa	17000	30.93

Table 45. Distribution of oranges at province level: ES. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Spain total	**139971**	
Andalucía	**57509**	**41.09**
Almería	4761	8.28
Córdoba	11660	20.28
Huelva	8687	15.10
Málaga	4347	7.56
Sevilla	25190	43.80
C. Valenciana	**70344**	**50.26**
Alicante	11182	15.90
Castellón	6388	9.08
Valencia	52774	75.02

In Appendix B, the distribution of oranges is reported as distribution in EU (27) at MS level (B.14.) and in EL, IT and ES at province level (B.15.).

3.2.2.8 PEACHES AND NECTARINES

2 regions in Greece represent more than 90% of the Greek production of peaches and nectarines (Table 46); 5 regions in Italy represent about 73% of the Italian production of peaches and nectarines (Table 47); and 5 regions in Spain represent more than 85% of the Spanish production of peaches and nectarines (Table 48).

Table 46. Distribution of peaches and nectarines at province level: EL. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Greece Total	**39404**	
Region of Central Macedonia	**33667**	**85.44**
Imathia	14692	43.64
Pella	18623	55.31
Region of Thessally	**2495**	**6.33**
Larissa	2331	93.41

Table 47. Distribution of peaches and nectarines at province level: IT. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Italy total	**62102**	
Emilia Romagna	**11069**	**53.30**
Ravenna	5900	29.78
Bologna	1301	11.75
Forlì-Cesena	3037	27.44
Sicilia	**7170**	**11.55**
Agrigento	2625	36.61
Caltanissetta	1650	23.01
Catania	600	8.37
Messina	670	9.34
Palermo	881	12.29
Campania	**19685**	**31.70**
Caserta	15387	78.17
Napoli	2841	14.43
Puglia	**4110**	**6.62**
Barletta-Andria-Trani	2150	52.31
Brindisi	800	19.46
Piemonte	**3729**	**6.00**
Cuneo	2070	79.86

Table 48. Distribution of peaches and nectarines at province level: ES. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Spain total	**77464**	
Aragón	**20475**	**26.43**
Huesca	11529	56.31
Zaragoza	7251	35.41
Cataluña	**20880**	**26.95**
Lleida	18375	88.00
C. Valenciana	**4417**	**5.70**
Valencia	3570	80.82
R. de Murcia	**13891**	**17.93**
Extremadura	**8567**	**11.06**
Badajoz	7146	83.41

In Appendix B, the distribution of peaches and nectarines is reported as distribution in EU (27) at MS level (B.16.) and in EL, IT and ES at province level (B.17.).

3.2.2.9 TANGERINES, CLEMENTINES, SATSUMAS

3 regions in Greece represent more than 85% of the Greek production of tangerines, clementines and satsumas (Table 49); 3 regions in Italy represent more than 85% of the Italian production of tangerines, clementines and satsumas (Table 50); and 4 regions in Spain represent almost 99% of the Spanish production of tangerines, clementines and satsumas (Table 51).

Table 49. Distribution of tangerines, clementines and satsumas at province level: EL. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Greece Total	**8179**	
Region of Epirus	**2875**	**35.14**
Arta	1372	47.74
Thesprotia	1368	47.59
Region of Western Greece	**858**	**10.49**
Etolia and Akarnania	544	63.41
Ilia	288	33.55
Region of Peloponnese	**3473**	**42.46**
Argolida	2052	59.10
Lakonia	1261	36.32

Table 50. Distribution of tangerines, clementines and satsumas at province level: IT. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Italy total	**34356**	
Sicilia	**6956**	**20.25**
Catania	2200	31.63
Messina	1110	15.96
Palermo	1853	26.64
Siracusa	1060	15.24
Calabria	**18509**	**53.87**
Cosenza	12250	76.10
Reggio Calabria	2350	14.60
Puglia	**5123**	**14.91**
Taranto	4830	94.28

Table 51. Distribution of tangerines, clementines and satsumas at province level: ES. Regional values are represented as a percentage of national values. Province values represent percentage at regional level

Regions / Provinces	ha	%
Spain total	**105583**	
Cataluña	**6536**	**6.19**
Tarragona	6535	99.98
C. Valenciana	**73068**	**69.20**
Alicante	6954	9.52
Castellón	27421	37.53
Valencia	38693	52.95
R. de Murcia	**5643**	**5.34**
Andalucía	**19971**	**18.91**
Almería	2593	12.98
Huelva	11689	58.53
Málaga	1857	9.30
Sevilla	3045	15.25

In Appendix B, the distribution of tangerines, clementines and satsumas is reported as distribution in EU (27) at MS level (B.18.) and in EL, IT and ES at province level (B.19.).

3.3 Characterization of the sampled population from the different surveys

3.3.1 Survey to sprayer dealers and manufacturers

3.3.1.1 Spain

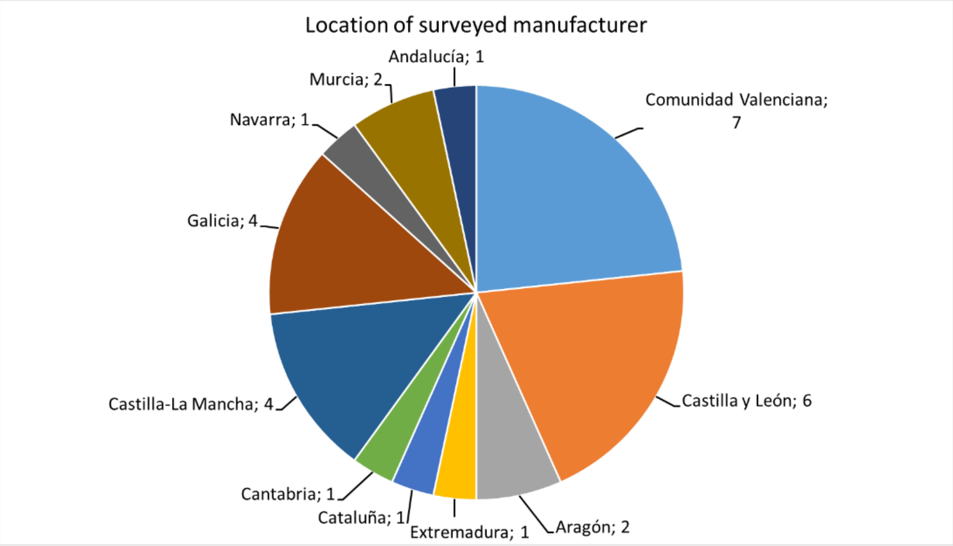

Figure 1. Geographic distribution of the surveyed sprayer manufacturers/dealers in Spain.

Figure 1 shows the geographical distribution of the sprayer companies surveyed, indicating the number of surveys carried out in each region. Of the 30 surveys performed, 7 were in the Comunidad Valenciana, 6 in Castilla y León, 4 in Galicia and Castilla-La Mancha, 2 in Murcia and Aragón, and 1 survey in Extremadura, Cataluña, Cantabria, Navarra and Andalucía, respectively. This means that the surveys were conducted in 11 of the 17 regions of Spain, where the main producers of 3-D crops in Spain are located.

Manufacturers and dealers can distribute their products throughout Spain and abroad (Figure 2). Considering just their sales inside Spain, the manufacturers and dealers surveyed cover all Spanish regions.

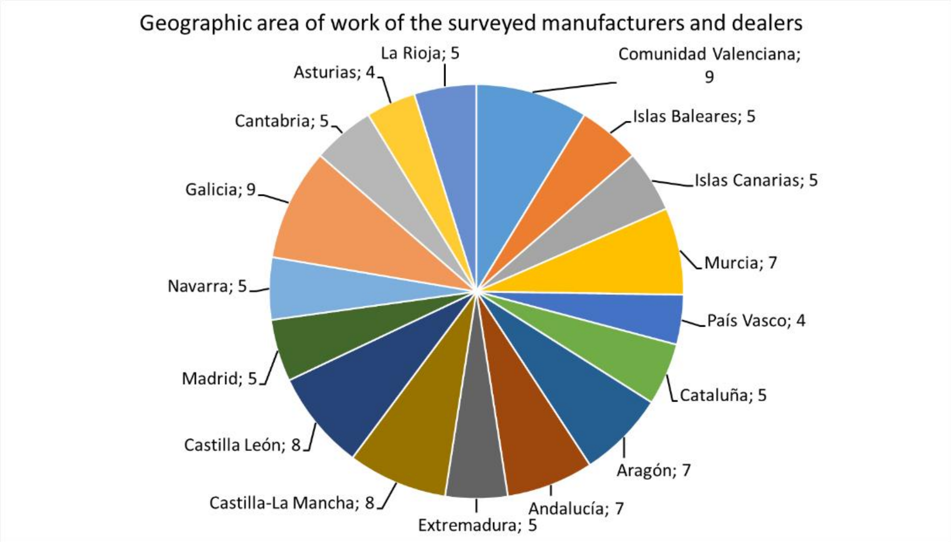

Figure 2. Geographic area of work of the surveyed sprayer manufacturers and dealers in Spain.

3.3.1.2 Greece

Figure 3 shows the geographical distribution of the sprayer companies surveyed, indicating the number of surveys carried out in each region. Of the 15 surveys performed, 8 were in Central Macedonia, 3 in Peloponnese, 2 in Thessaly, 1 in Attica and 1 in Central Greece.

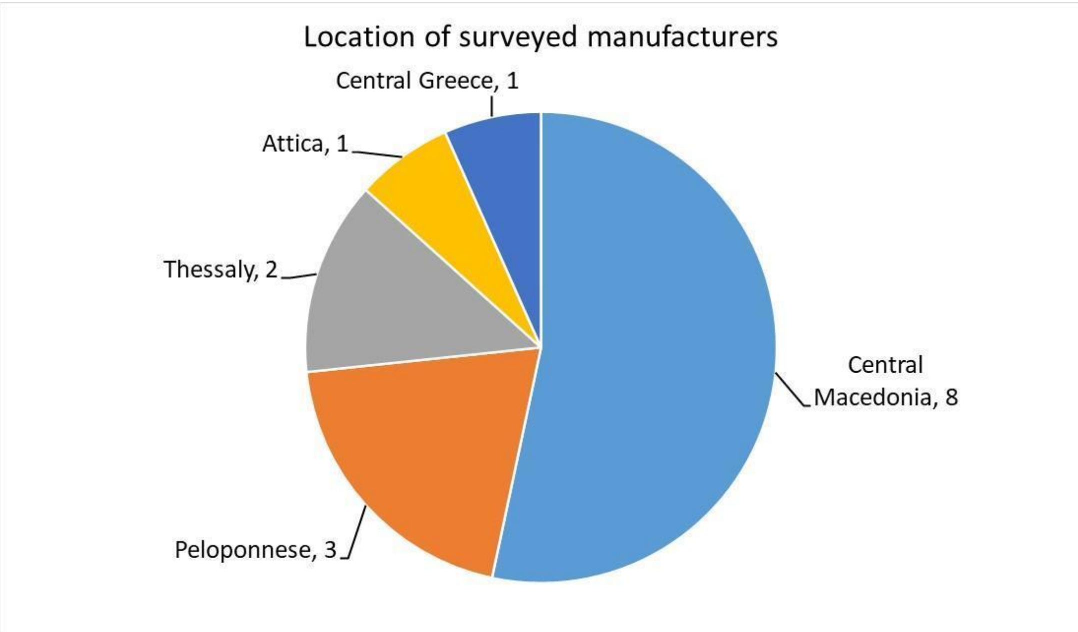

Figure 3. Geographic distribution of the surveyed manufacturers/dealers in Greece.

Manufacturers and dealers can distribute their products throughout Greece and abroad. (Figure 4). Considering just their sales inside Greece, the manufacturers and dealers surveyed cover most of the regions in Greece.

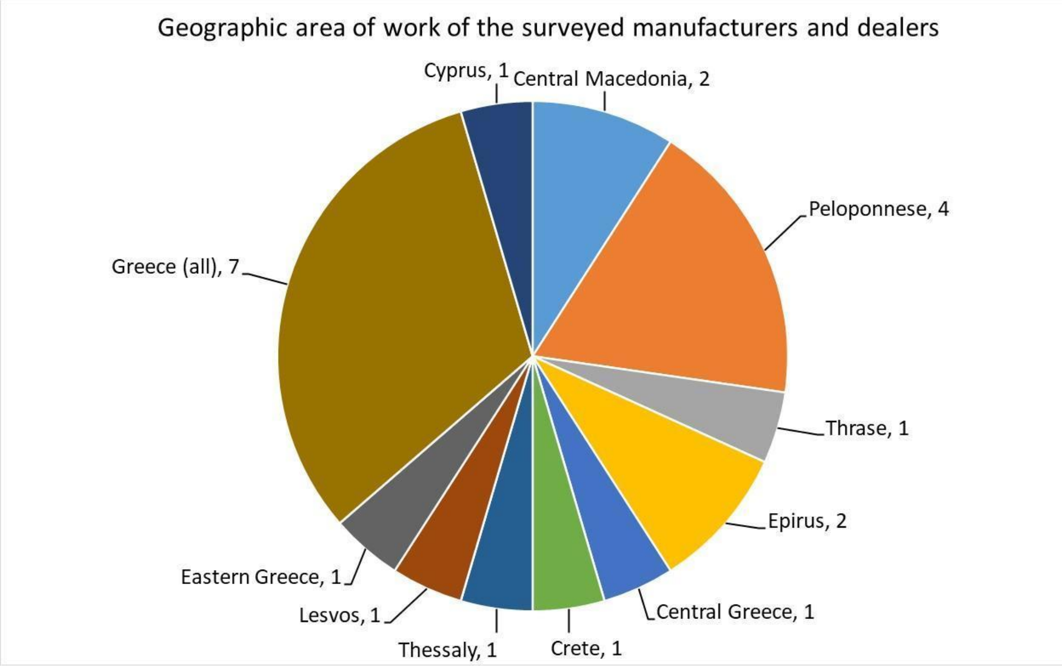

Figure 4. Geographic area of work of the surveyed sprayer manufacturers and dealers in Greece.

3.3.1.3 Italy

The main task was to obtain a sample that is representative of the national territory. Therefore, the pollster has submitted the survey to sprayer dealers or manufacturers allocated in different regions. Figure 5 displays how the interviewed population is distributed between North, Central and Southern Italy.

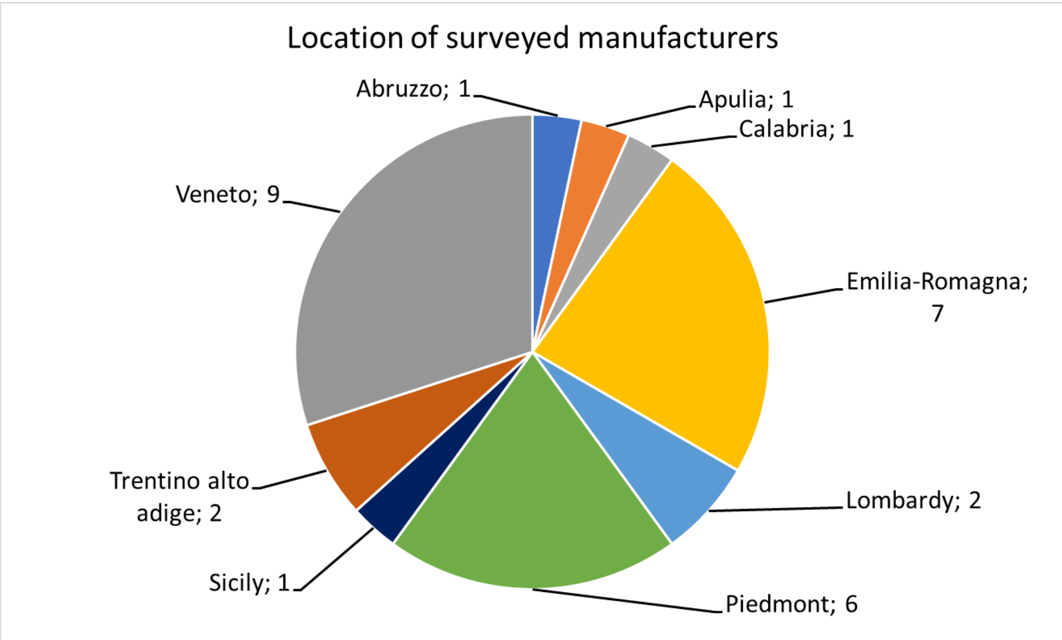

Figure 5. Geographic distribution of the surveyed sprayer manufacturers/dealers in Italy.

Normally, the manufacturers sell their spraying equipment in a wider territory than the region where they are located. In fact, 8 of the polled report that they operate in the whole national territory.

Figure 6 displays that an important quote of the Italian manufacturers operates also abroad. Between this quote, the reported geographic area of works are different: some operate in Europe, over sea (North and South America), New Zealand, others in Africa and Asia.

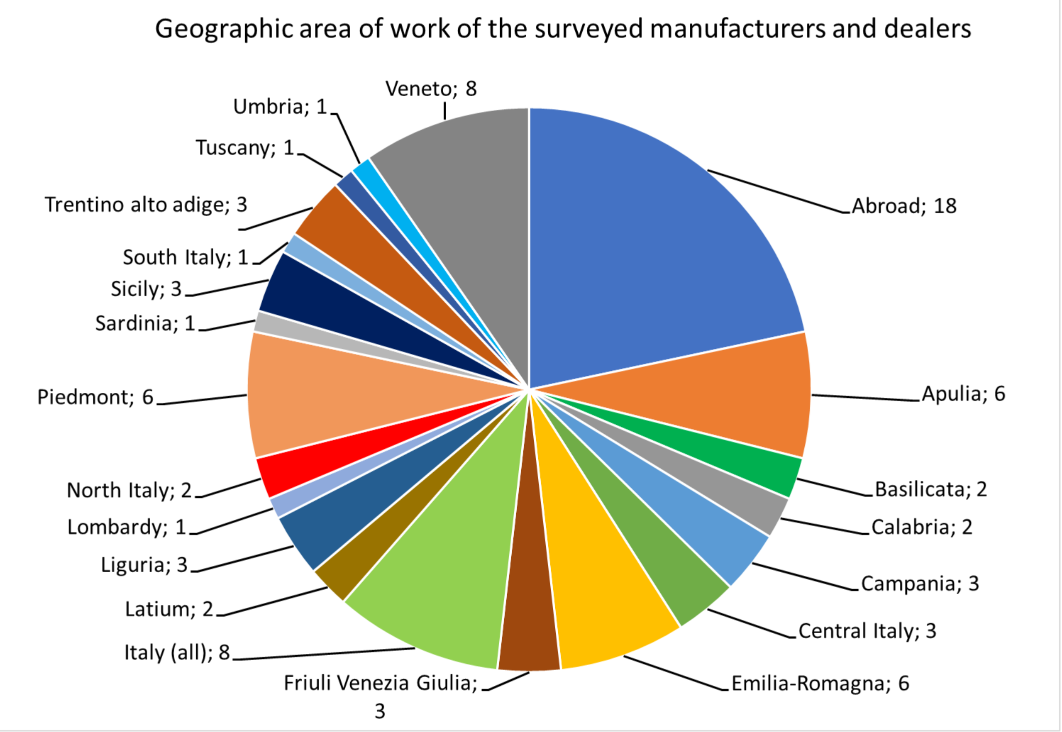

Figure 6. Geographic area of work of the surveyed sprayer manufacturers and dealers in Italy.

3.3.2 Survey to sprayer inspection station

3.3.2.1 Spain

Figure 7 shows the distribution of the geographical location of the sprayer inspection stations surveyed, indicating the number of surveys carried out in each region. Out of the 30 surveys carried out, 8 were in Andalucía, 7 in Comunidad Valenciana, 4 in Castilla-La Mancha and Murcia, 2 in Aragón, and 1 survey in Castilla y León, Cataluña, Madrid, Galicia and the Islas Canarias, respectively. This means that surveys have been conducted in 10 of the 17 regions of Spain, which are those with the majority of inspection stations in their territory and where plant production predominates.

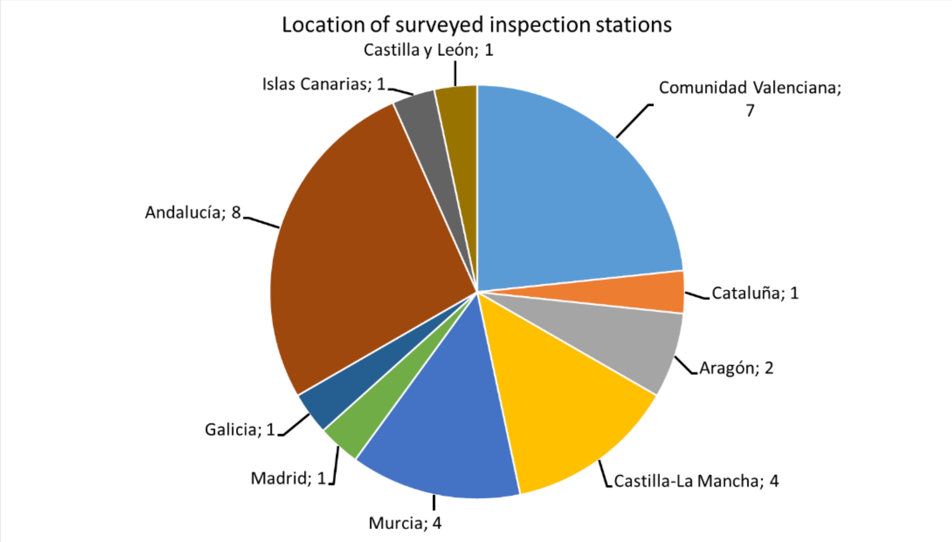

Figure 7. Distribution of the geographic location of the surveyed inspection stations in Spain.

The inspection stations are registered in one region but can work in the rest of the regions, therefore, the geographical scope of work of the inspection stations surveyed is greater (Figure 8) and covers 12 of the 17 regions, and among these are those in which plant production has the greatest weight.

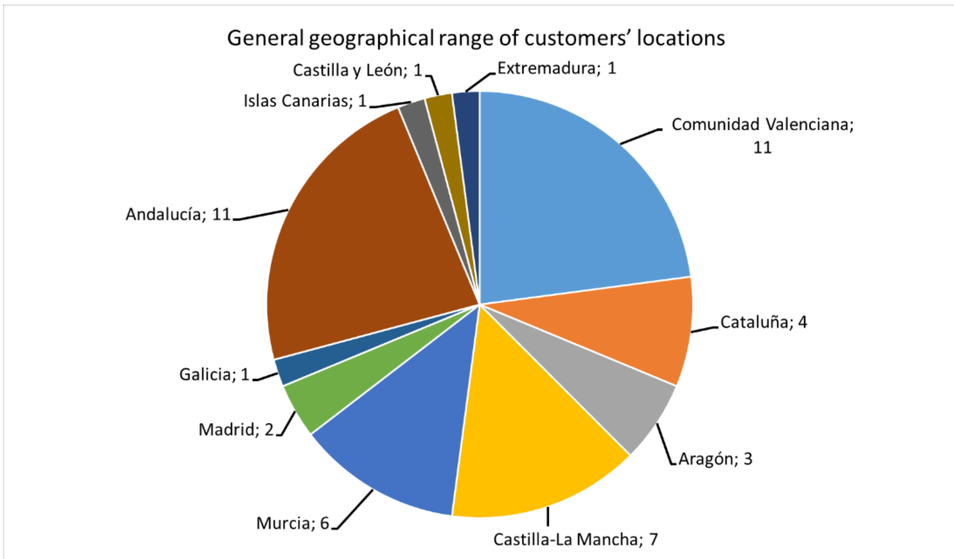

Figure 8. Geographic scope of work of the surveyed inspection stations in Spain.

3.3.2.2 Greece

The 30 surveys were conducted proportionally based on the number of inspection stations in each region, among the "regions of interest", as those were defined based on the cultivation areas of the crops of interest of the project. The 30 surveys cover 40% of the active inspection stations. Figure 9 shows the distribution of the geographical location of the inspection stations surveyed, indicating the number of surveys carried out in each region. This distribution is also presented in Table 52.

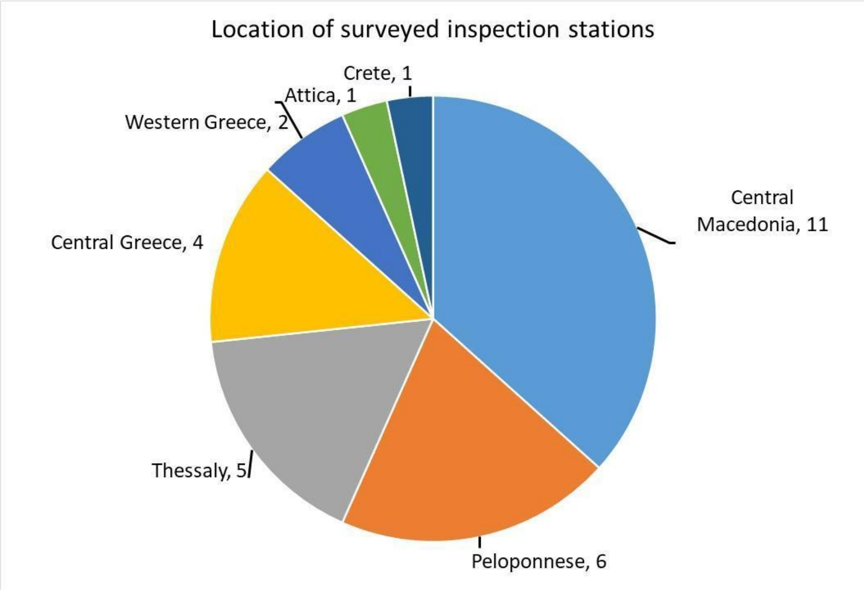

Figure 9. Distribution of the geographic location of the surveyed inspection stations in Greece.

Table 52. Distribution of inspection stations surveys in regions of interest – Greece

REGION:	Percentage of total active stations	Surveys No.
Peloponnese	18.5%	**6**
Crete	3.7%	**1**
W. Greece	3.7%	**2**
C. Greece	13.0%	**4**
Attica	1.9%	**1**
Thessaly	18.5%	**5**
C. Macedonia	38.8%	**11**
Epirus	1.9%	**-**
	100%	**30**

The inspection stations are registered in one region but can work in the rest of the regions, therefore, the geographical scope of work of the inspection stations surveyed is greater (Figure 10) and covers the entire country.

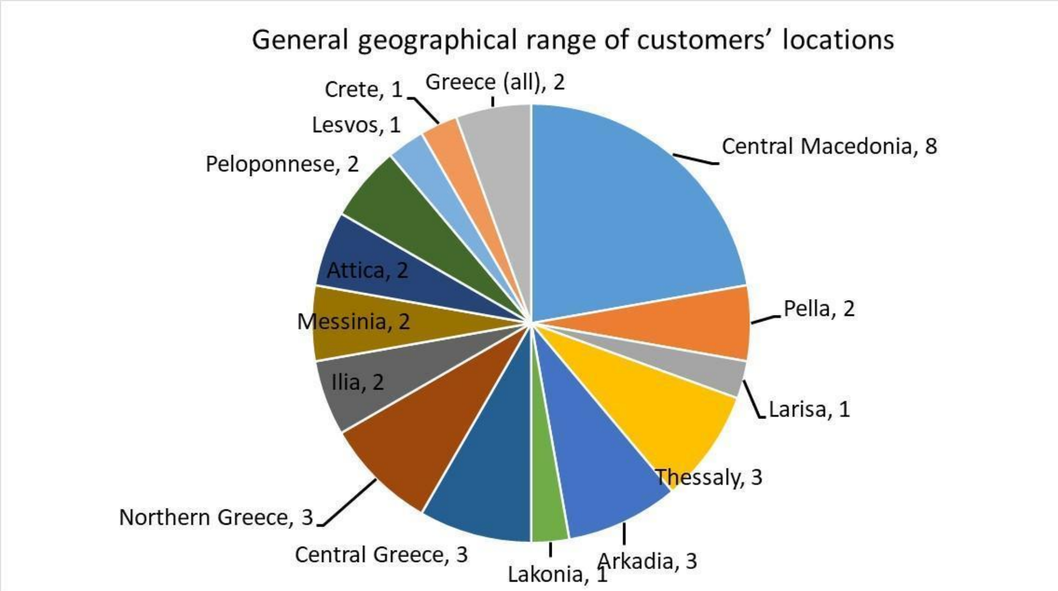

Figure 10. Geographic scope of work of the surveyed inspection stations in Greece.

3.3.2.3 Italy

41 questionnaires were distributed in different quotes between the regions, as reported in Figure 11. The main task was to obtain a representative sample of the whole national territory. In Piedmont, Veneto and Emilia-Romagna the pollsters have submitted more surveys because in these regions there is a higher concentration of inspection stations and there is the most relevant presence of 3-D crops selected for the grower's survey.

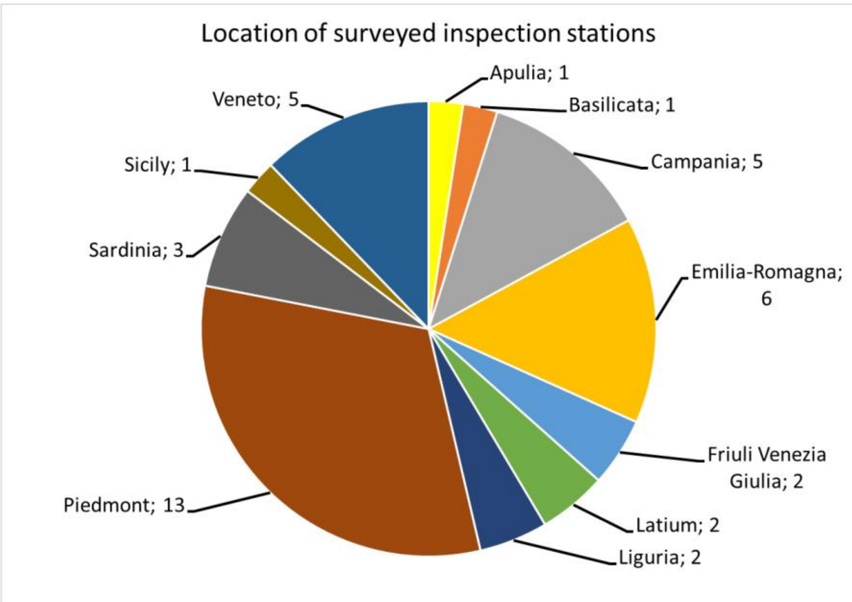

Figure 11. Geographical distribution of the surveyed sprayer inspection stations in Italy.

3-D orchards

The inspection stations are registered for administrative purposes in a single region, but some of those surveyed work at national level also operating in regions different from that where they are registered. Therefore, as reported in Figure 12, the 41 inspection stations cover almost all the national territory.

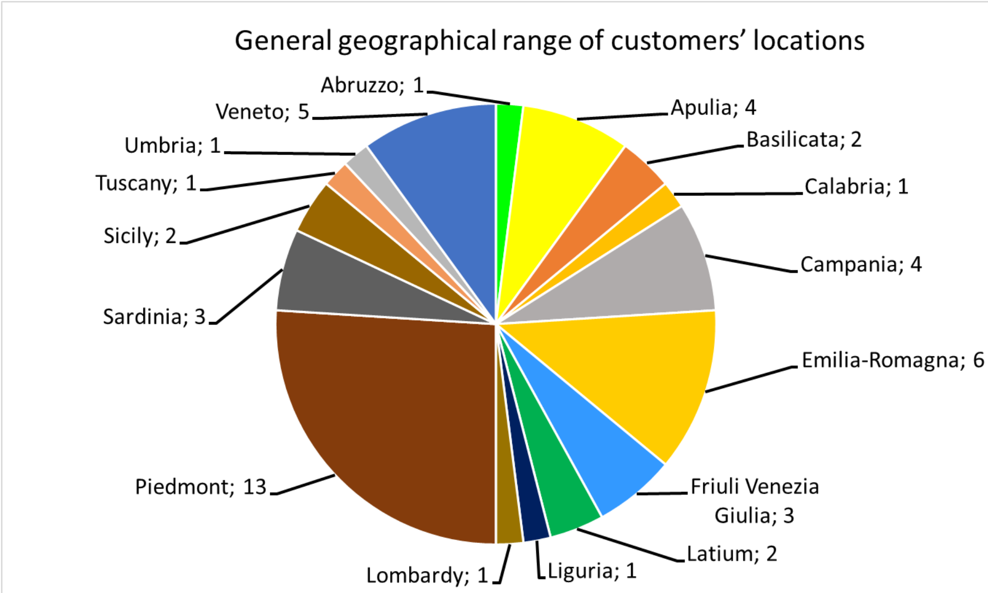

Figure 12. Regions where the surveyed sprayer inspection stations operate in Italy.

3.3.3 Survey to farmers

The 3-D orchards identified in §3.1 and §3.2, were grouped in 5 major classes: citrus, olive, grapes, fruit trees (other than apple and pear), and nuts.

3.3.3.1 Spain

30 questionnaires were collected per each of the five crops in the different regions of Spain, as reported in Figure 13. The main task was to obtain a representative sample of the crops under assessment.

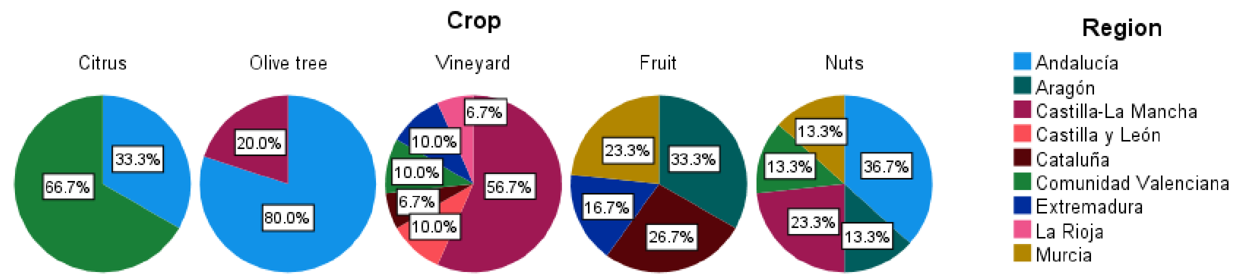

Figure 13. Regions where the questionnaire were distributed in Spain divided by crop

3-D orchards

Due to the different distribution of crops in Spain, as already discussed in § 3.2.2, different regions were considered for different crops. In particular, for citrus and olives just 2 regions out of 17 were considered, for fruit orchards 4 out of 17, for nuts 5 out of 17 and for vines, the most distributed crop, 6 out of 17 regions. Among all the regions in Spain, half of them (9) are enough to represent the Spanish cultivation of 3-D orchards.

3.3.3.2 GREECE

30 questionnaires were collected per each of the five crops in the different regions of Greece, as reported in Figure 14. The main task was to obtain a representative sample of the crops under assessment.

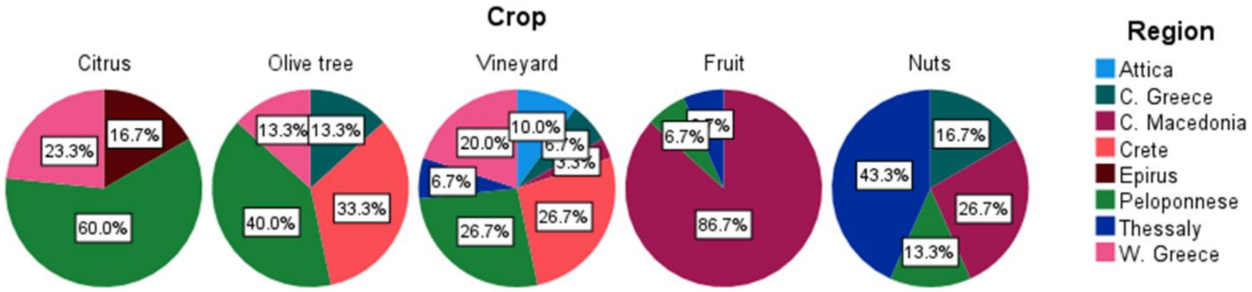

Figure 14. Regions where the questionnaire were distributed in Greece divided by crop

Due to the different distribution of crops in Greece (see § 3.2.2), different regions were considered for different crops. In particular, for citrus and fruit orchards just 3 regions out of 13 were considered, for olives and nuts 4 out of 13 and for vines, the most distributed crop also in Greece, 7 out of 13 regions. Among all the regions in Greece, 8 of them represent well the area cultivated with 3-D orchards.

3.3.3.3 ITALY

30 questionnaires were collected for four of the five crops while for nuts the number was reduced due to difficulties in obtaining answers. The distribution in the different regions of Italy is reported in Figure 15. The main task was to obtain a representative sample of the crop under assessment.

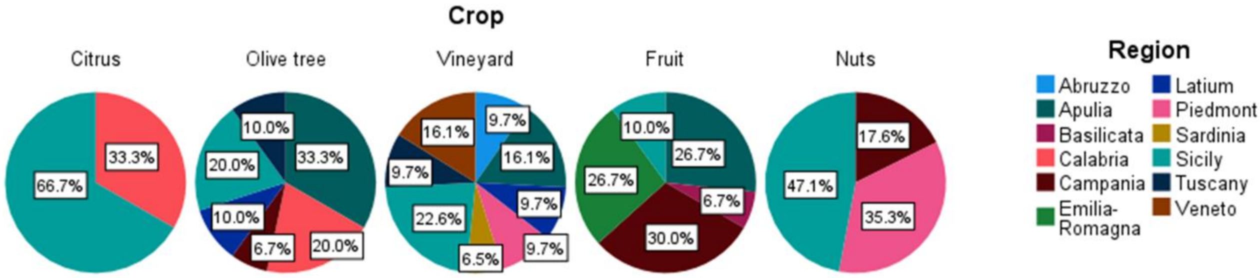

Figure 15. Regions where the questionnaire were distributed in Italy divided by crop

3-D orchards

Due to the different distribution of crops in Italy (see § 3.2.2), different regions were considered for different crops. In particular, for citrus just 2 regions out of 20 were considered, for nuts 4 out of 20, fruit orchards 5 out of 20, olives 6 out of 20 and for vines, the most distributed crop also in Italy, 8 out of 20 regions. 3 D-orchards are quite spread in Italy, with 12 regions representing their distributions.

3.4 Results and discussion from the surveys

3.4.1 Topic A: Growers, crop, PPP application practices

The data presented in the following paragraphs are mainly derived by the questions on the farmer surveys. Bars shows frequency of occurrence ± SEM, divided by crop type and country. Data averaged over the three countries are representing SEU (blue bars).

3.4.1.1 Farmers informations

The repartition between professional and part-time farmers follows a similar trend for all SEU and the five crops object of the survey, as reported in Figure 16. In almost all the crop types (excluding Olives), more than 80% of the farmers are professionals. Even though the part-time farmers are a small percentage of the surveyed, they still are relevant to the survey's scope. The importance of the part-time farmer stands to the fact that these growers, usually, are not trained in pesticide applications and they use old sprayers (in some cases hand crafted sprayers that could be very dangerous for both the environment and the operator).

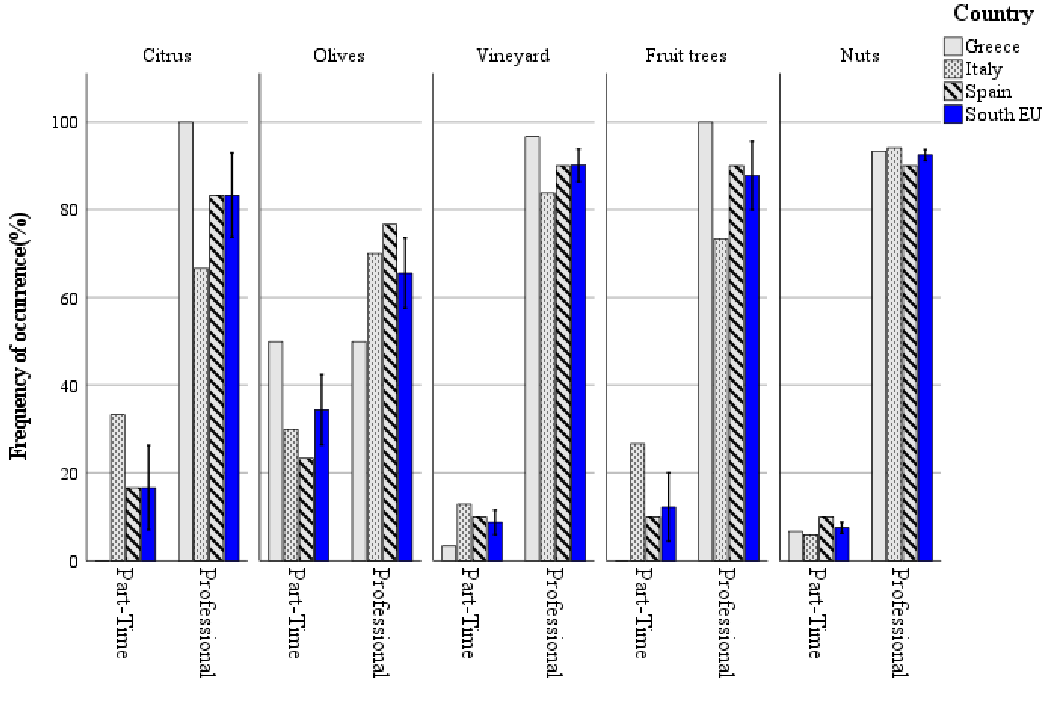

Figure 16. Occurrence for the farmers' answers related to the question *Are you professional or part-time Farmer?*

3-D orchards

As reported in Figure 17, in general, the grower frequently is the spray application operator.

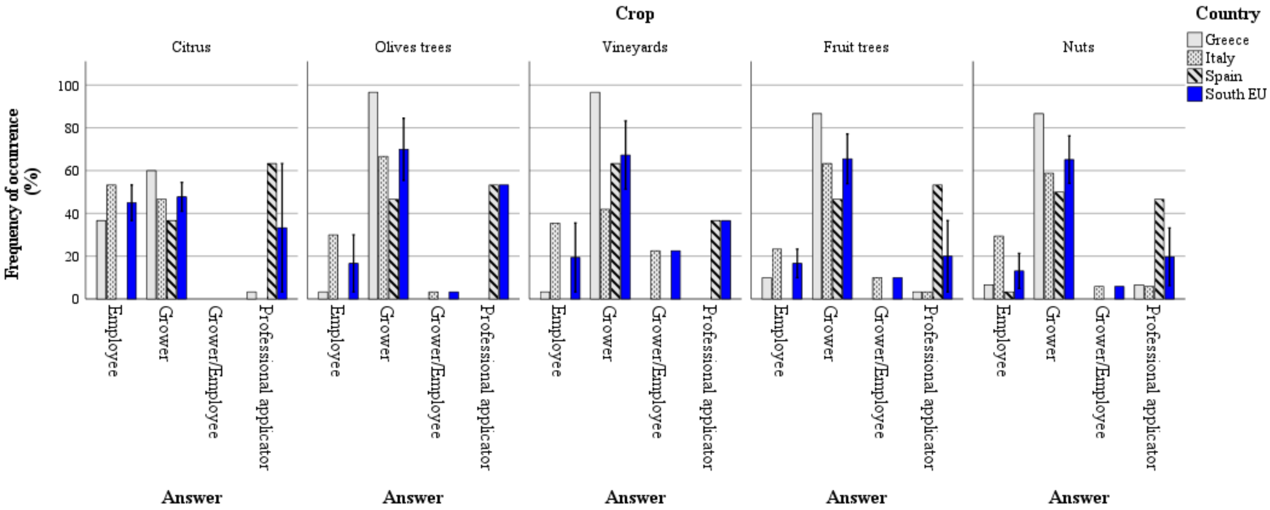

Figure 17. Occurrence for the farmers' answers related to the question *Who do usually carry out the pesticide applications (grower, employee, professional applicator, cooperative, etc)?*

In Greece, the percentage of growers who apply the PPPs are even higher than in the other countries. Probably, this is related to the fact that the farm surveyed in this state are smaller when compared to the other states. Related to this topic, Spain deviates from the average trend. In detail, the percentage of professional applicators is higher than in the other states, especially in citrus where it's even higher than the percentage of growers. In detail, the occurrence ranged between ~ 60% on citrus and ~ 40% on vineyards, with the other crops in intermediate situations.

3.4.1.2 Crops information

Figure 18 shows the land characteristics of the farms surveyed. In all SEU most of the farms are in plain land, independent of the crop. In some cases, the farms are located in some intermediate situations, for example they have both terrains in flat and some in hilly areas. Regarding nuts, in general more farms are in hilly areas. An explanation to this could derive from the crop adaptability itself. For example, hazelnut is suitable for soil with different characteristics (e.g., different pH, texture). Moreover, the hazelnut cultivation in Italy has an important heritage in Langhe area (Pedmont region) that is landscaped mainly with hills.

The information of land characteristics is really relevant to the scope of the survey, because they have a direct influence on the spray application equipment (SAE). For example, considering the vineyard scenario, in plain areas the spray application can be executed with tunnel recycling sprayers, which are demonstrated to be the most efficient type of sprayer. In mountain areas instead, the application is typically carried out with knapsack sprayer and in perspective could be made also exploiting new technologies. The latter could be represented by a fixed spray delivery system (FSDS) or uncrewed aerial spray system (UASS).

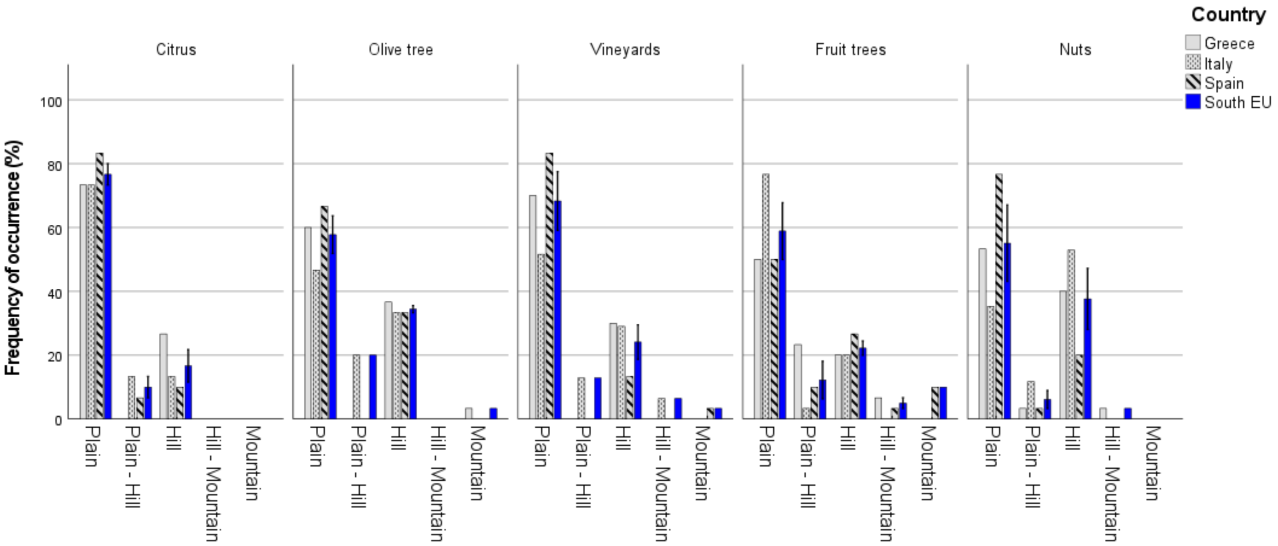

Figure 18. Occurrence for the farmers' answers related to the question *Which are the land characteristics?*

Considering the cultivated surface area, reported in Figure 19, the trend is slightly different between the states and the crop types. In general, the farms in Greece are smaller when compared to the other states, independently of the crop considered.

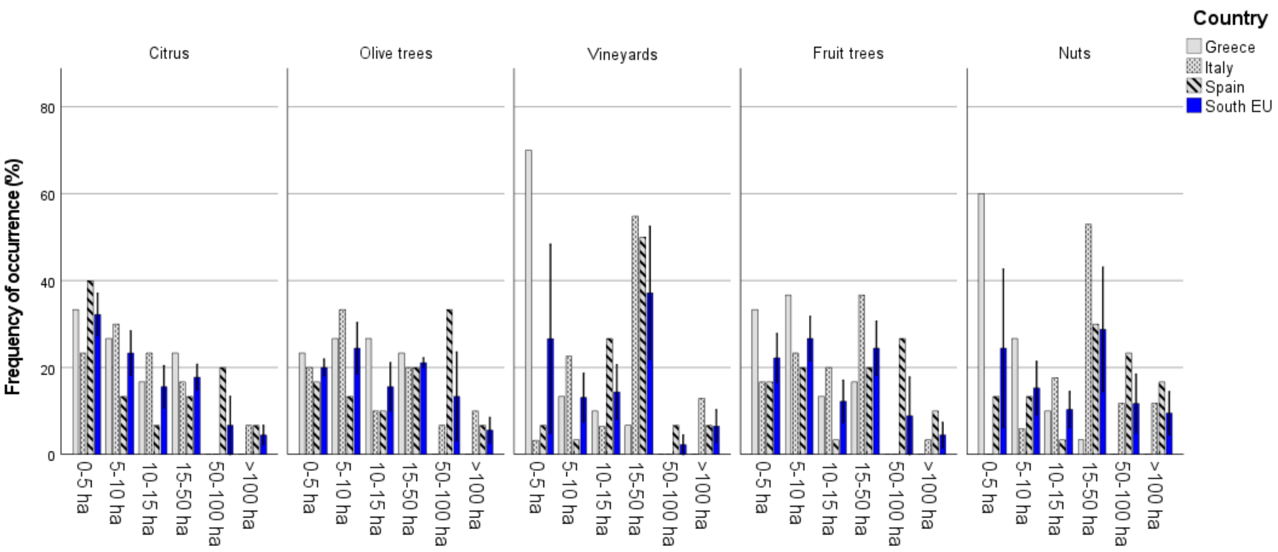

Figure 19. Occurrence for the farmers' answers related to the question *How much is your total cultivated area?*

Considering the training system adopted, excluding vineyards, it can be divided into three macro-categories: traditional, extensive and intensive, as Figure 5 reports. Traditional training systems constitute intended fields with low density (large inter-row distance and plant widely spaced on the rows), canopy developed in volume and non-continuous vegetative wall. The extensive system differs from the previously described only because it has a slightly higher density. Therefore, during the spray application in both these two training systems the spraying should be activated in correspondence of the canopies and deactivated between two subsequent plants.

The intensive system is quite different from the previous two. This type of training system allows a higher density, resulting in a continuous vegetative wall along the rows. The main advantages of this type of training system, when compared to the previous two, are mainly related to the increase of the yield and the possibility to easier mechanise the operations in the field, and the reduction of hours of labour required. The crop training systems differ for each crop, but their occurrence is similar in the SEU. For all the crops reported in Figure 20, Greece tends to have more traditional training systems, with the exception of citrus.

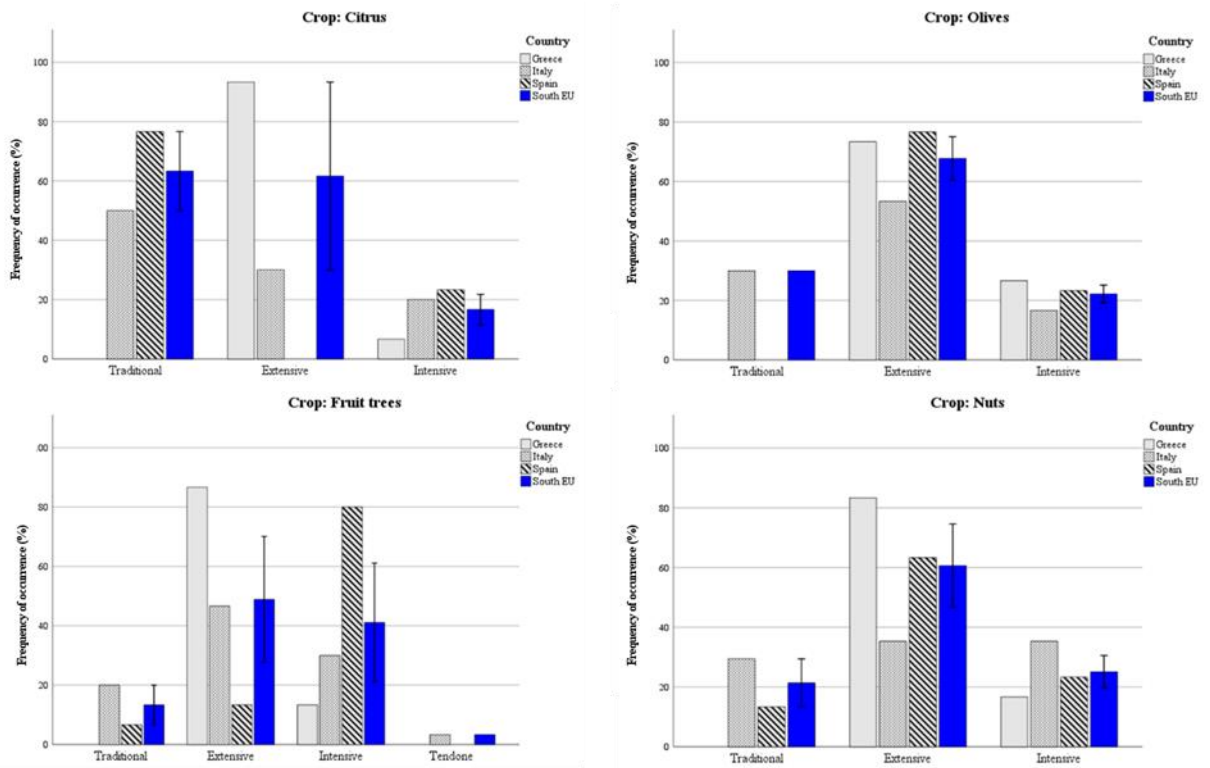

Figure 20. Occurrence for the farmers' answers related to the question *What type of cultivation/ training system do you use*

The training system in vineyards requires a dedicated analysis. In this crop indeed, the training system influences more the shape of the canopy (Figure 21), when compared to the other target crops of this survey. In the vineyard case, the training system influences also the type of PAE adopted. For example, in the "pergola" or "tendone" training system, tunnel sprayers can't be used due to the shape of the canopy.

Figure 21. Example of different training systems in vineyard. From left to right: goblet, trellissed and pergola.

Figure 22 reports the training system used by the surveyed growers. Independent of the country considered, the trellised vineyard is widely the most common. This may depend on the fact that with this training system all the operations are fully mechanised. Even though the other training systems are reported in very few cases among the interviewees, they are still important. Focusing on the Italian scenario, for example, the pergola training system is adopted a lot in Trento region (in more than 80% of the vineyards).

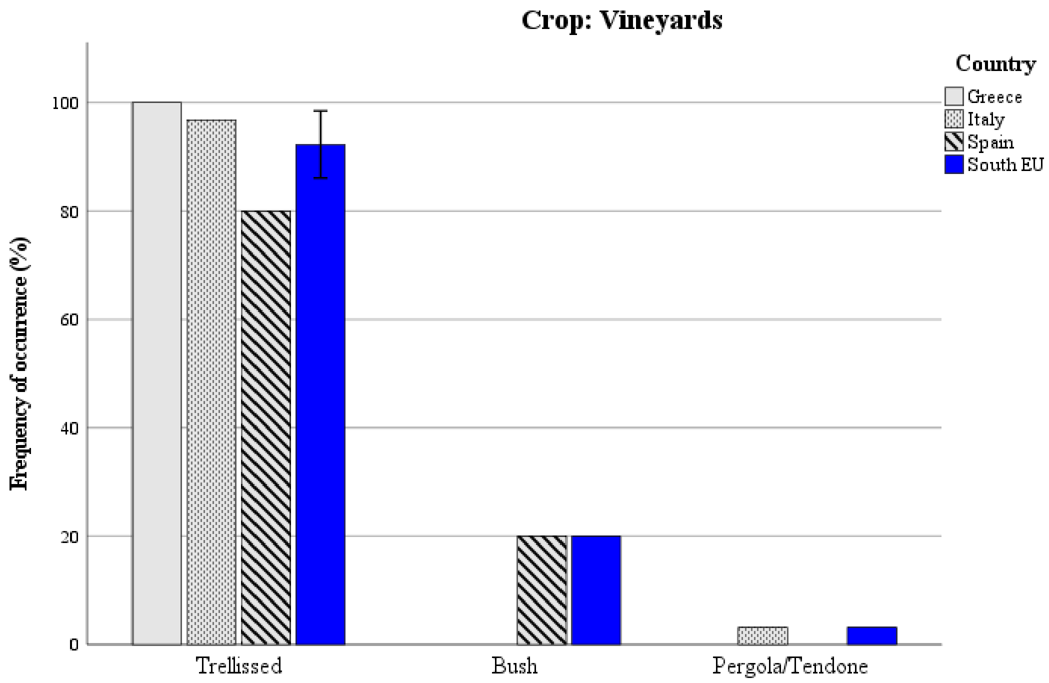

Figure 22. Occurrence for the farmers' answers related to the question *What type of cultivation/ training system do you use?*

3-D orchards

Considering the crop protection strategy, in all the SEU countries, the integrated pest management (IPM) is the most adopted, regardless the type of crop considered, as Figure 23 shows. The organic cultivation system is more limited, it reaches out 30% in nuts in Greece. Compared to the other crops, the organic farming system is even rarer in fruit orchards, maybe because the crop protection strategy is more complex compared to other crops (more pests are present). Among all the farmers surveyed, only one reported to adopt a Biodynamic farming system. The latter relies on pseudo-scientific concepts, and it's limited to very few farmers.

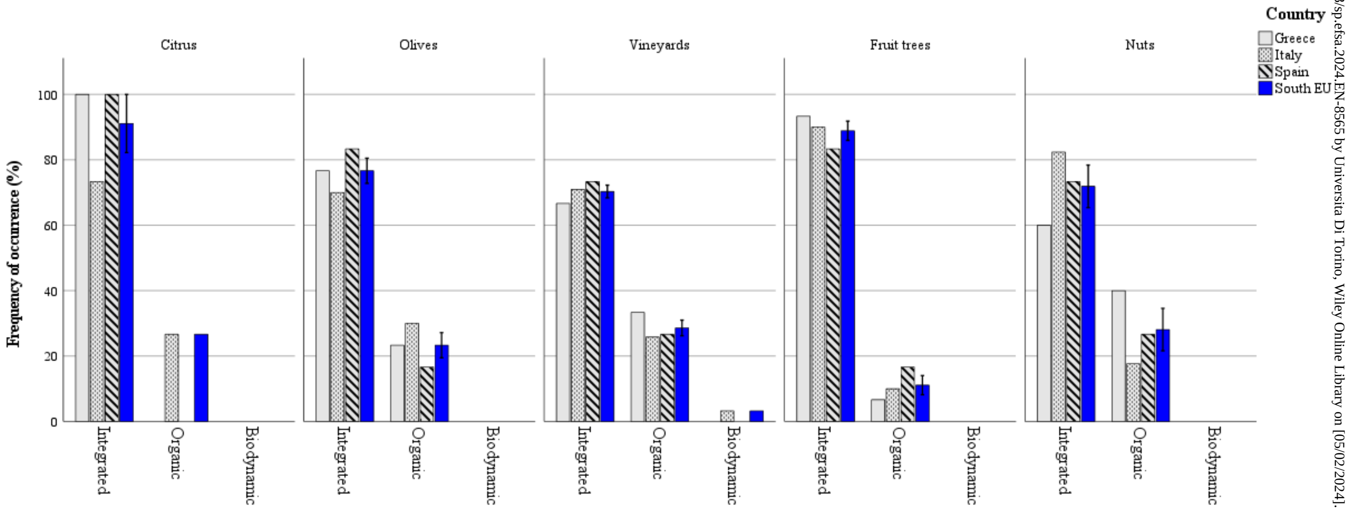

Figure 23. Occurrence for the farmers' answers related to the question *Is the production integrated or organic?*

The majority of interviewees report that they do not have interconnection with sensitive areas. The most frequent sensitive areas reported near the orchards are the suburban areas close to the vineyards (Figure 24). Despite the general limited occurrence of interconnection with sensitive areas, considering this is still important because an inadequate spray application in these areas could lead to direct (if the orchard is close to suburban areas) and indirect (e.g., field nearby basin) effects on human health. In addition to this, in some cases the field could be directly bordering with sensitive areas (Figure 25), so the risk for human health is even higher.

3-D orchards

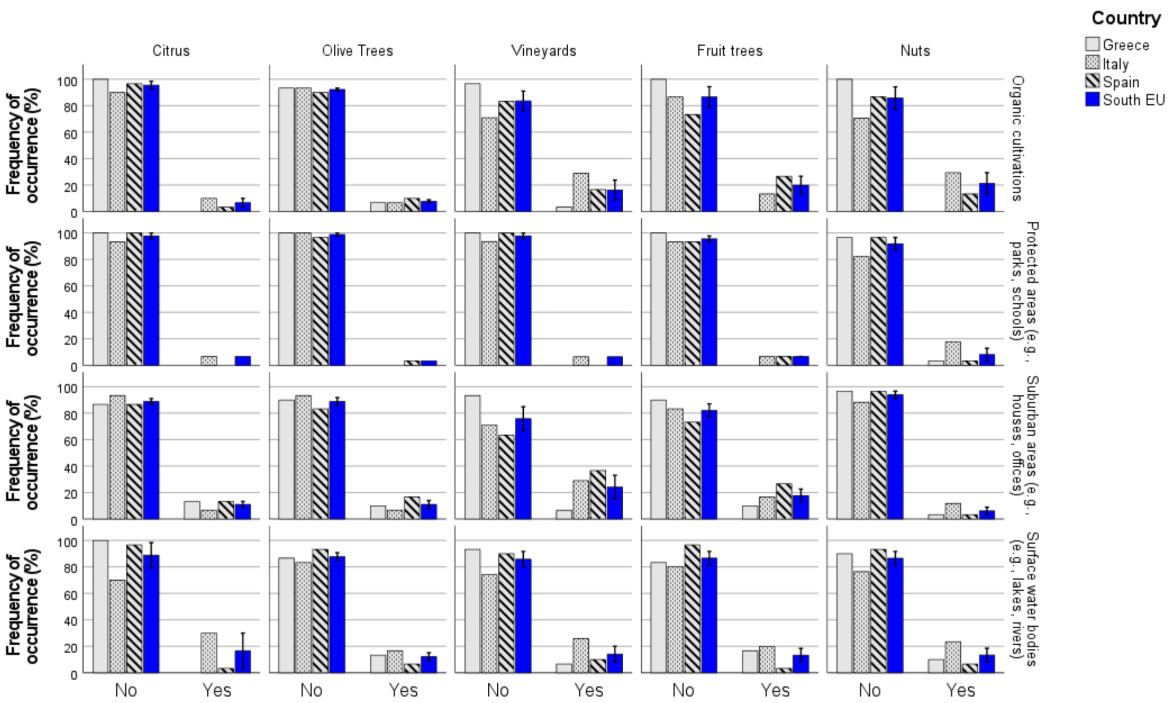

Figure 24. Occurrence for the farmers' answers related to the question *Are there sensitive areas nearby your farm?*

Figure 25. Example of a vineyard bordering a sensitive area.

3.4.1.3 PPP SPRAY APPLICATION PRACTICES

Figure 26 and Figure 27 show the different PAE used by the farmers, the PAE ages, and the percentage of certified sprayers for use. The trend is very similar in the different SEU states: the airblast sprayer is widely the most common PAE, with the class from 5 to 10 years old resulting more frequent, with some minor differences among the crops. Considering other types of sprayers, some farmers report to use boom sprayers, in these cases it is considered that the farms carry out herbicide treatments in the 3D orchards and/or the farms also produce arable crops. With limited occurrence, there are some growers that use knapsack sprayers and hoses and guns sprayers; these cases are mainly related to small farms with traditional training systems or farms where conventional PAE could not be used (e.g., farms in sloped areas). Considering the occurrence of inspected sprayers in use, there is a common trend in all SEU states, regardless of the crop considered. In detail, the majority of the interviewees states to have the PAE inspected. This is important because the scope of the inspection is to ensure that the PAE works properly.

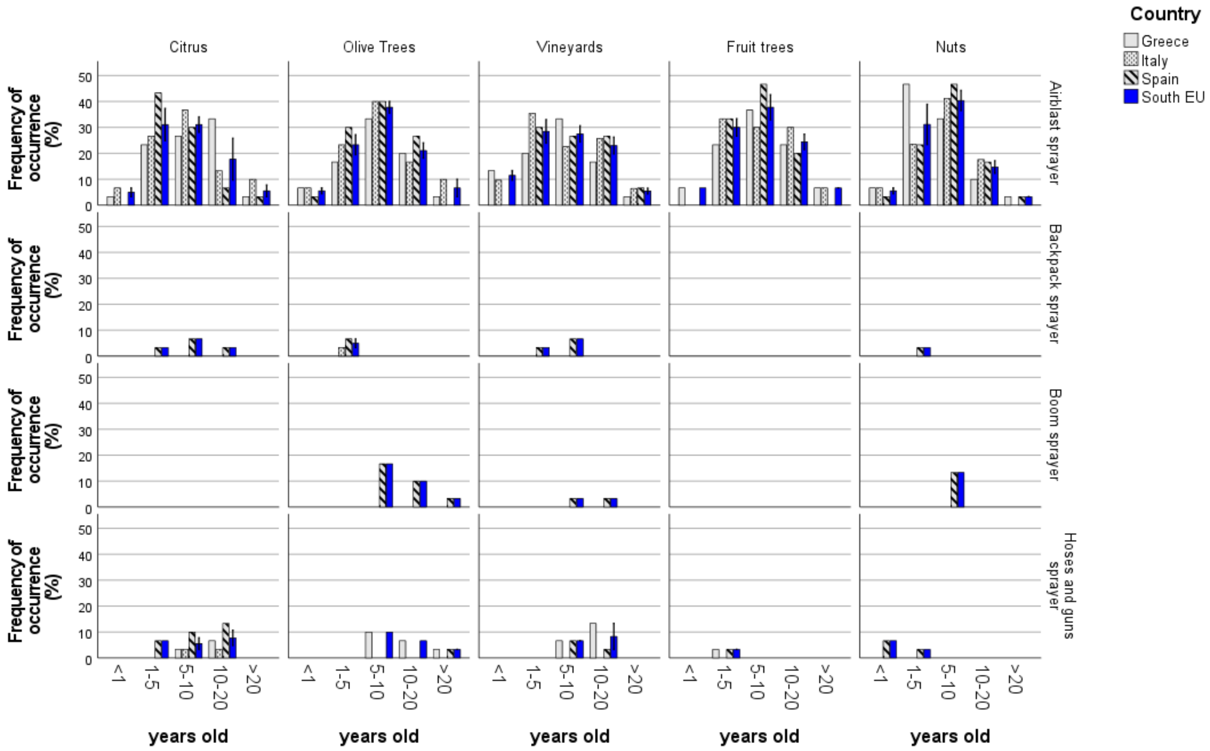

Figure 26. Occurrence for the farmers' answers related to the question *What type of spraying equipment do you use and how old are they?*

3-D orchards

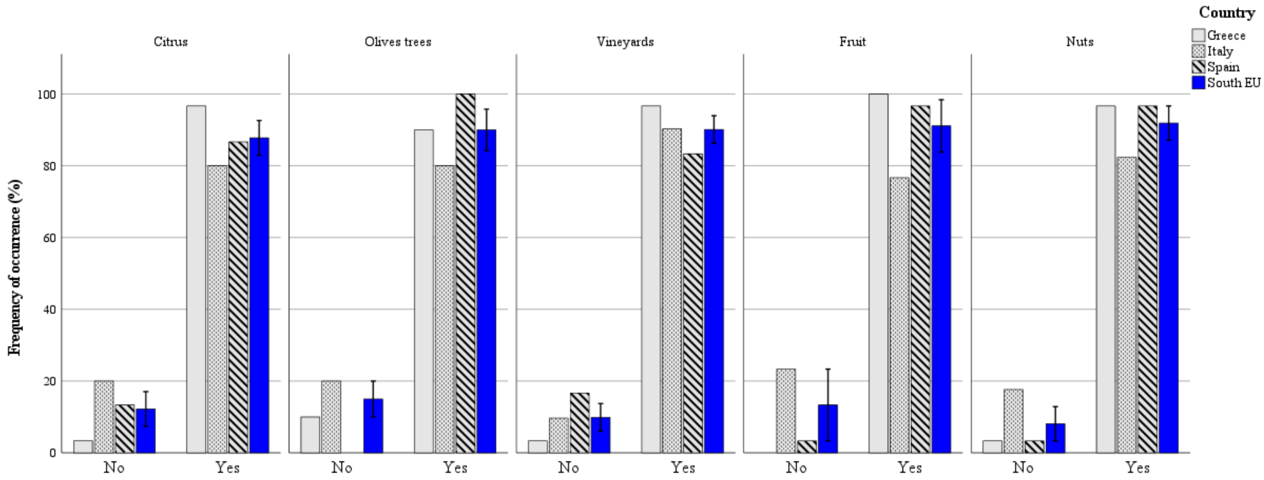

Figure 27. Occurrence for the farmers' answers related to the question *Are your sprayers inspected and certified for use?*

Figure 28 reports the importance range for different criteria for growers when buying a new sprayer. The criteria range from 1 (not relevant) to 5 (very important). From a general overview of the data the criteria could be divided into three different levels of importance. The criteria considered most relevant by farmers when purchasing a new PAE are: spray efficacy, precision application, operator safety, reduction of PPP usage, environmental protection and the selling price. Most of these criteria were expected to be relevant for farmers (e.g., spray efficacy and selling price), but operator safety and environmental protection weren't expected to be rated so important. The relevance obtained by these criteria puts evidence that farmers, nowadays, are starting to take care about the environment and human health. On a second layer of importance, they consider functionality certificate, high level of automatization, brand reputation and familiarity. What they consider of less interest when purchasing equipment is the sprayer advertisement.

3-D orchards

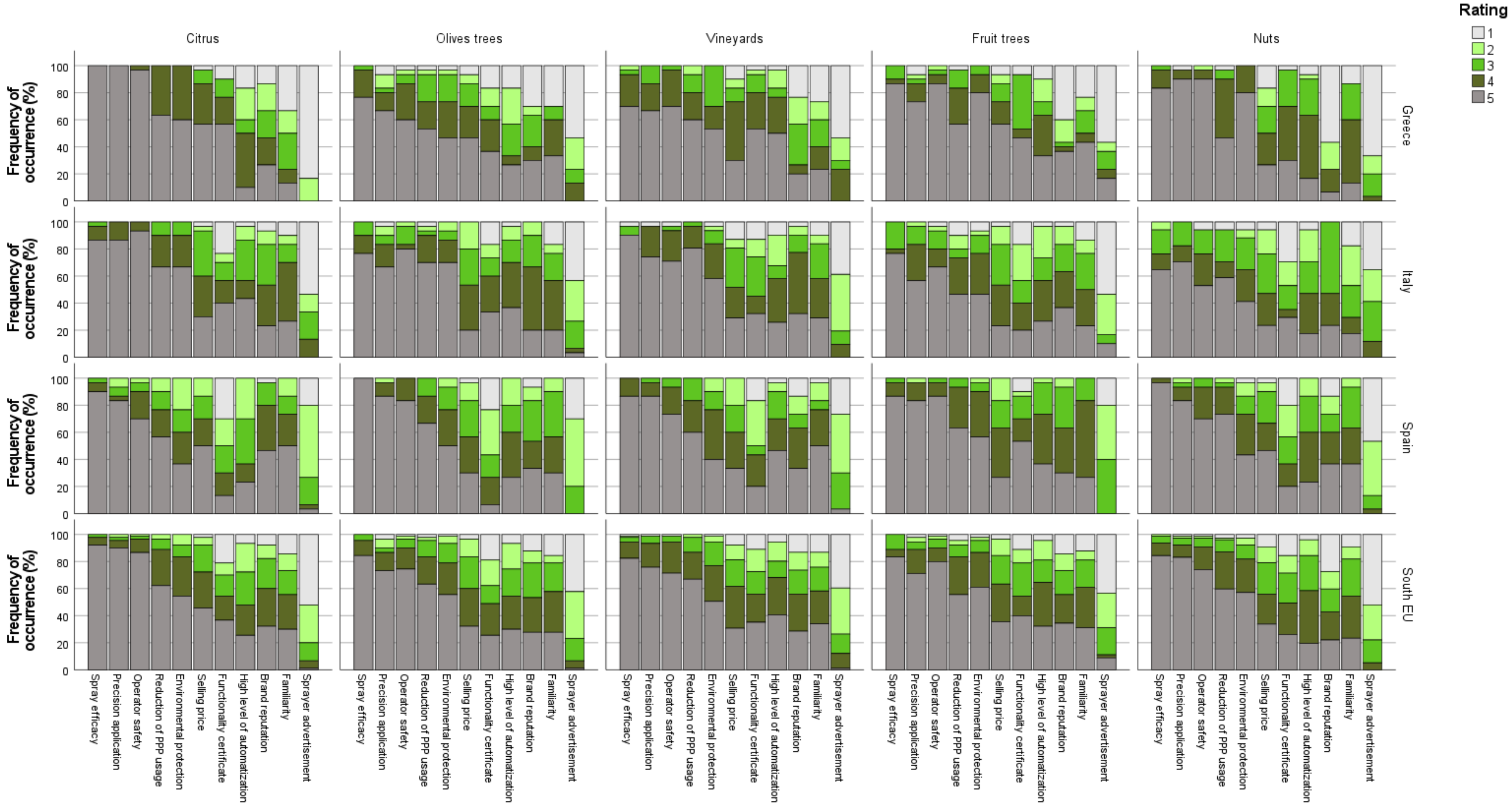

Figure 28. Occurrence of farmers' answers related to the question *Which are your criteria when you buy/acquire your spraying equipment?* Stacked bars show the importance range from 1 (not important) to 5 (very important). SEU data is an average of the three countries.

3-D orchards

The vast majority of the interviewees, irrespective of the crop type, reports to be familiar with technology and innovation, as Figure 29 shows.

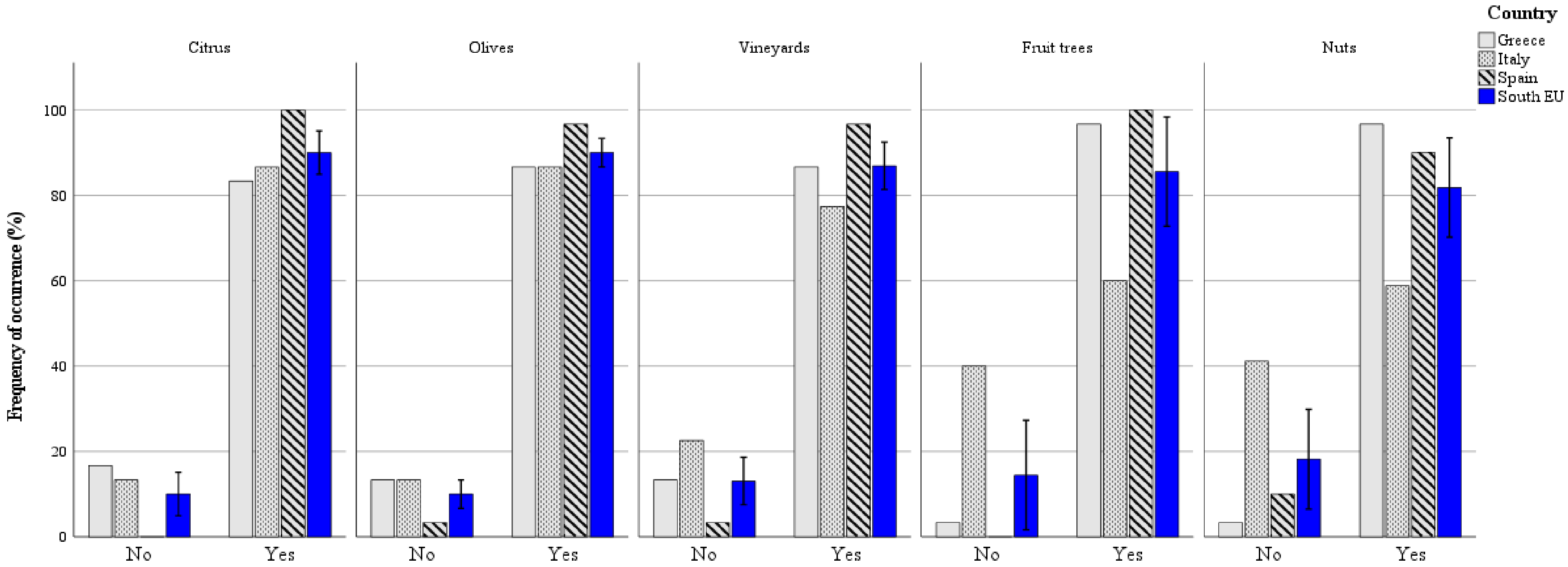

Figure 29. Occurrence for the farmers' answers related to the question *Are you familiar with technology and innovation?*

Figure 30 reports the importance of different sources of information on the way farmers operate the PAE. The answers obtained are heterogeneous both among the crops and countries. The value of the SEU shows a typical trend for each crop. The criteria rated as most important by the farmers were the private advisor and the PAE inspection station. The less relevant to them were the articles and other farmers. Other categories are in intermediate positions.

3-D orchards

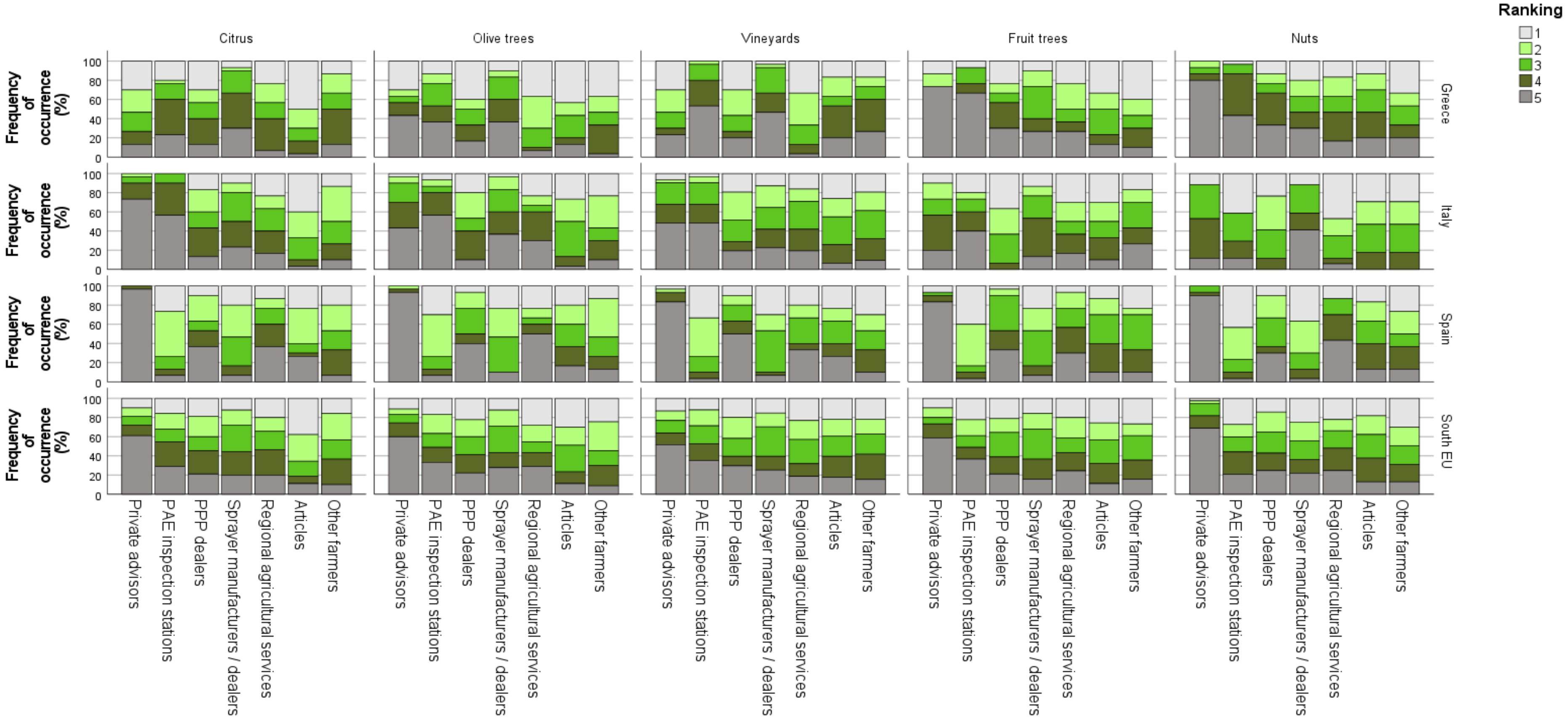

Figure 30. Occurrence of farmers' answers related to the question *How important are the following sources of information on the way you operate your spraying equipment?* Stacked bars shows the importance range from 1 (not important) to 5 (very important). SEU data is an average of the three countries.

3-D orchards

Figure 31 shows the frequency of PAE adjustments or calibration and the parameters adjusted. For each crop type and country, the percentage of farmers that do not adjust any parameters is always below 20%. Focussing on the parameters adjusted, it is possible to state that SEU farmers have a similar behaviour. Indeed, almost all of the growers report to modify the volume rate and the spray pressure along the vegetative season, as Figure 32 reports. Moreover, almost all the surveyed growers report to modify at least two operative parameters. According to them, the parameters related to the airflow characteristics (fan speed and air direction) are on a secondary level of importance. To a lesser extent, they report to change the number of active nozzles. In addition, almost all the interviewees stated that they try to maintain a constant forward speed during the spray application.

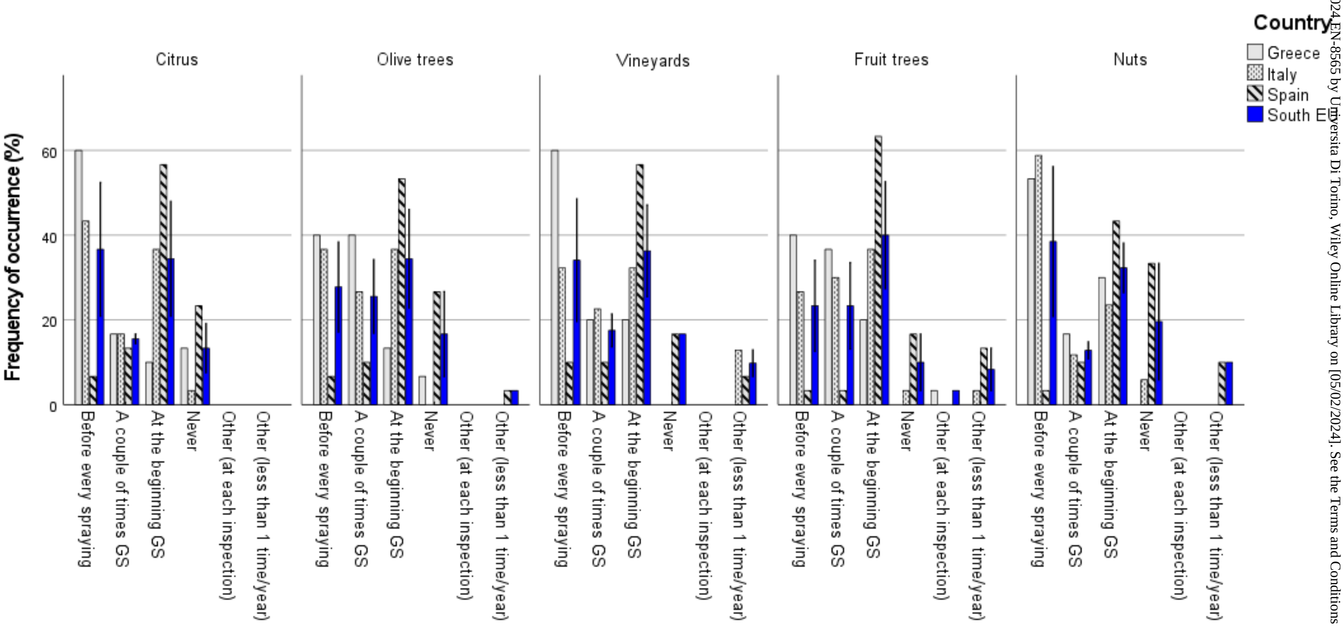

Figure 31. Occurrence for the farmers' answers related to the question *How often do you adjust/calibrate your spraying equipment?*

3-D orchards

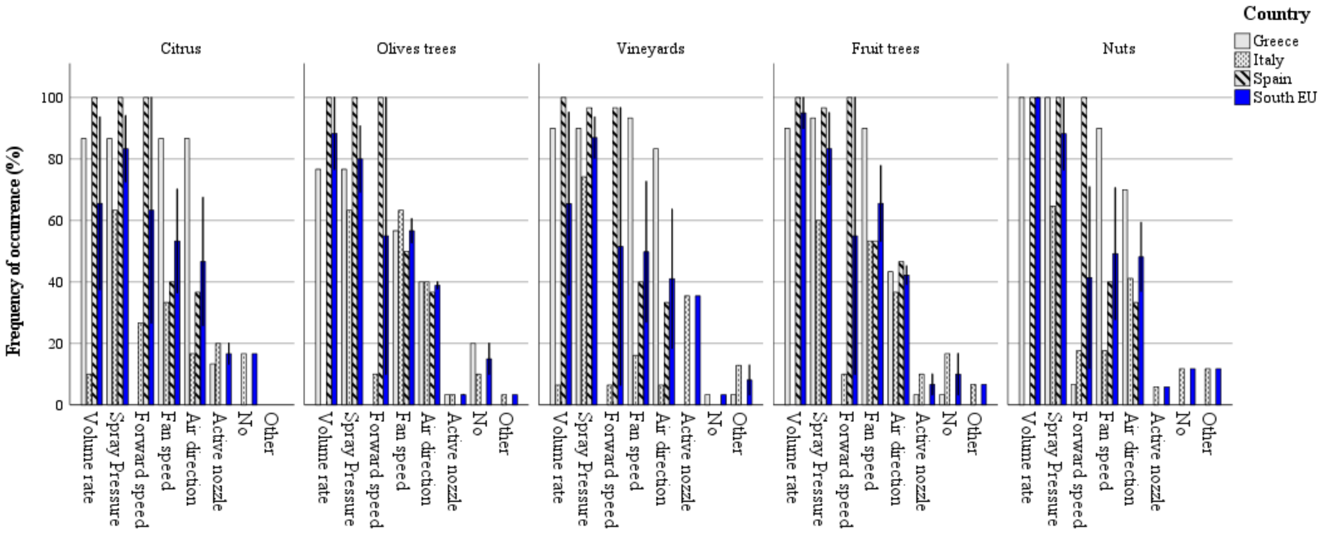

Figure 32. Occurrence for the farmers' answers related to the question *Do you make adjustments to your spraying equipment based on the growth stage of your crop, the quantity of vegetation, the target pest, etc? Which parameter/s do you adjust?*

Even though farmers report to modify the volume rate applied during the vegetative season, only a limited number of them use volume adjustments tools of any sort (Figure 33). As already proven, the adoption of these decision support systems could lead to an increase in the efficiency of the pesticide application. Almost the totality of growers states that they try to maintain a constant speed during the pesticide applications (Figure 34).

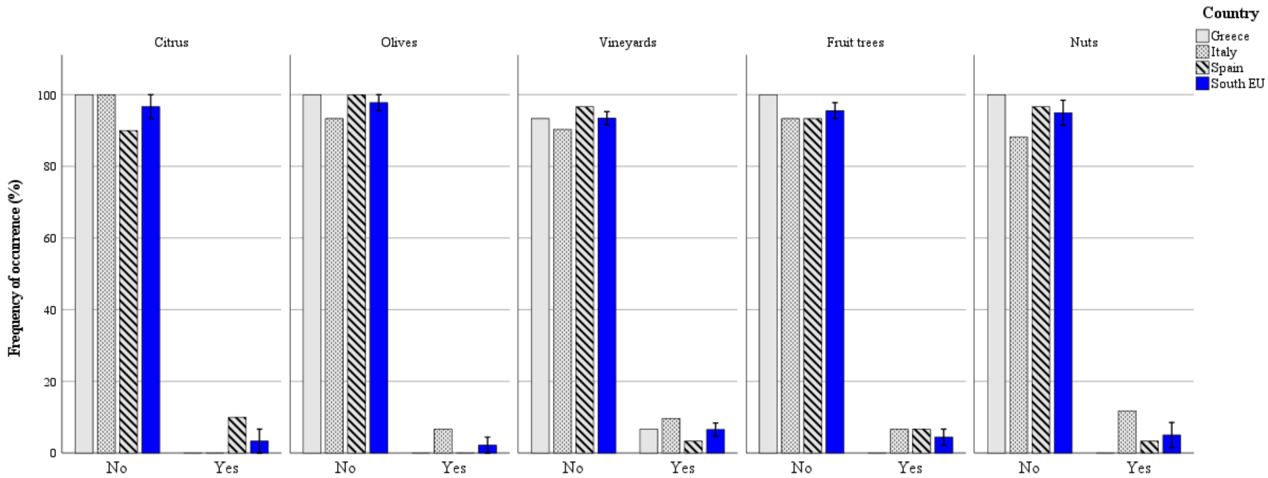

Figure 33. Occurrence for the farmers' answers related to the question *Do you use any volume rate adjustment tool to decide the volume rate to use in your PPP applications?*

3-D orchards

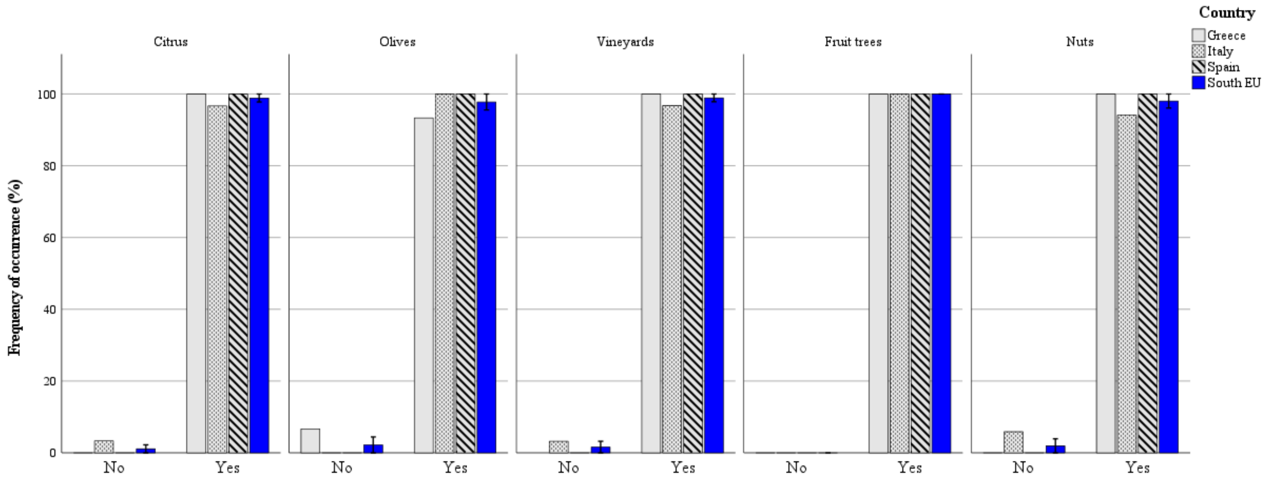

Figure 34. Occurrence for the farmers' answers related to the question *Do you try to maintain a constant speed during the spray application?*

Occurrence of the nozzle substitution is evenly distributed among the classes, with some differences among the crops, as reported in Figure 35. Also in this case, there is a similar trend in the SEU states.

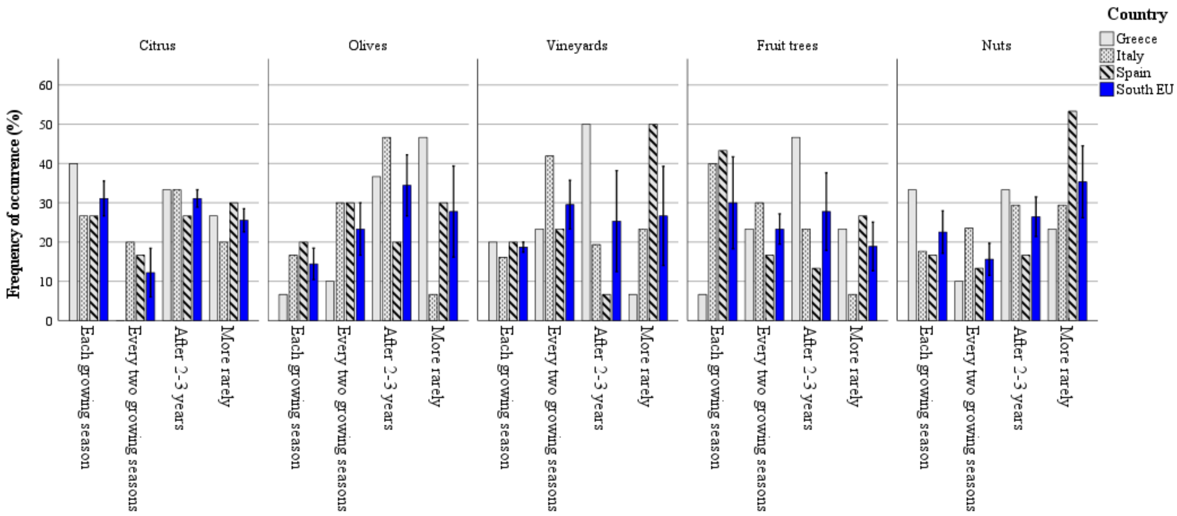

Figure 35. Occurrence for the farmers' answers related to the question *How often do you change spray nozzles in your equipment?*

According to the interviewees, the spray application timing is decided by taking into account the advice of plant scientists or based on the personal experience of the growers themselves. The information derived from other farmers and sources is reported to be less important

(Figure 36). The data reported in Figure 37 show that even nowadays, an important portion of farmers do not use electronic tools to register the PPP applications.

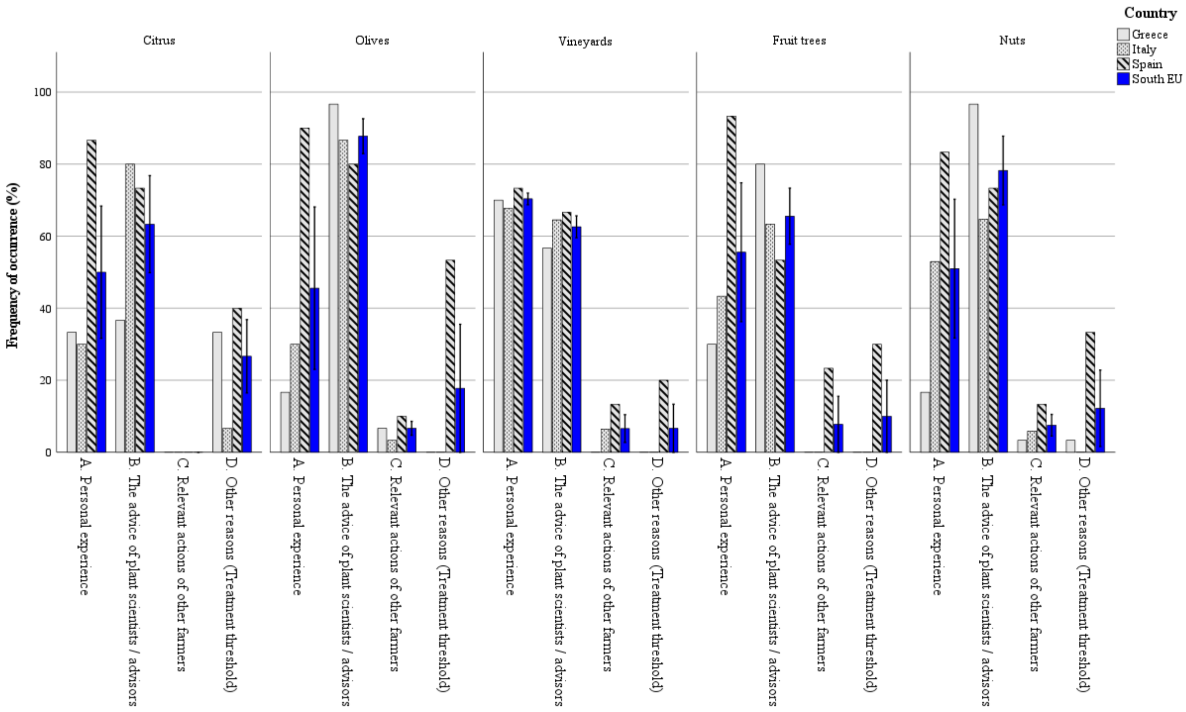

Figure 36. Occurrence for the farmers' answers related to the question *Based on what do you decide on the moment in the season to apply PPP to your crop?*

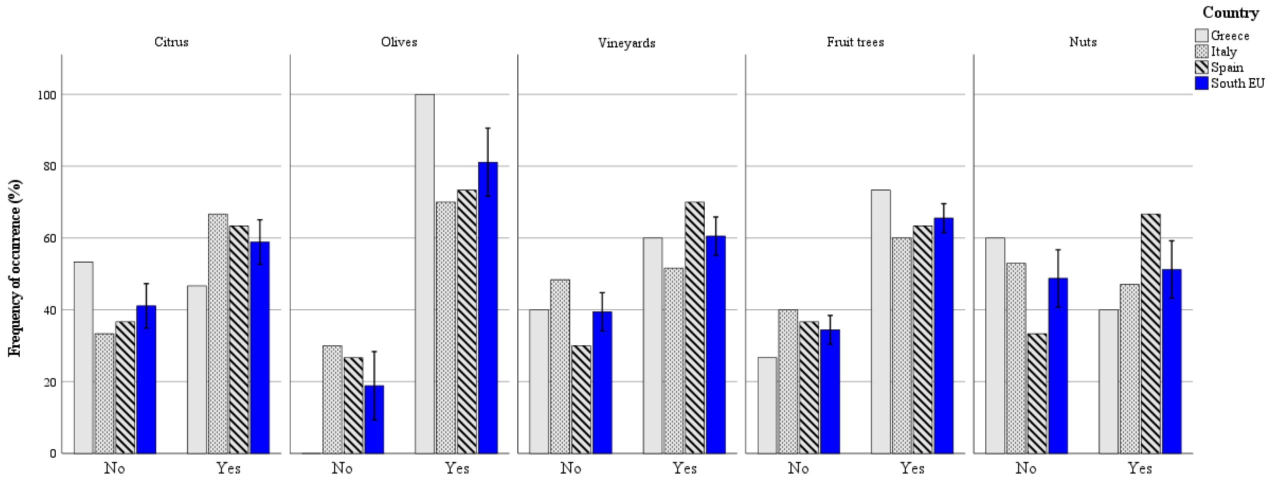

Figure 37. Occurrence for the farmers' answers related to the question *Do you record PPP applications in an electronic way?*

3-D orchards

The operative time needed to spray one hectare per sprayer and operator is reported in Figure 38. In every crop type considered in the survey, most of the farmers declare to spend between 0.5 hour to 1 hour to spray one hectare. It is relevant to point out that in this question there is no distinction between different PAE types, which directly affect the operative time. Directly linked to this topic are the number of hectares sprayed in a day (Figure 39). Surprisingly, an important portion of the surveyed farmers states to spray one hectare or less per day. The class with the higher occurrence is the one between 1 ha to 5 ha sprayed a day.

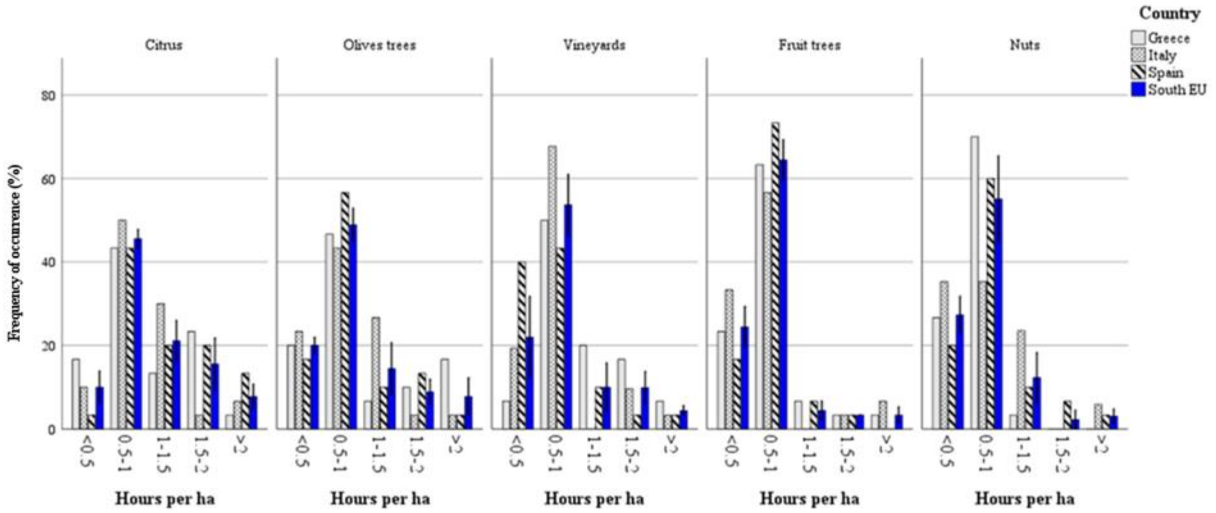

Figure 38. Occurrence for the farmers' answers related to the question *How many hours do you take in spraying one hectare?*

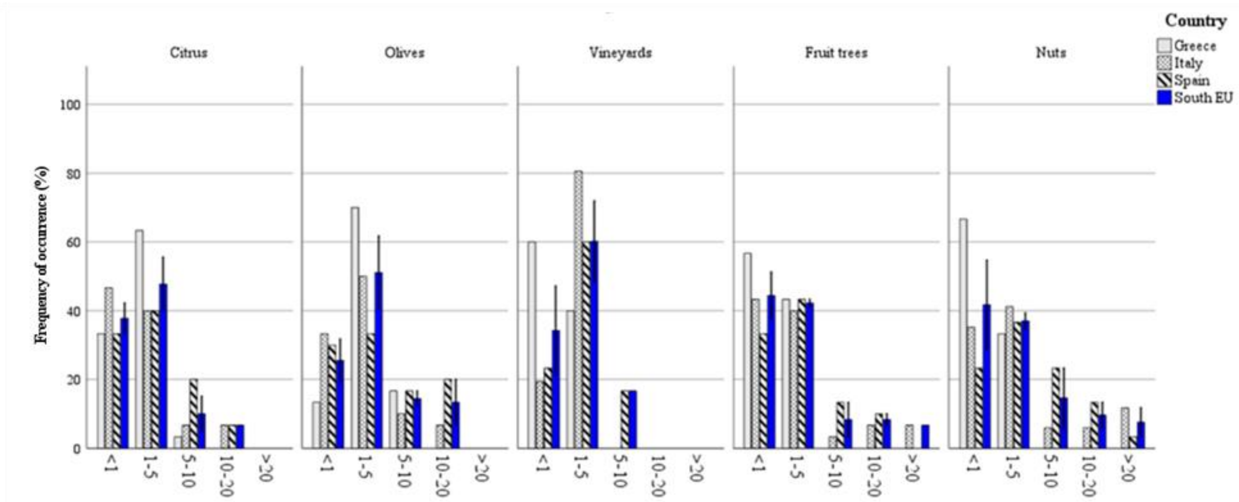

Figure 39. Occurrence for the farmers' answers related to the question *How many hectares do you spray in a day?*

3-D orchards

Figure 40 reports the days that farmers need to spray all the farm surface. The trend is typical of each crop type, because it is also influenced by the total surface, which is slightly different between the crops considered (Figure 19).

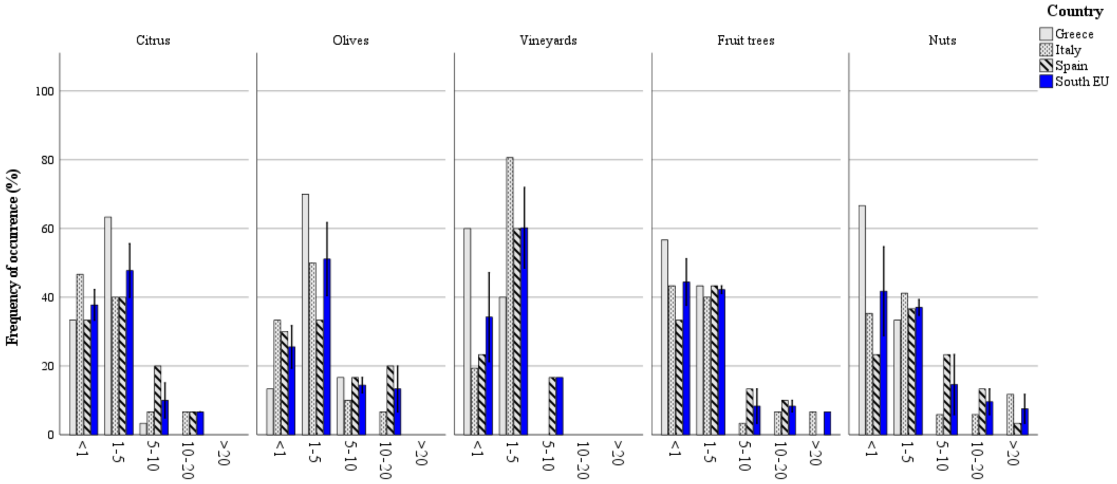

Figure 40. Occurrence for the farmers' answers related to the question *How many days/hours do you take in spraying all your crop surface?*

As expected, each type of crop follows a specific pattern related to the month when the spray application is carried out (Figure 41). The trend among the SEU states is almost coincident in each crop type, with the exception of citrus. In this crop, when compared to other states, fewer Spain growers spray in the late summer.

The annual number of spray applications for each crop (Figure 42) is even among the different states. Fruit growers perform more applications yearly. These crops require more applications because the consumer requires a product without any damage caused by pests, therefore the intervention threshold is set to a lower level. In this crop the number of insecticide applications conducted in Italy is higher due to some outliers.

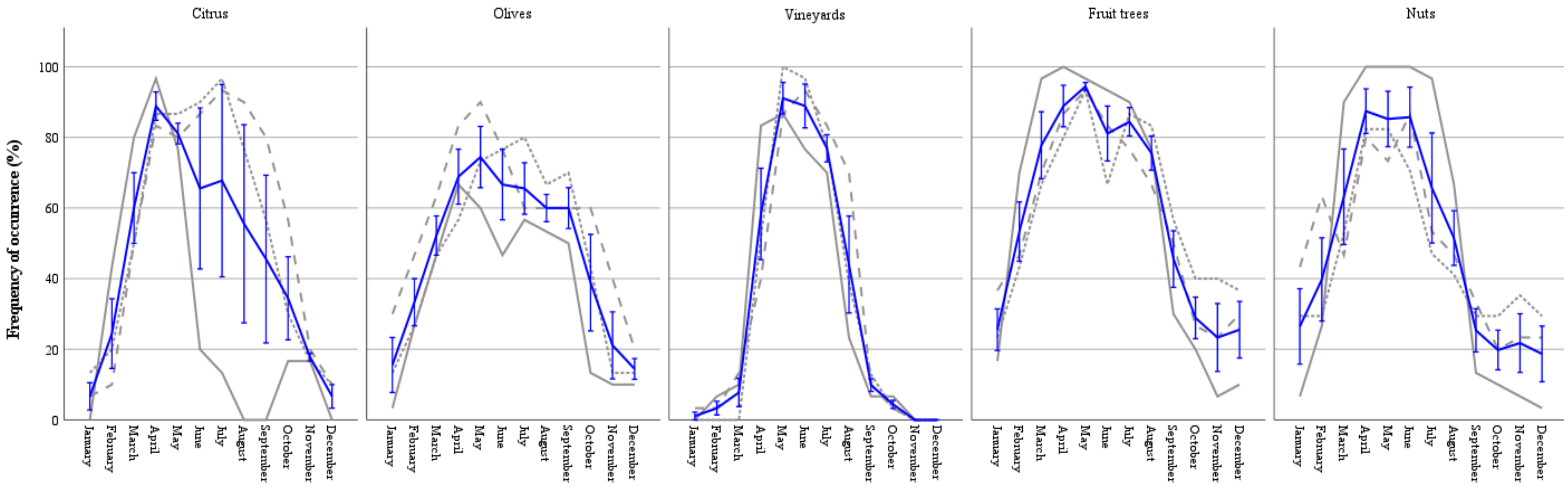

Figure 41. Occurrence for the farmers' answers related to the question *Which months of the year do you usually spray?* In detail, Greece, Italy, Spain, and SEU data are reported as dotted grey, dashed grey, solid grey, and blue solid lines, respectively. Lines show average values (± SEM) divided by crop type and country.

3-D orchards

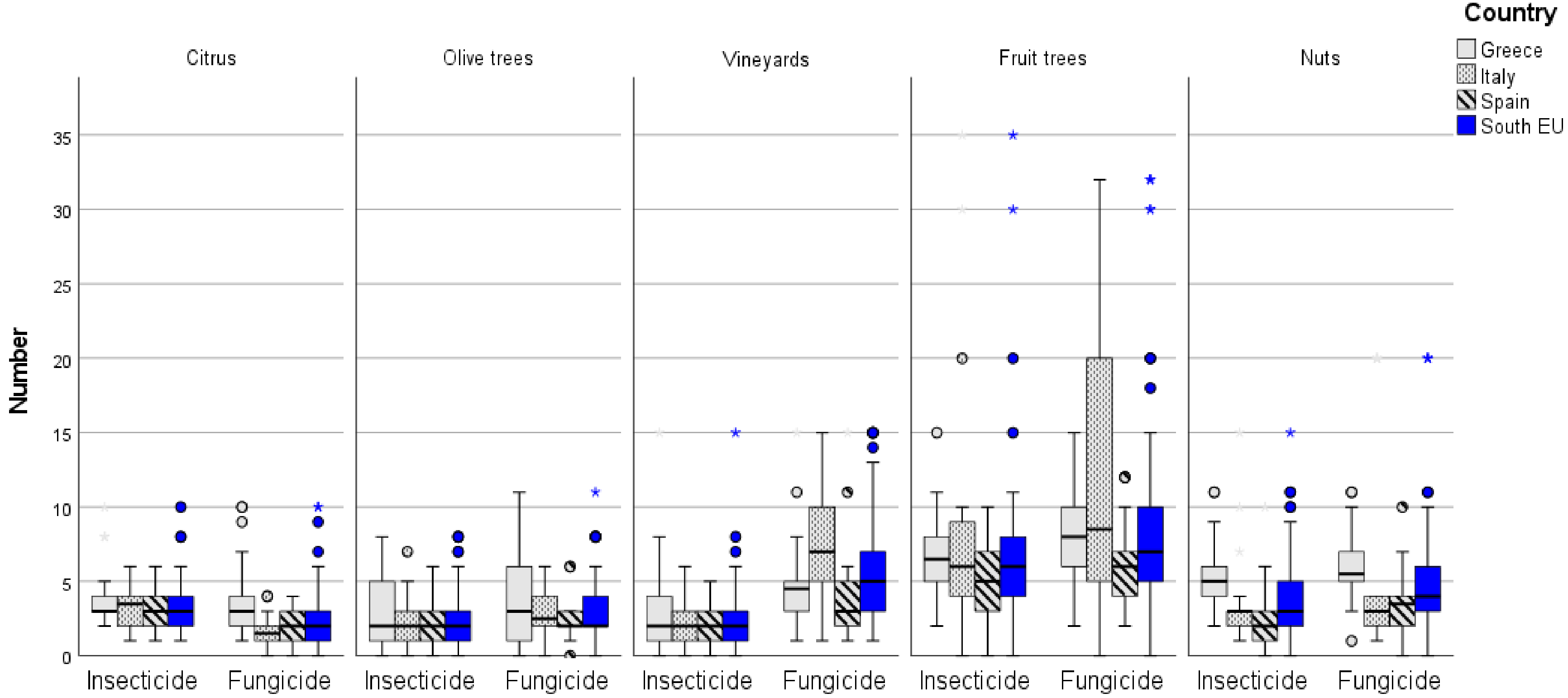

Figure 42. Boxplot showing the distribution of spray application numbers declared by farmers' in relation to the question *How many spray applications do you perform per year?*.

3.4.1.4 PPP USAGE

Almost the totality of the interviewees state that they read the labels on the PPPs, independent of the crop or the states considered (Figure 43). The next question of the survey was still related to the PPPs labels, specifically the topic was whether the farmers were aware that the dose in the labels could be expressed as quantity of PPP per sprayed hectare or in terms of concentration of the spray mixture (e.g. kg or L of PPP/ 100 L of water - Figure 44). As in the previous question, almost all the interviewees report to be aware of that. Regarding the question related to the respect e of the dosage on the labels (Figure 45), almost all the growers comply with it, this trend is representative of the SEU for all the crops. In all the crops examined, few growers state that they apply more PPPs amounts than those recommended on the labels. The vineyard case is slightly different, as in this crop there were some Italian farmers that reported to apply less product than the dose reported on the label. Among these farmers, some used tunnel recycling sprayer so they reduce the dosage because they have greater deposition when compared to conventional axial fan sprayer. Complying with the dosage is a key point of the plant protection process, because application of lower dosage could lead to lack of efficacy and development of resistance. Instead, applying higher dosage could pose an environmental and human risk.

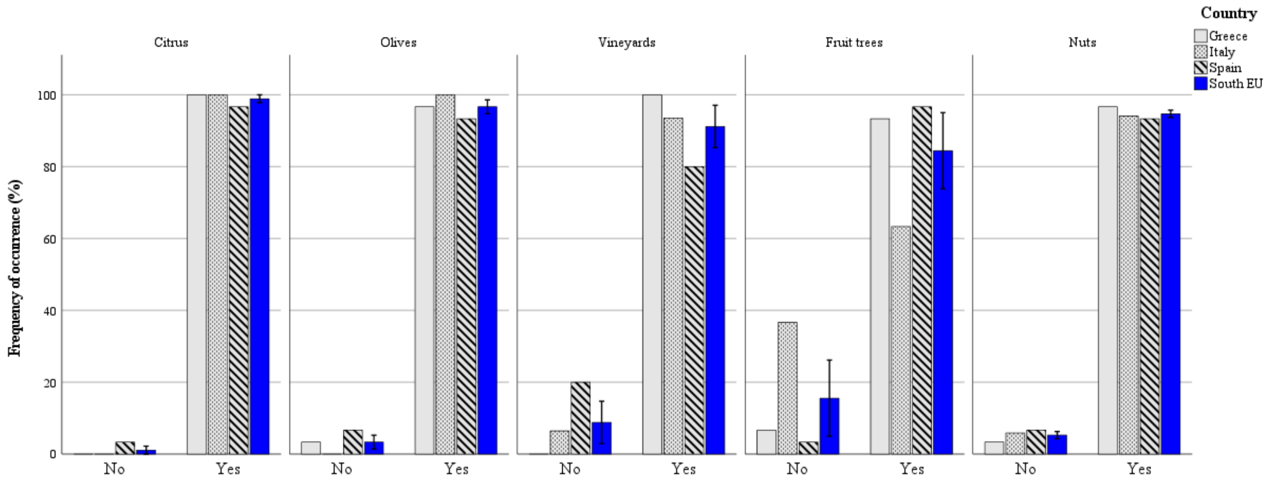

Figure 43. Occurrence for the farmers' answers related to the question *Do you read the instructions of your purchased PPP?*

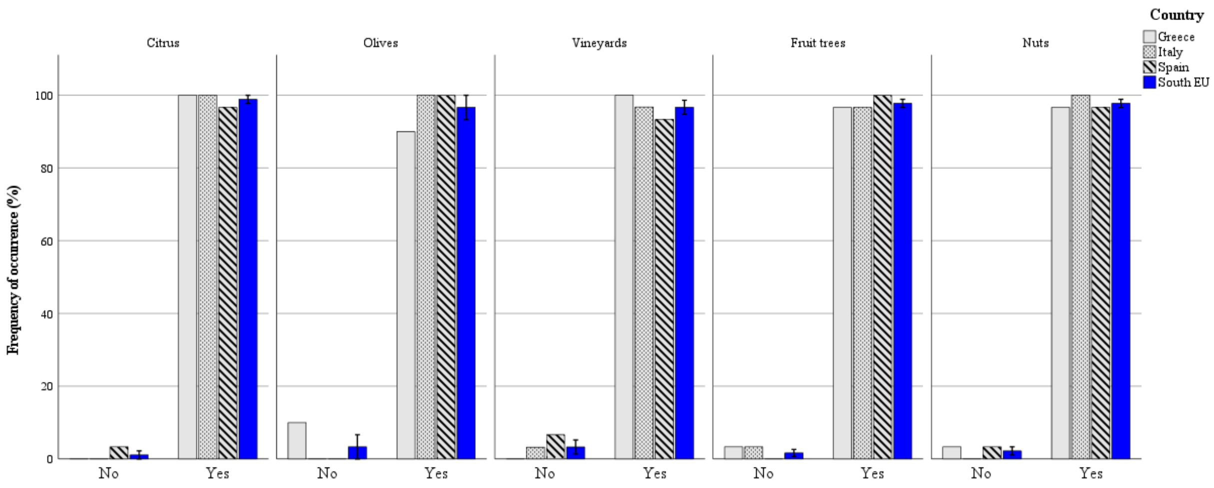

Figure 44. Occurrence for the farmers' answers related to the question *Do you know that some PPP indicate the dose per hectare and others indicate the concentration?*

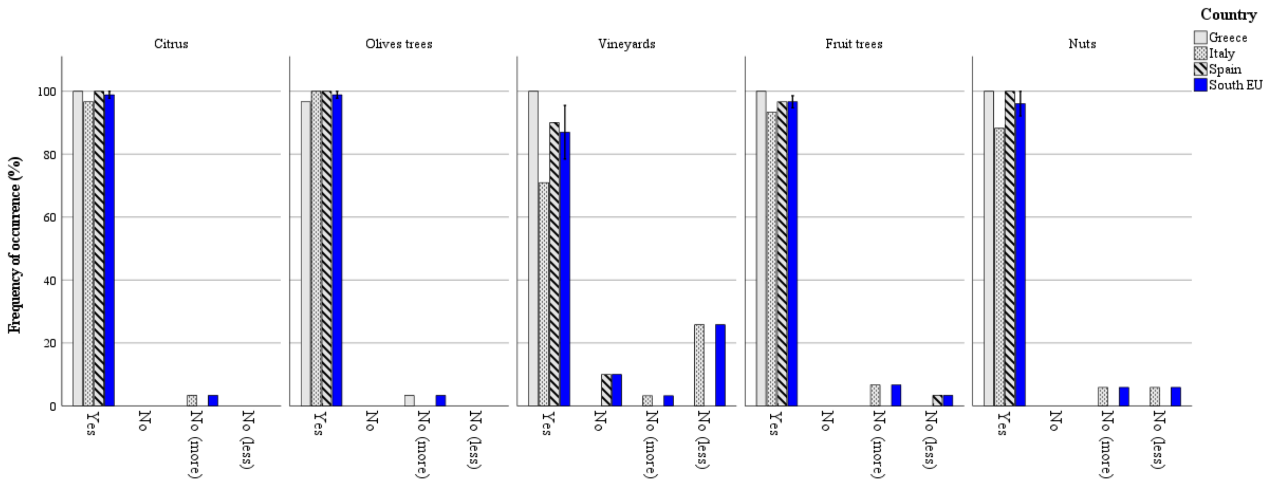

Figure 45. Occurrence for the farmers' answers related to the question *Do you comply with the indicated application doses/concentrations?*

3.4.1.5 PPP REMNANTS MANAGEMENT

The correct handling of PPP remnants after the spray application has a primary role on human and environmental safety. The TOPPS (training of Operators to prevent Pollution from Point Sources) activity has already demonstrated that the potential pollution derived from point sources could overcome 50% of the total PPP potential pollution (calculated at the sum of point and diffuse sources). Point sources pollution is related to the: i) sprayer filling, ii) sprayer cleaning and iii) residual mixture waste management. Figure 46 shows the different management of the excess mixture at the end of the spray application. Also in this topic the SEU farmers seem to have a similar behaviour. Based on the data obtained, the most common practice is to spray it on the crops (with or without pre-dilution). Some of the surveyed growers reported that they do not have any exceeding mixture. Especially in citrus, olive and vineyard, the practice of remediation systems (intended as both bio-remediation and evaporation systems) is adopted by an important percentage of growers. The wrong practices (e.g., emptying the tank on the ground or in the sewer system) was conducted by a limited number of growers. The data obtained by this question could not be completely truthful, since some farmers declare to use a remediation system but have a very small farm and these systems are quite expensive. Presumably, the real number of growers that adopt wrong remnants management practices is higher than what is reported.

3-D orchards

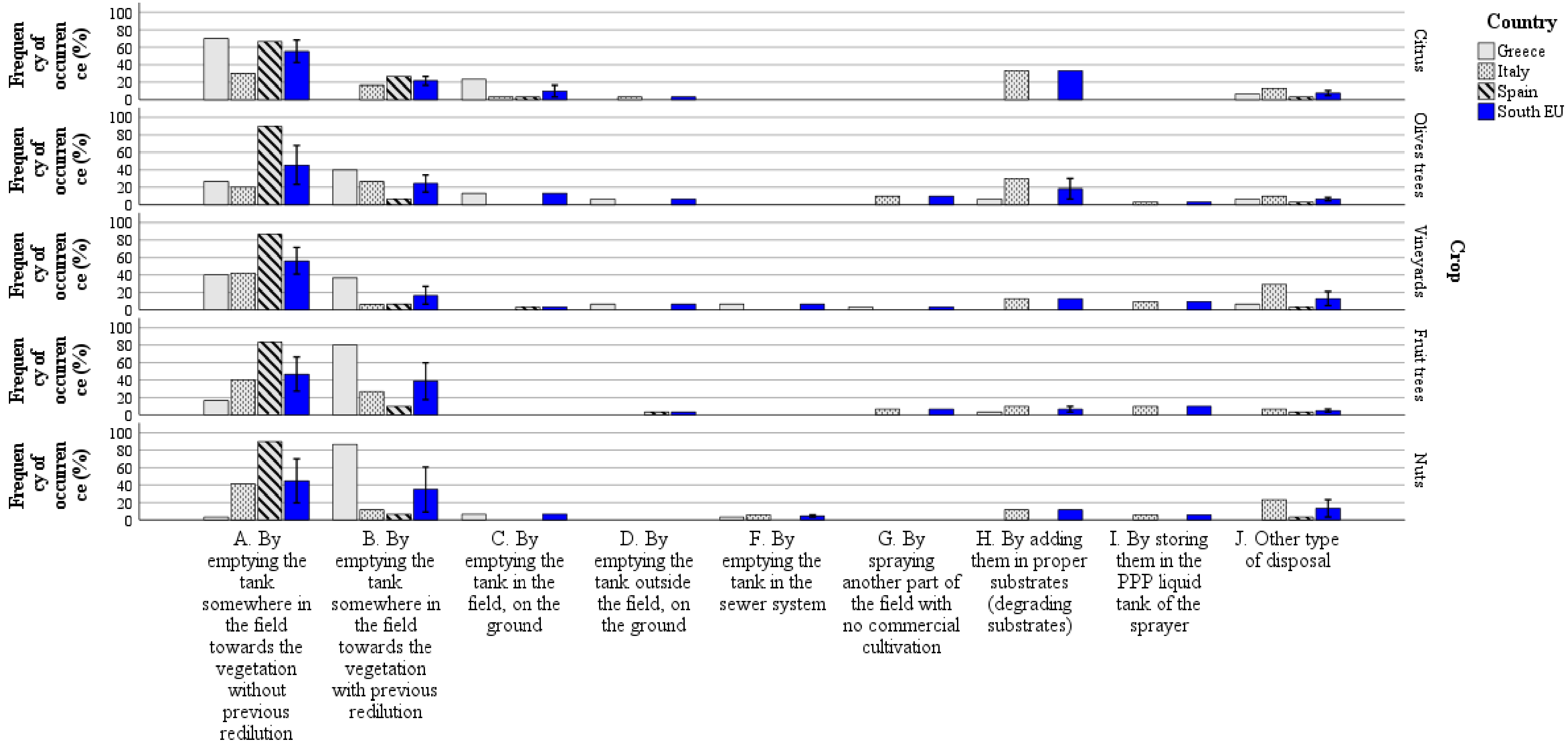

Figure 46. Occurrence for the farmers' answers related to the question *How do you dispose of any PPP remnant after spraying?*

3-D orchards

Regarding the frequency of the PAE internal cleaning, reported in Figure 47, for every crop at least 60% of farmers report to clean the equipment at the end of every spray application. The survey was focused on the internal cleaning but external cleaning is important too and deserves attention. The water waste from this process must be properly managed, otherwise it will become a point source pollution. The management of the contaminated washing solution is shown in Figure 48. For each crop considered, the variation in occurrence between categories is shown. The most common practice is to drain the water waste over the ground (point pollution). A limited percentage report to address the remnants on the sewer system or over draining channels. Depending on the crop, between 15 to 25% states to convey the water on adequate substrate.

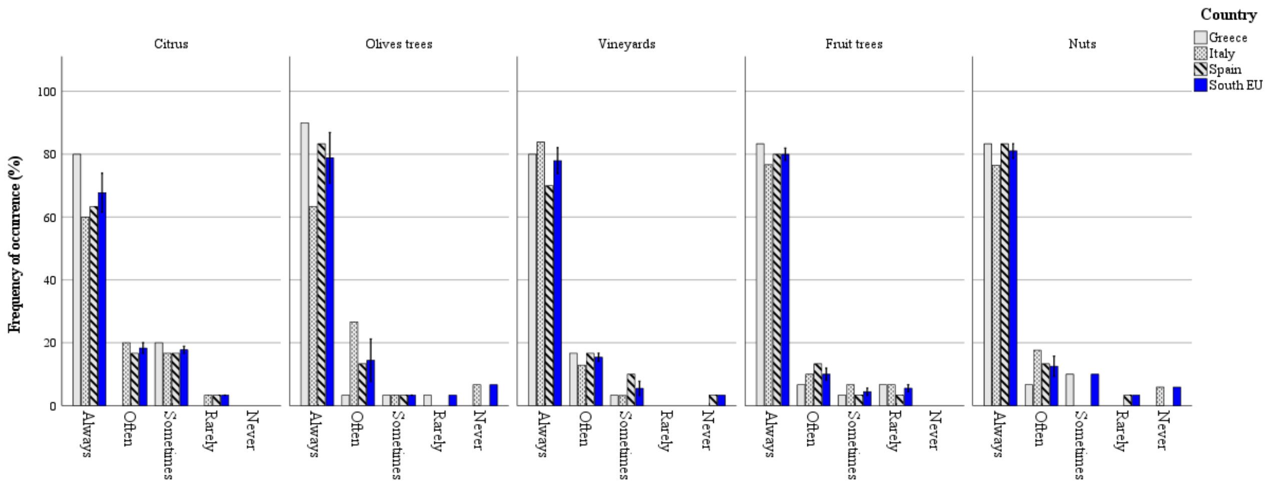

Figure 47. Occurrence for the farmers' answers related to the question *Do you wash the spraying equipment after completing the PPP application?*

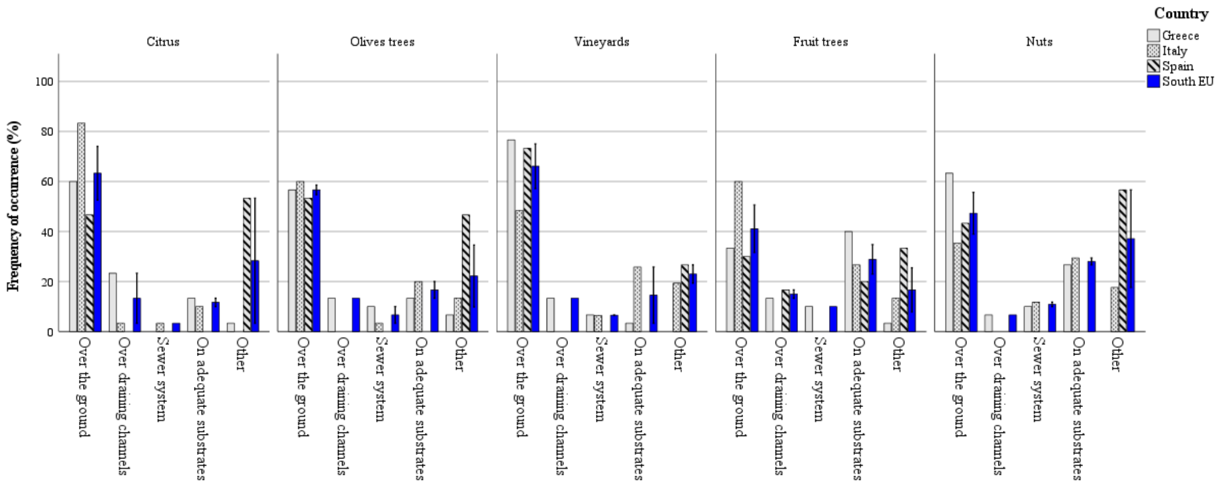

Figure 48. Occurrence for the farmers' answers related to the question *Where do you drain the water from washing the spraying equipment?*

3.4.1.6 OPERATOR SAFETY DURING PPP APPLICATION

The European Commission defines Personal Protection Equipment (PPE) as "products that the user can wear or hold, to be protected against risks either at work, at home or whilst engaging in leisure activities". The European legal framework related to PPE consists of a series of Directives and decisions. The first of those is the Council Directive 89/686/EEC, adopted to harmonise the European legal framework on health and safety requirements PPE must fulfil. In recent years the Regulation 425/2016 lays down requirements for the design and manufacture of PPE. Figure 49 shows that almost the totality of the surveyed farmers regularly wear PPE during the spray application. Figure 50 reports the type of PPE used. It is important to point out that this question was not asked if the PPE was certified according to the European framework. The most used PPE were gloves, mask with filter and coverall. The less adopted were the common mask (intended as a mask without filter) and the hat.

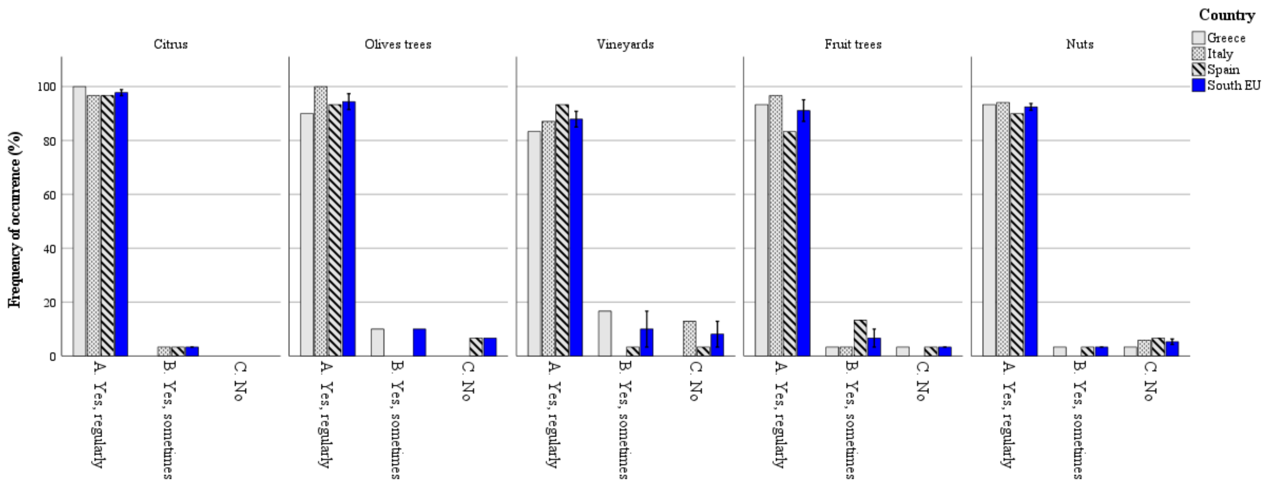

Figure 49. Occurrence for the farmers' answers related to the question *Does the operator use personal protection equipment during spraying?*

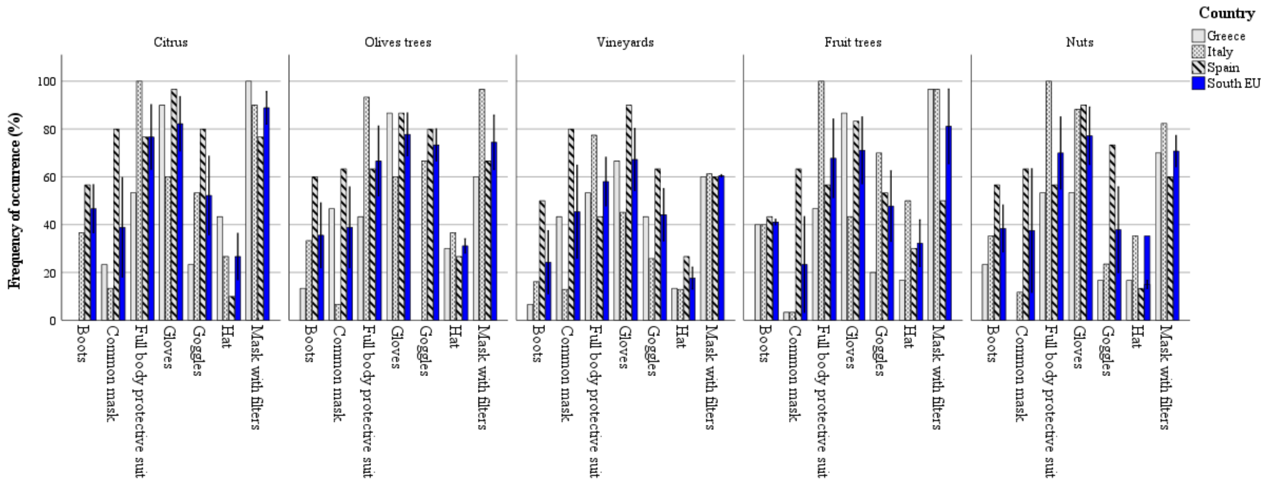

Figure 50. Occurrence for the farmers' answers related to the question *If the operator uses personal protection equipment, which ones does he/she usually use?*

Another important factor on operator exposure is the tractor itself. Specifically, the type of cab (if there is any). The main types of cab on tractor are divided based on the filtration capability in: i) Cat 1: no defined level of protection against hazardous substances; ii) Cat 2: protection against dust; iii) Cat 3: protection against dust and aerosols and iv) protection against dust, aerosols and vapour (EN 15695-1:2017). Based on the data presented in Figure 51, most of the farmers use cab-less tractors or tractors with cab and filters. Other categories were reported only in isolated cases. Related to the tractor with cab and filter, the survey was not specifically on the type of filter.

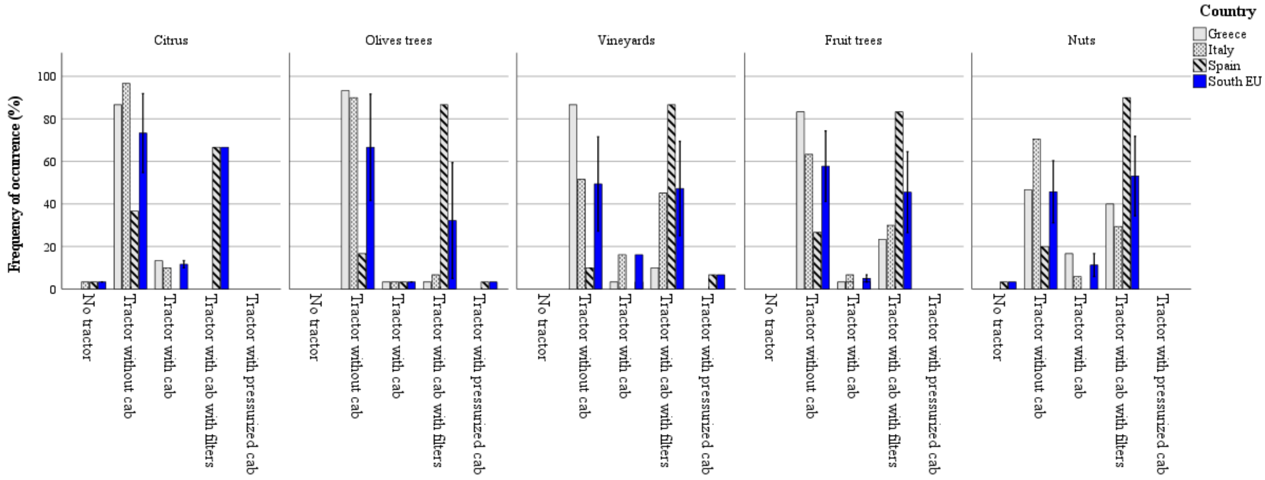

Figure 51. Occurrence for the farmers' answers related to the question *What type of tractor are you using for foliar treatments?*

3.4.2 Topic B: State of spraying equipment and the habits of equipment owners

In this section, the answers of the surveys from sprayer dealers and manufacturers and the answers of the surveys from the sprayer inspection stations in the three SEU countries are analysed, so that relevant conclusions considering the state of spraying equipment and the habits of equipment owners can be drawn.

Regarding the types of spraying equipment mostly sold and inspected (Figure 52 and Figure 53, respectively), the vast majority of both sold and inspected equipment concerns airblast sprayers in all three countries, while in Spain, hoses and guns sprayers and also boom sprayers are quite common. It should be noted here that, since boom sprayers are usually used in field crops and not in 3-D crops (only to apply herbicides), and that the questionnaires specifically stated that the answers must solely refer to 3-D crops, a large portion of Italian surveys and all Greek surveys did not include boom sprayers in their possible answers. However, this does not influence the fact that airblast sprayers are by far the most widespread type of spraying equipment sold and inspected in all three countries.

3-D orchards

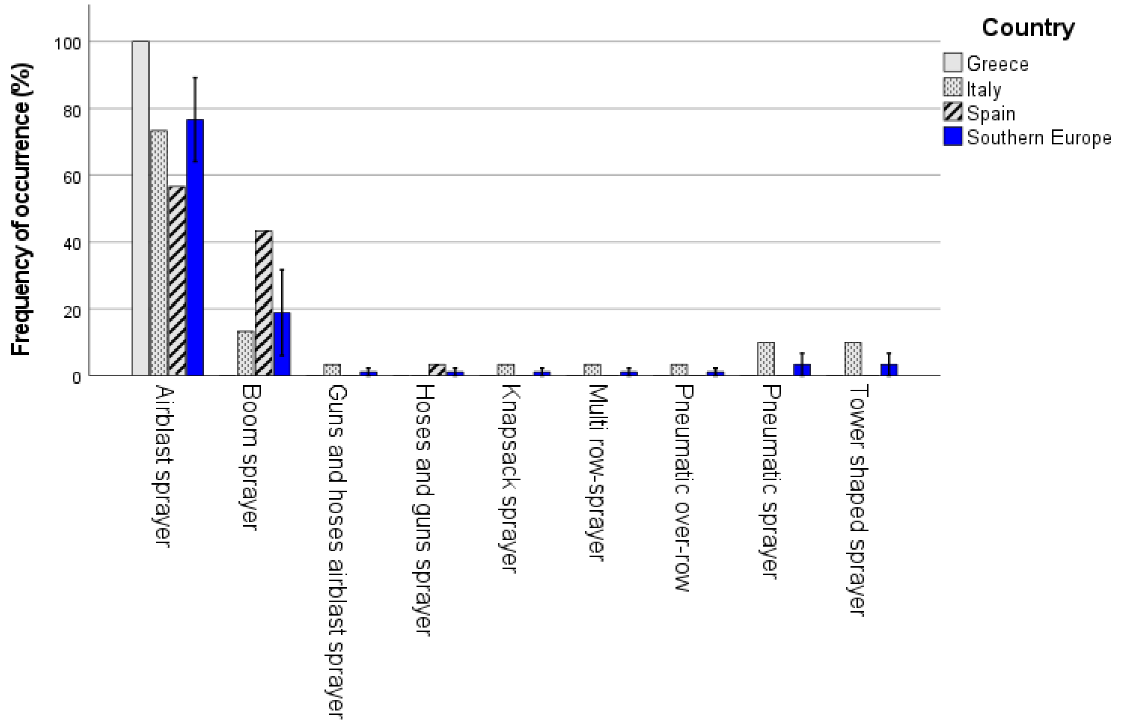

Figure 52. Occurrence for the manufacturers' answers related to the question *What is the most widespread type of spraying equipment sold?*

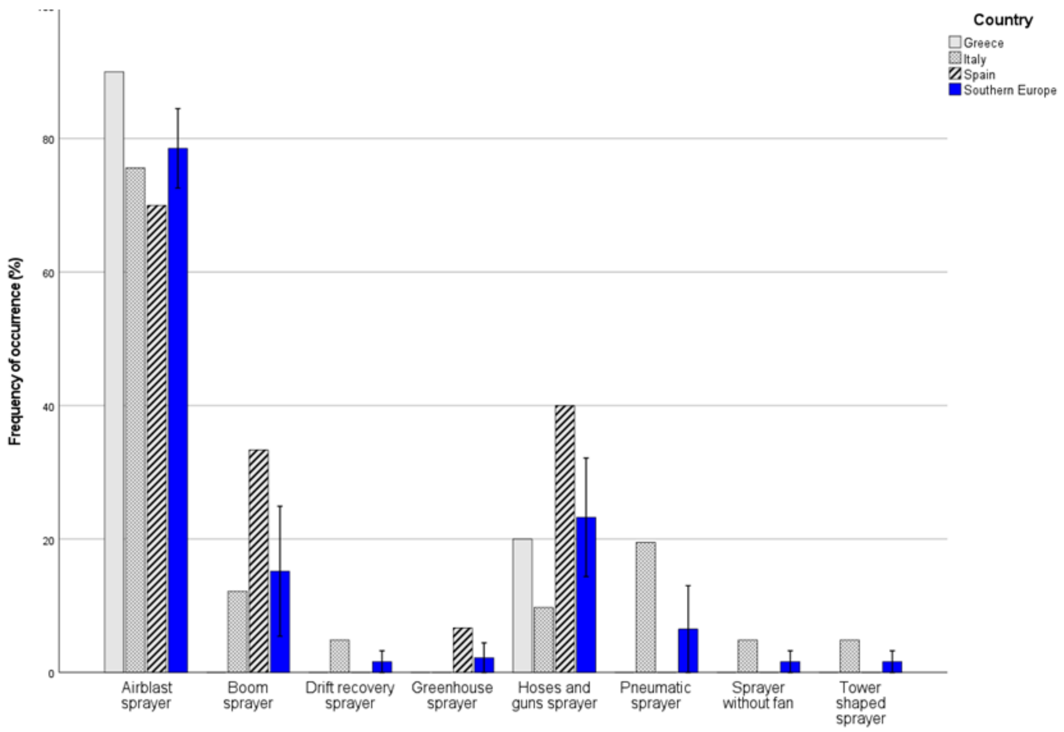

Figure 53. Occurrence for the inspectors' answers related to the question *What is the most widespread type of spraying equipment inspected?*

Specifically concerning the inspections of spraying equipment, Figure 54 shows the average monthly number of inspected spraying equipment per inspection station in all three countries. It is evident that Greece has smaller inspection stations with the majority of them inspecting less than 10 equipment per month, while something similar holds for Italy, where, of course, there are also some large stations with dozens of inspected equipment per month. On the other hand, the majority of inspection stations in Spain are larger, with 10-20 inspections per month, while a substantial percentage of them inspect more than 80 sprayers per month. Concerning the percentage of these inspected sprayers that get approved after inspection (Figure 55), it seems that inspection stations in Spain apply stricter criteria since they present lower approval rates than those in Italy and particularly in Greece. However, in general, a very high percentage of equipment inspected in all three countries gets the approval label, which might raise some concern about the quality of the inspection procedures.

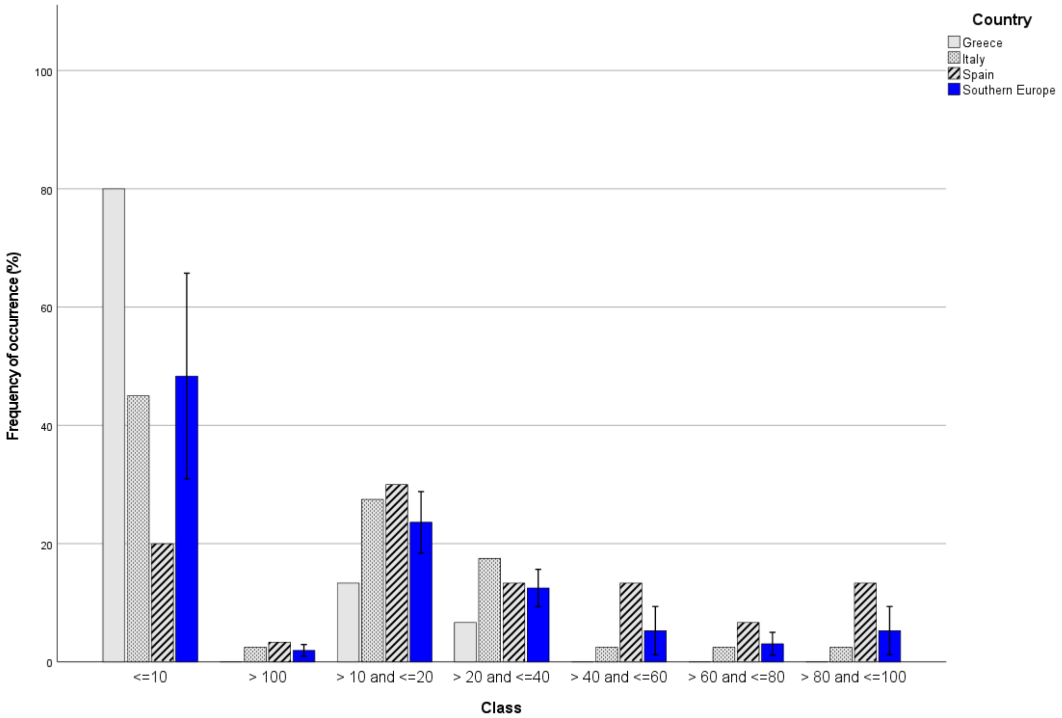

Figure 54. Occurrence for the inspectors' answers related to the question *Which is the average number of inspected equipment per month*?

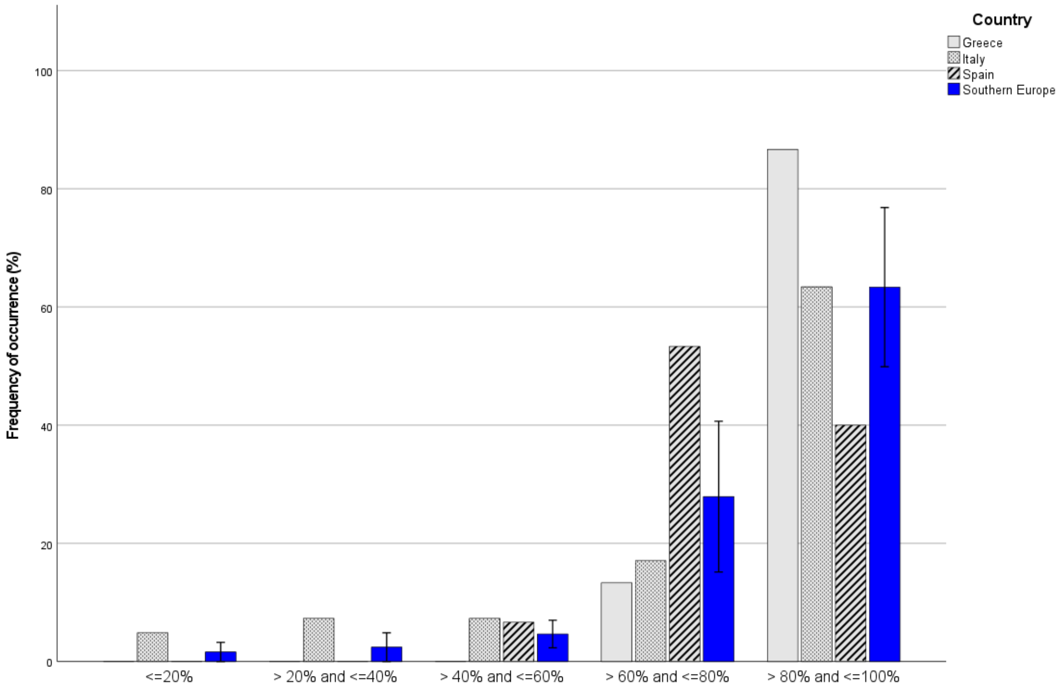

Figure 55. Occurrence for the inspectors' answers related to the question *Percentage of inspected equipment that get the approval certification*.

In the following figures, answers are rated versus five specific degrees of intensity: very positive, slightly positive, no change, slightly negative, very negative (or equivalent options, depending on the type of question). The figures refer to the percentage of answers (y-axes in the plots) of either dealers and manufacturers of spraying equipment or inspection stations falling in a specific degree of intensity.

In relation to the trend of the characteristics that are being mostly promoted by manufacturers and dealers in the sprayers in recent years, the efficacy of the equipment stands out, followed by user safety and endurance (see Figure 56). There is a general consistency between the popularity of the characteristics between the three countries, with the autonomous operation being by far the least popular. Just Italy presents a slight differentiation in the case of PPP input reduction and safety to the environment, which have greater importance relative to the other two countries. In the case of inspection stations, the trends in equipment characteristics preferences in the inspected sprayers are very similar to those reported by dealers and manufacturers (Figure 57), and also in this case, Italy seems to be more consistent than before with the other two countries, with the exception only of safety to the environment, which is again higher in the rank of desired characteristics.

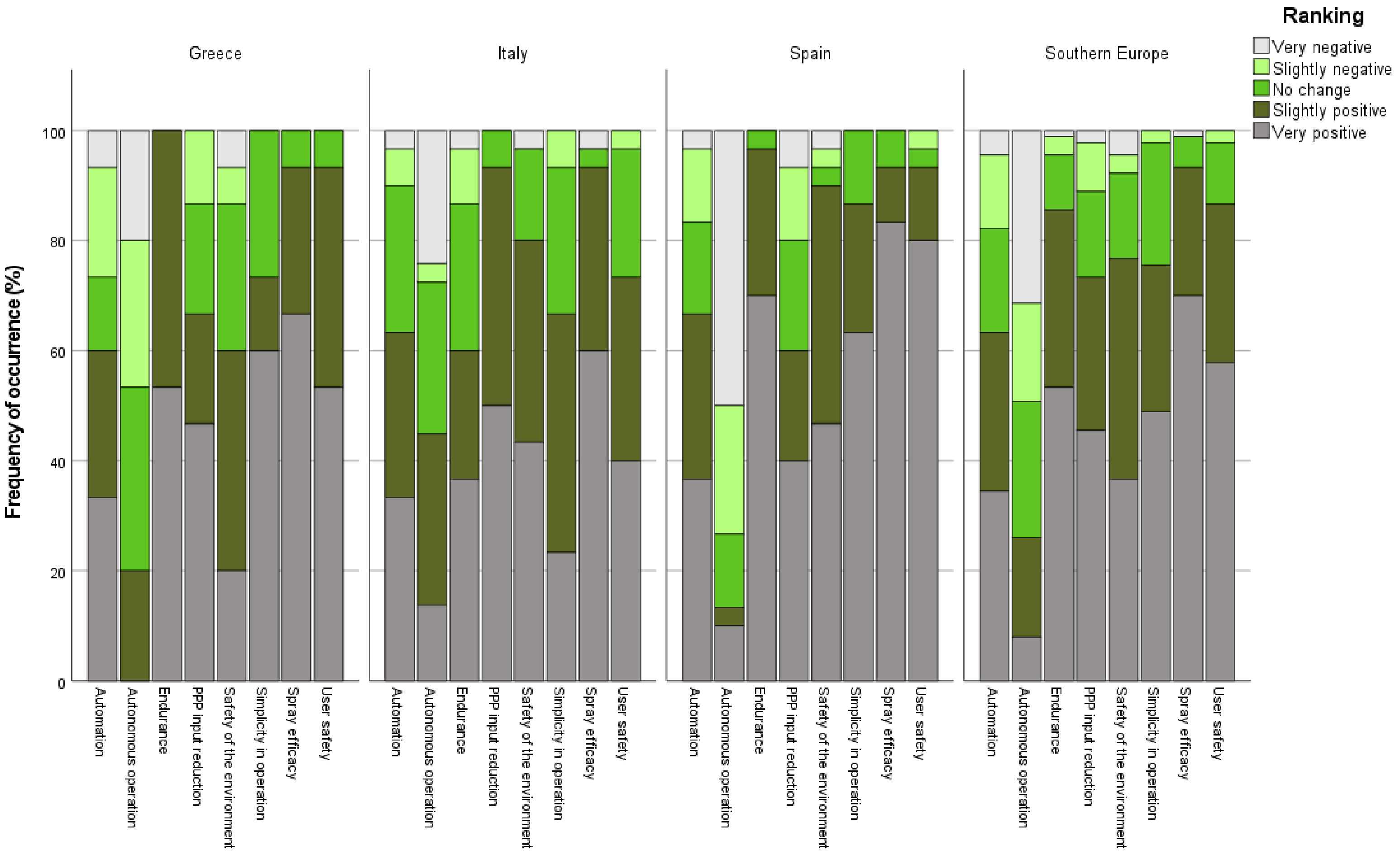

Figure 56. Occurrence for the manufacturers' answers related to the question *What is the trend in the characteristics/ devices of the demanded spraying equipment in the last 10-15 years related to the next topics?* Stacked bars show the importance range from "very negative" to "very positive". SEU data is an average of the three countries.

3-D orchards

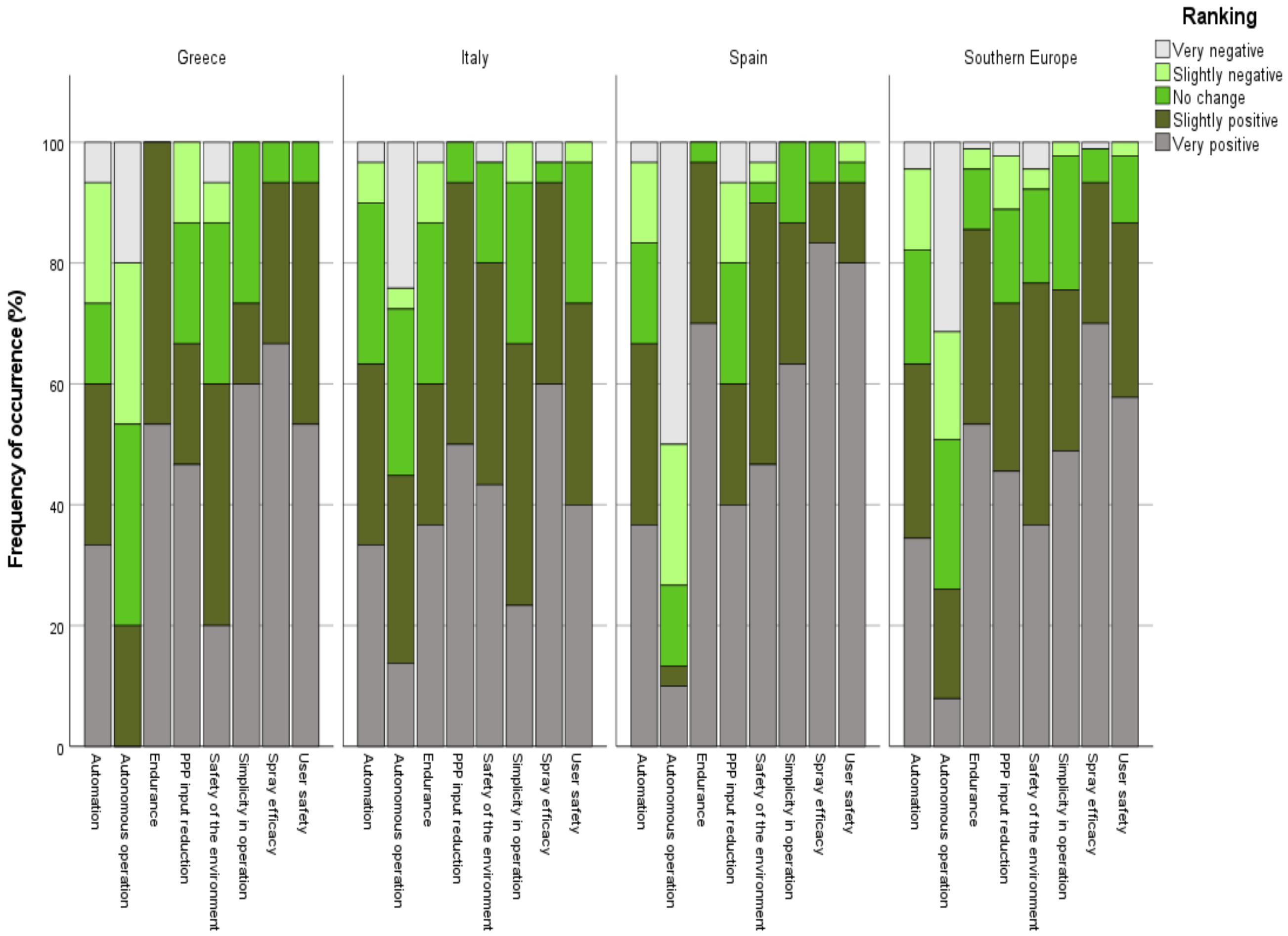

Figure 57. Occurrence for the inspectors' answers related to the question What is the trend in the characteristics/devices of the inspected spraying equipment in the last years related to the next topics. Stacked bars show the importance range from "very negative" to "very positive". SEU Europe data is an average of the three countries.

3-D orchards

Concerning the percentage of buyers of sprayers who bring their equipment for regular maintenance services to the dealers/manufacturers from where they bought it (Figure 58), there is a clear differentiation in the trends among the three countries: in Spain, more than 50% of the manufacturers answered that more than 75% of their customers bring their equipment for regular maintenance services, while the corresponding percentages of manufacturers in Italy and Greece were much lower (around 20%). In these two latter countries, 30-40% of the manufacturers reported that less than 25% of their customers bring their sprayers for regular maintenance services, while in Spain that percentage was just 10%. So, it seems that in Spain, spraying equipment is more regularly maintained by the manufacturers than in Italy and Greece.

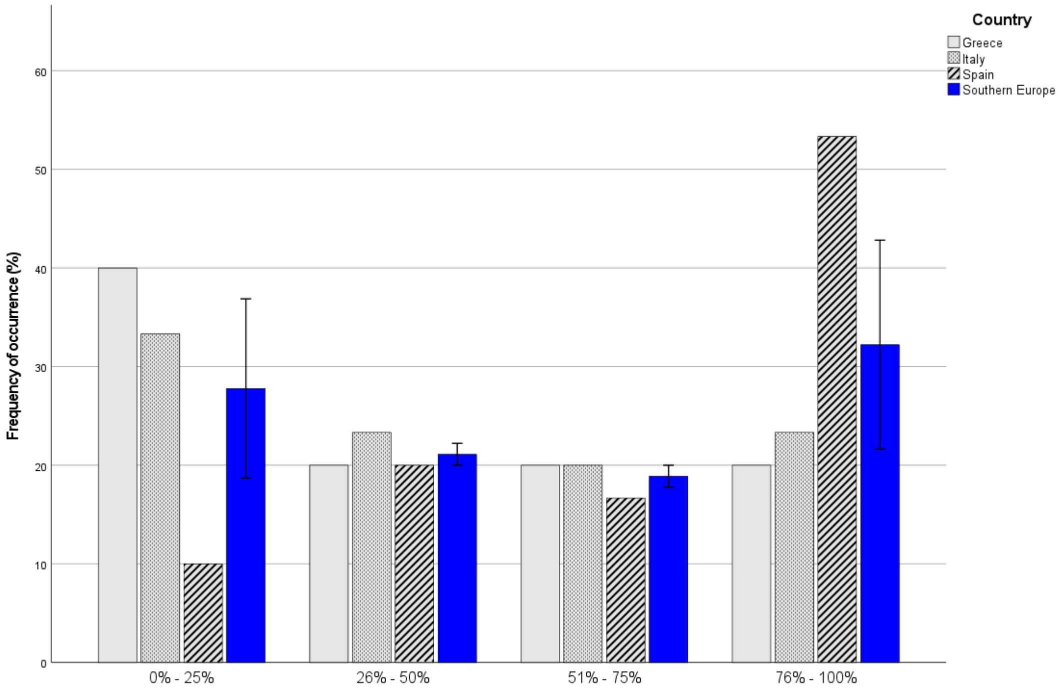

Figure 58. Occurrence for the manufacturers' answers related to the question *In what percentage do sprayer buyers bring their equipment for regular maintenance services?*

When it comes to technical services for repair, a similar overall picture can be observed (Figure 59), however, the situation in Greece is slightly shifted towards that of Spain.

3-D orchards

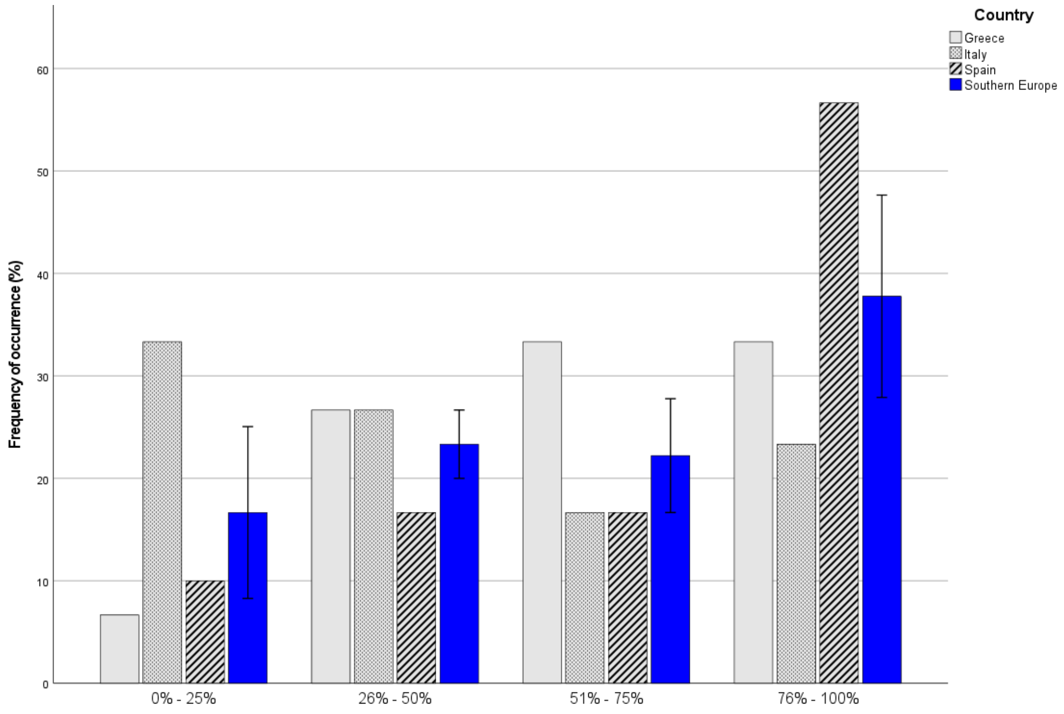

Figure 59. Occurrence for the manufacturers' answers related to the question *In what percentage do sprayer buyers bring their equipment for repair to the technical service?*

Regarding third party certification, the situation is very similar to all three countries (Figure 60): the vast majority of dealers and manufacturers (around 80%) reported that less than 25% of the sprayers that they sell have been certified by some 3rd party (e.g., ENTAM), which is something to be expected, as this kind of certification is not mandatory in any of these countries.

3-D orchards

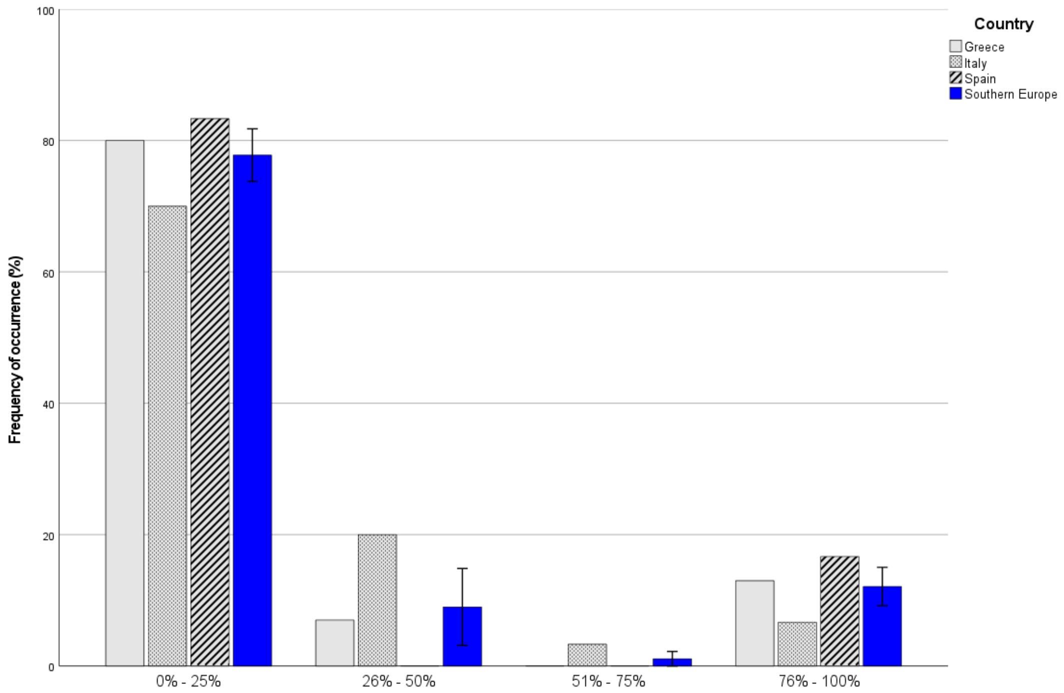

Figure 60. Occurrence for the manufacturers' answers related to the question *What percentage of sold spraying equipment are certified by third part (e.g. ENTAM)?*

During maintenance and repair, it seems that the most problematic parts are the pump, the nozzles, the measurements, control and calibration systems, and the filters (Figure 61), with a high consistency between the 3 countries being evident in the answers. On the other hand, the fan, the tank and the mixer seem to be the parts with the least frequent problems during maintenance and repair. However, in the case of inspection (Figure 62), with the exception of Greece, it seems there is a high differentiation in the answers regarding the most frequent problematic parts, particularly with the tank (tank content gauge) in the case of Italy, and with the power transmission parts in the case of Spain, which use to have rare problems during maintenance and repair, but frequent problems during inspection. This leads to the conclusion that in several cases, these kinds of problems do not force the owners to bring their sprayer for repair, and that maintenance is not performed regularly. Another observation is that in all three countries, pump problems are much less frequent during inspection than during maintenance and repair, leading to the conclusion that problems in the pump are timely repaired when they occur.

3-D orchards

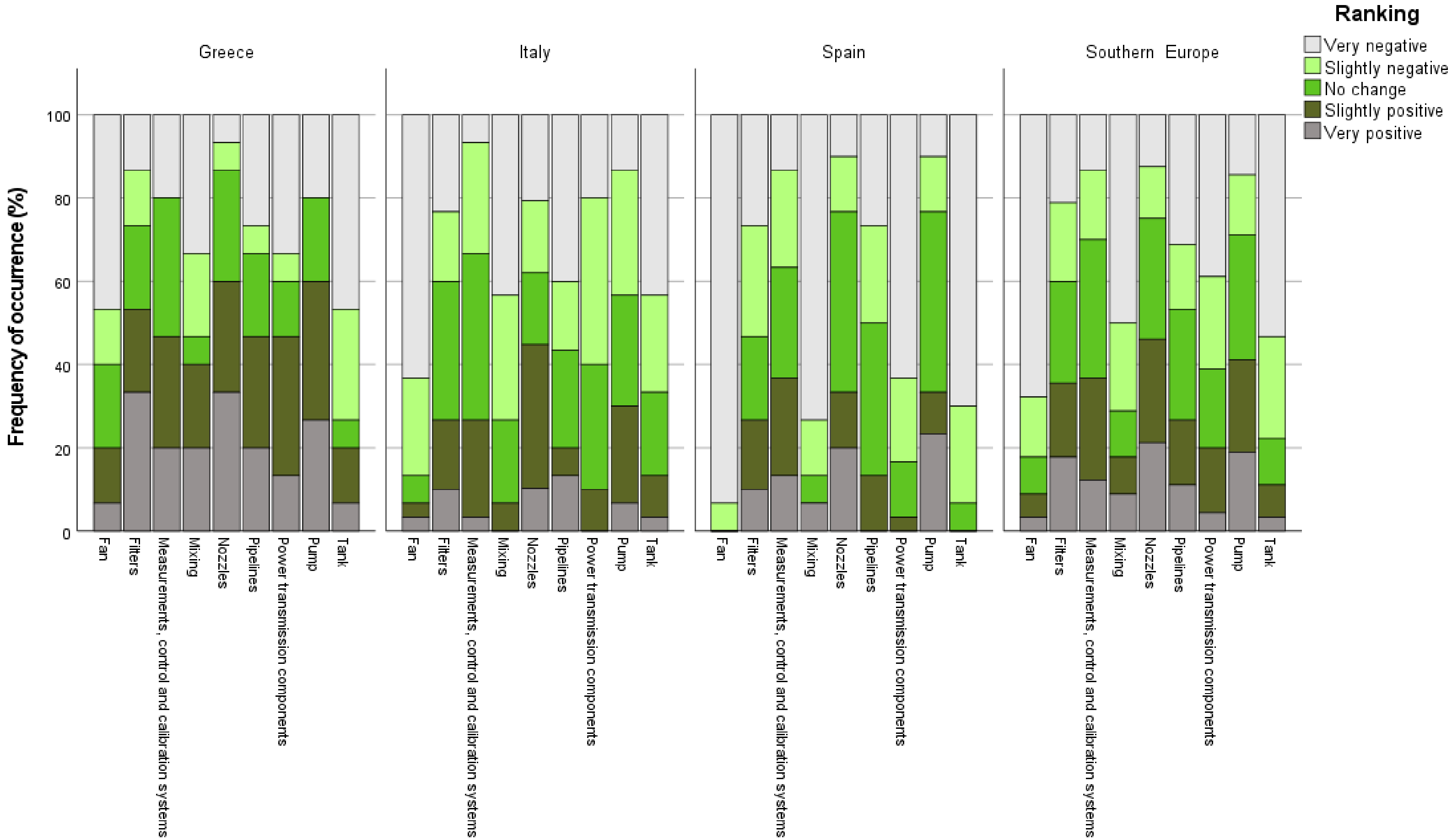

Figure 61. Occurrence for the manufacturers' answers related to the question *How common are major problems in the following parts of the revised/repaired spraying equipment?* Stacked bars show the importance range from "very rare" to "very common" SEU data is an average of the three countries.

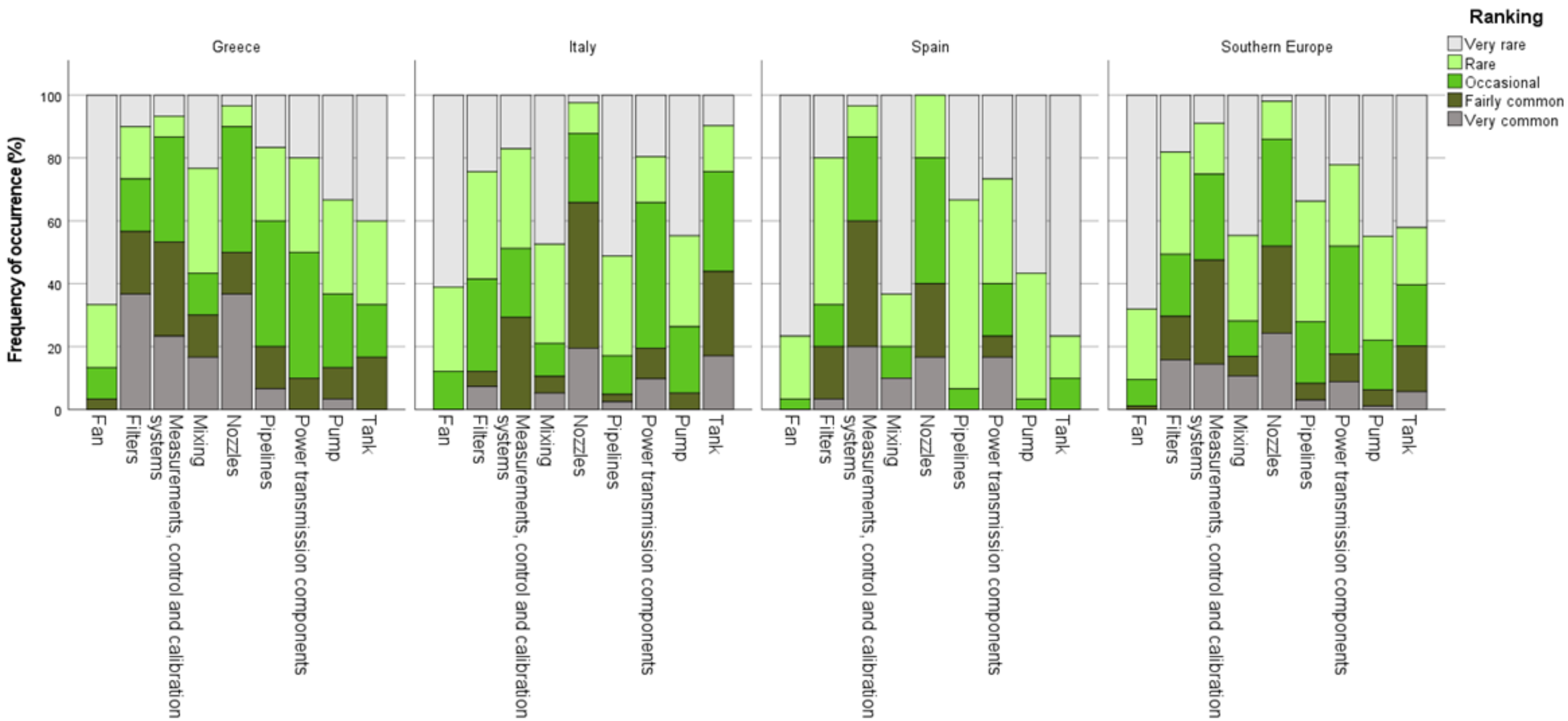

Figure 62. Occurrence for the inspectors' answers related to the question *How common are major problems in the following parts of the inspected spraying equipment?* Stacked bars show the importance range from "very rare" to "very common". SEU data is an average of the three countries.

3-D orchards

Specifically concerning the air system of the sprayers, it can be seen from the plots in Figure 63 that no specific problem stands out, as all three countries interviewed considered that the problems (damages to the fan, fan casing and/or air-flow deflectors, problems with the fan speed, and problems with the adjustment of the deflectors position) are quite rare during maintenance and repair. The same is more or less true in the case of inspections (Figure 64).

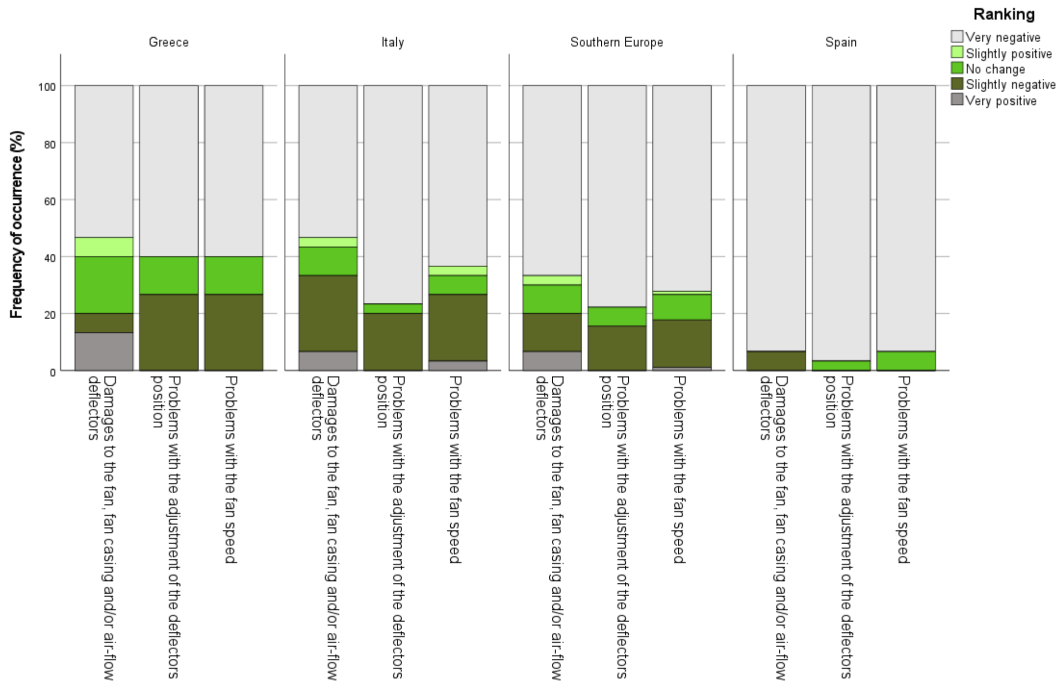

Figure 63. Occurrence for the manufacturers' answers related to the question *How common are the following problems specifically in the air system of the revised/repaired spraying equipment?* Stacked bars show the importance range from "very rare" to "very common". SEU data is an average of the three countries.

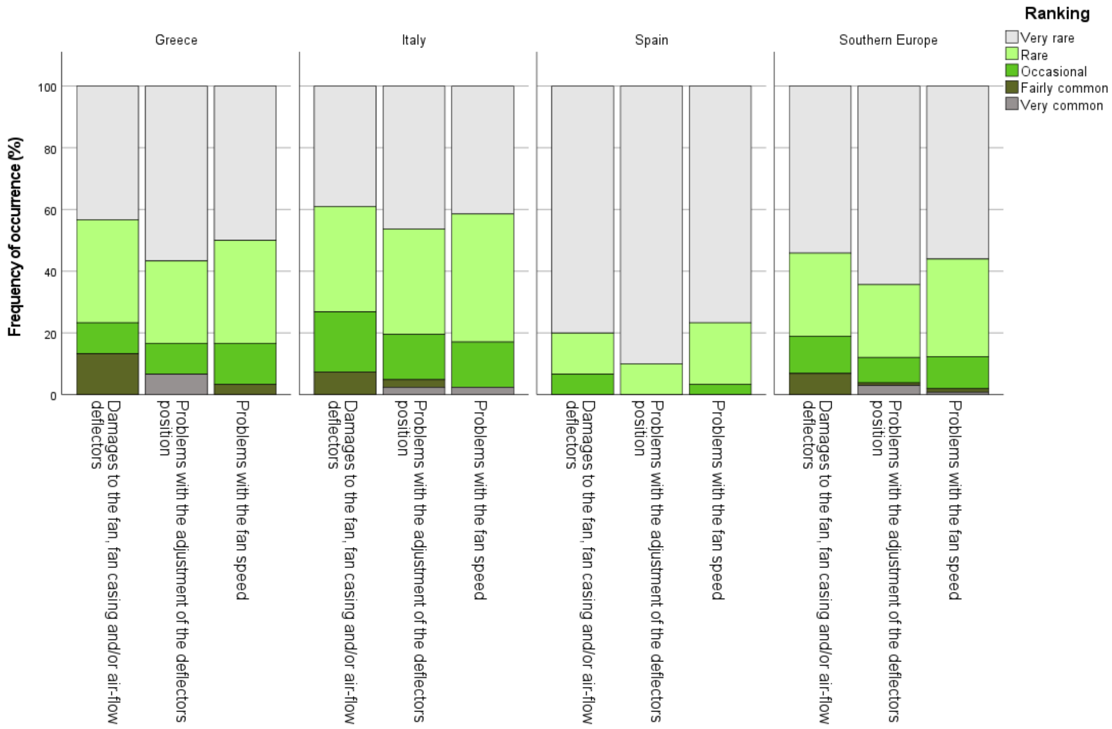

Figure 64. Occurrence for the inspectors' answers related to the question *How common are the following problems specifically in the air system of the inspected spraying equipment?* Stacked bars show the importance range from "very rare" to "very common". SEU data is an average of the three countries.

In the case of equipment parts related to the tank of the sprayer, again, most of the relevant problems are not common, in all three countries, both in the case of maintenance and repair (Figure 65) and during inspection (Figure 66).

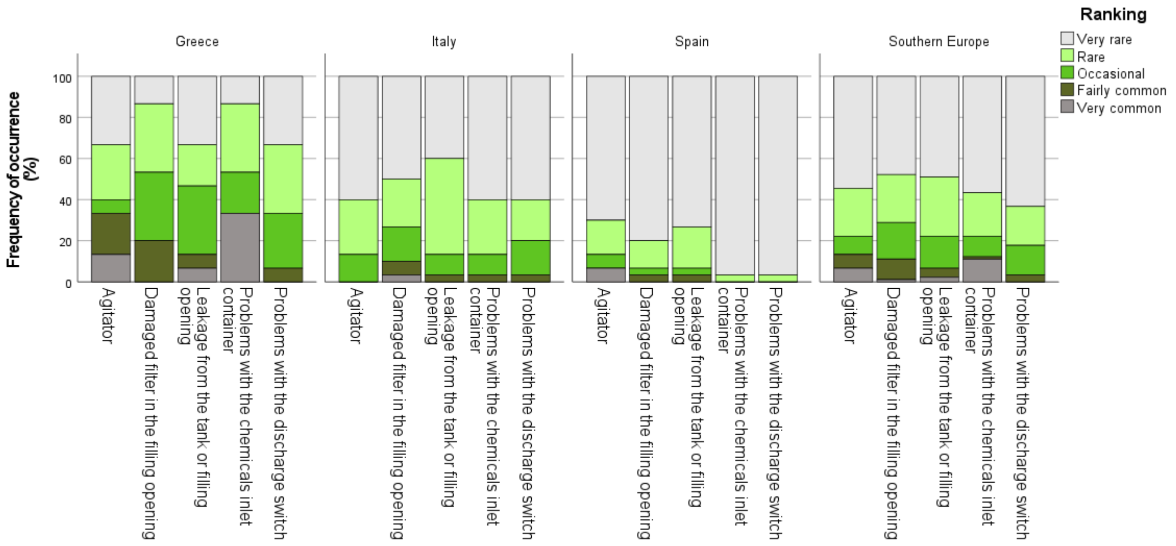

Figure 65. Occurrence for the manufacturers' answers related to the question *How common are the following problems specifically in the tank of the inspected spraying equipment?* Stacked bars show the importance range from "very rare" to "very common". SEU data is an average of the three countries.

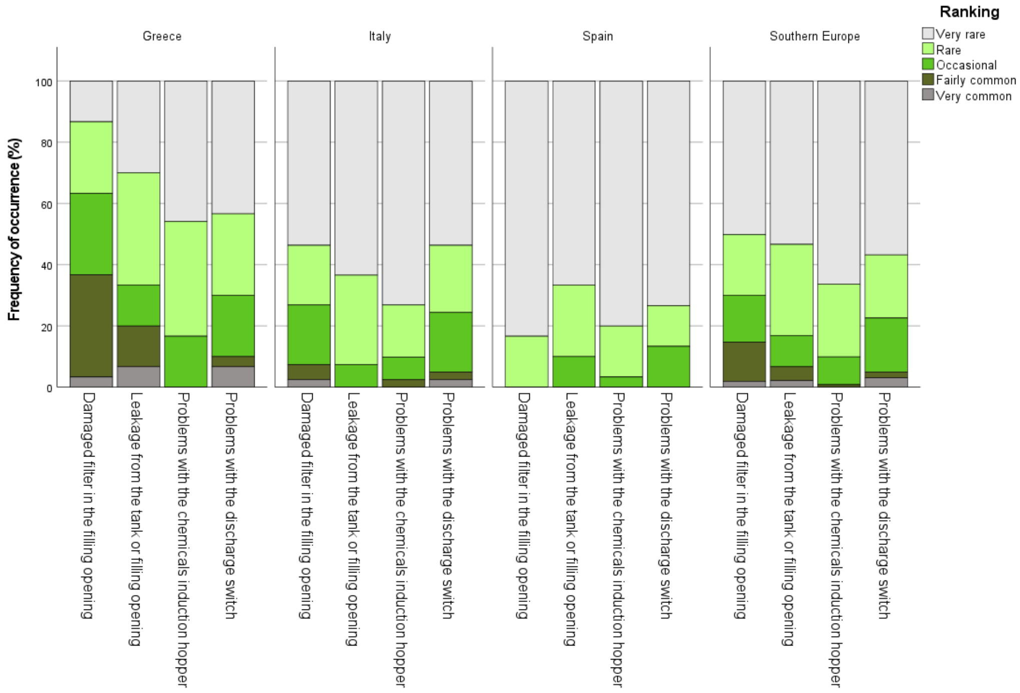

Figure 66. Occurrence for the inspectors' answers related to the question *How common are the following problems specifically in the spray liquid tank of the inspected spraying equipment?* Stacked bars show the importance range from "very rare" to "very common". SEU data is an average of the three countries.

On the other hand, specific problems related to the nozzles are quite common, without any differentiation between maintenance and repair (Figure 67) and inspection (Figure 53). However, there is some differentiation in the case of Italy, as the problem of broken nozzles, which is the most frequent one in Spain and Greece, is rather rare in Italy. Nozzle flow rate problems (either higher or lower than the nominal values) are quite frequent in all three countries, while the problem of non-uniform flow rate is not that common.

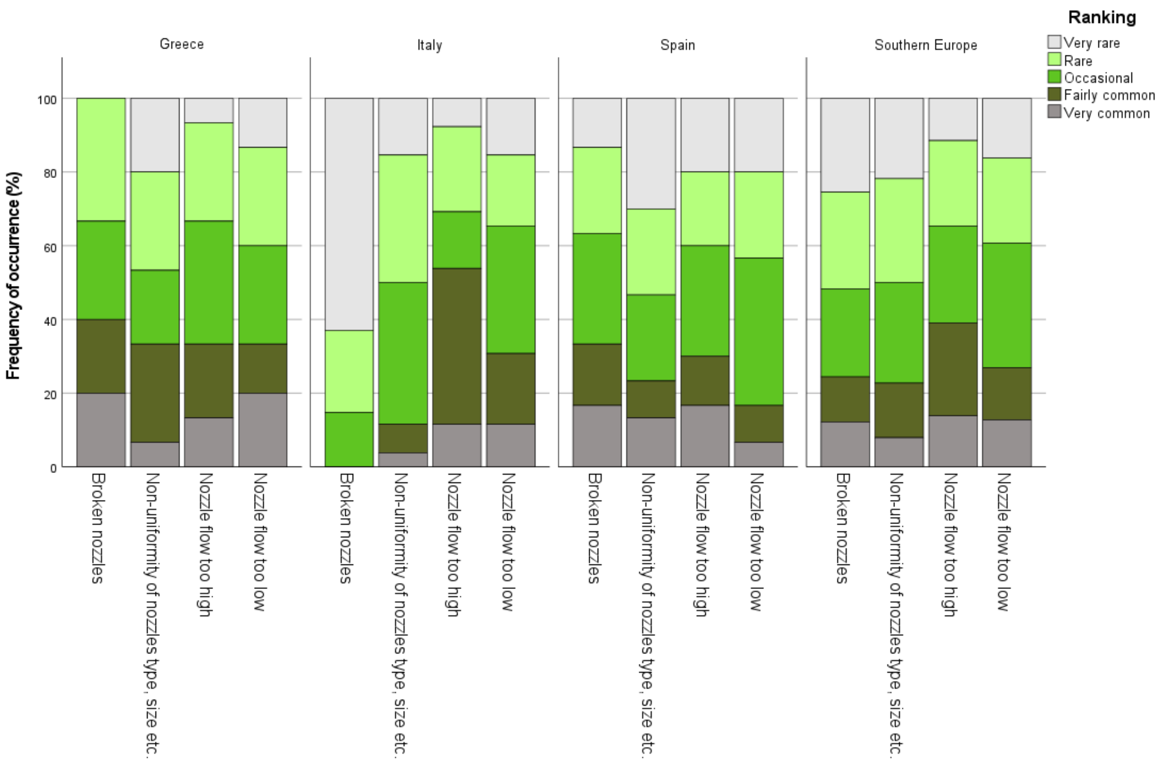

Figure 67. Occurrence for the manufacturers' answers related to the question *How common are the following problems specifically in the nozzles of the revised/repaired spraying equipment?* Stacked bars show the importance range from "very rare" to "very common". SEU data is an average of the three countries.

3-D orchards

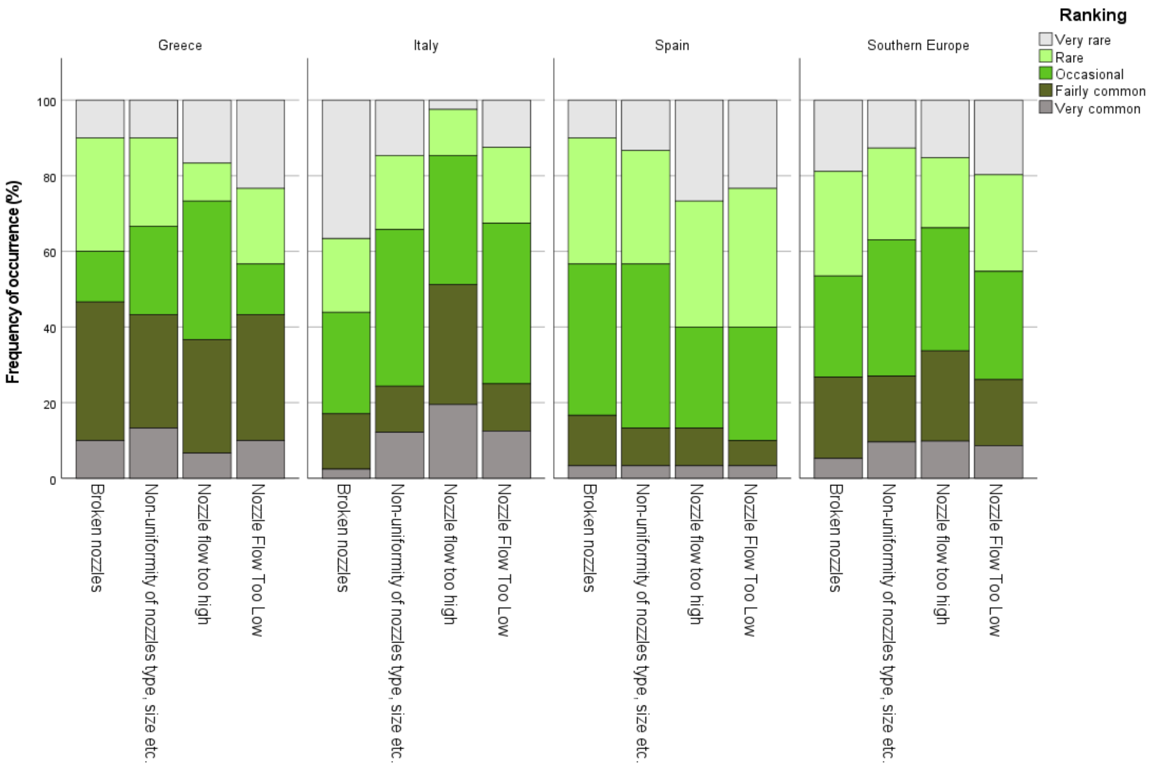

Figure 68. Occurrence for the inspectors' answers related to the question *How common are the following problems specifically in the nozzles of the inspected spraying equipment?* Stacked bars show the importance range from "very rare" to "very common". SEU data is an average of the three countries.

Regarding specific problems related to the pump, it seems that there is a general agreement among the answers from all three countries that this kind of problems are occasional in the case of maintenance and repair (Figure 69), with pressure problems being the most common in Italy and Greece, and leakage from the pump being the most common in Spain. During inspection, all three problems considered are generally rarer (Figure 70), with an absolute agreement between the three countries about their relevant occurrence.

Finally, concerning the frequency of other equipment problems in specific parts of the sprayers during maintenance and repair and during inspection (pressure gauge problems, solenoid valve problems, and control command problems), it seems that there is an absolute agreement between all three countries in the occurrence, both in the case of maintenance and repair (Figure 71) and in the case of inspections (Figure 72). Pressure gauge problems are quite frequent, while the other two problems considered are from occasional (in Greece) to rare or very rare (in Italy and Spain).

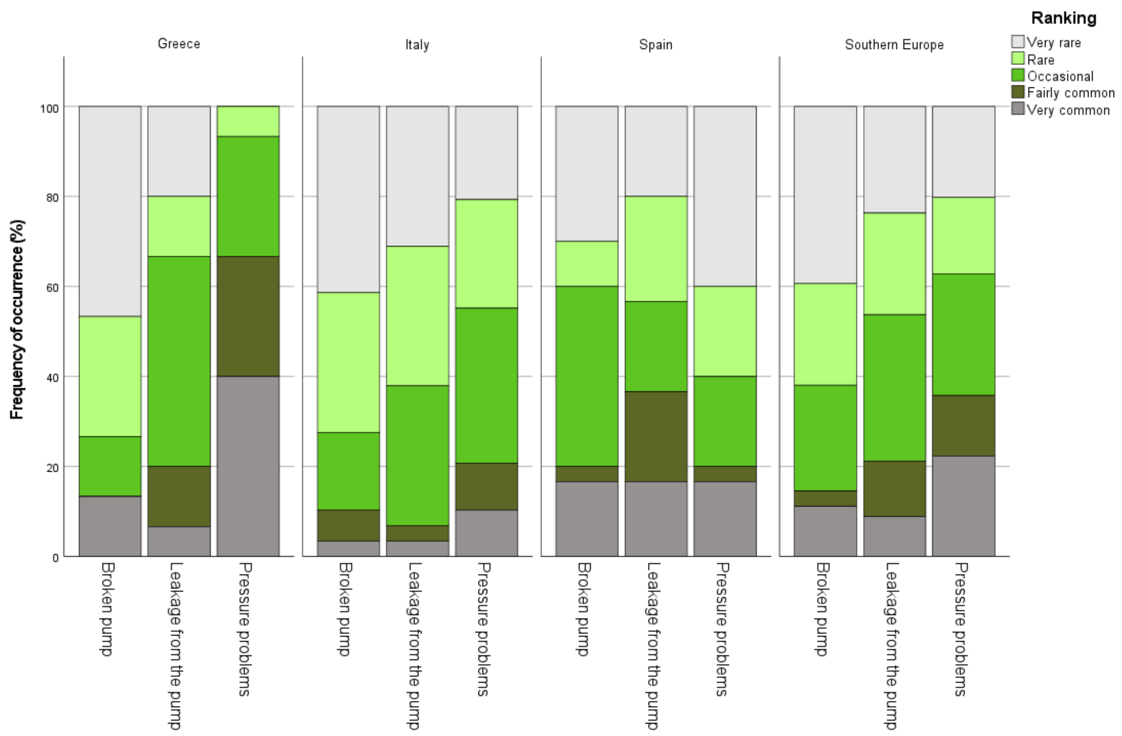

Figure 69. Occurrence for the manufacturers' answers related to the question *How common are the following problems specifically in the pump of the revised/repaired spraying equipment?* Stacked bars show the importance range from "very rare" to "very common". SEU data is an average of the three countries.

3-D orchards

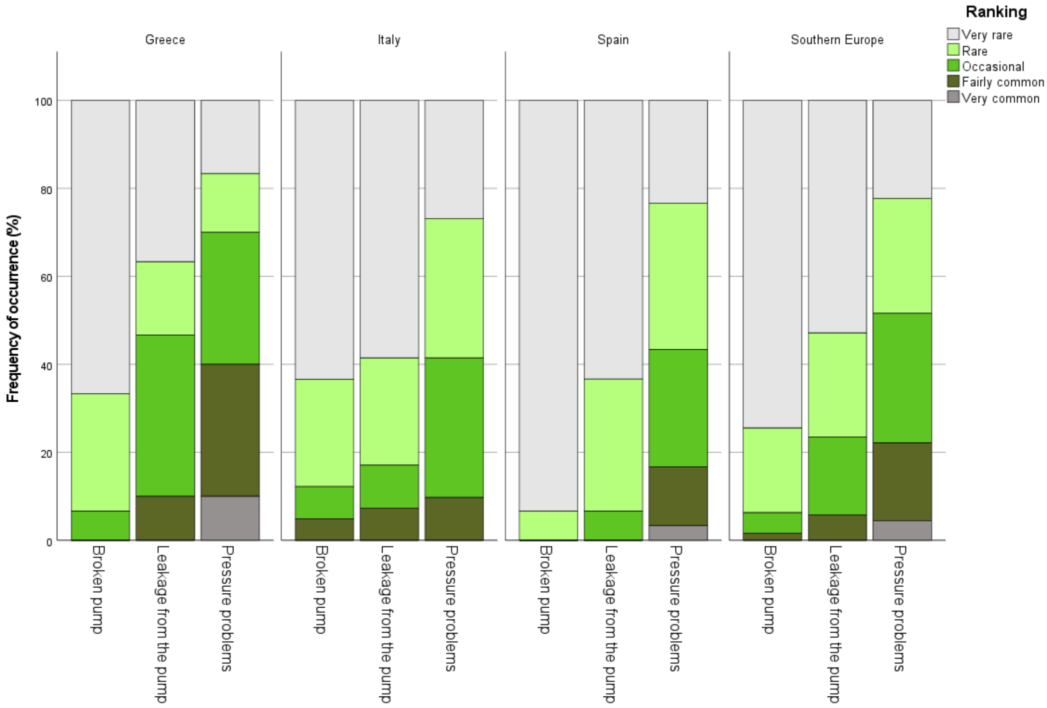

Figure 70. Occurrence for the inspectors' answers related to the question *How common are the following problems specifically in the pump of the revised/repaired spraying equipment?* Stacked bars show the importance range from "very rare" to "very common". SEU data is an average of the three countries.

3-D orchards

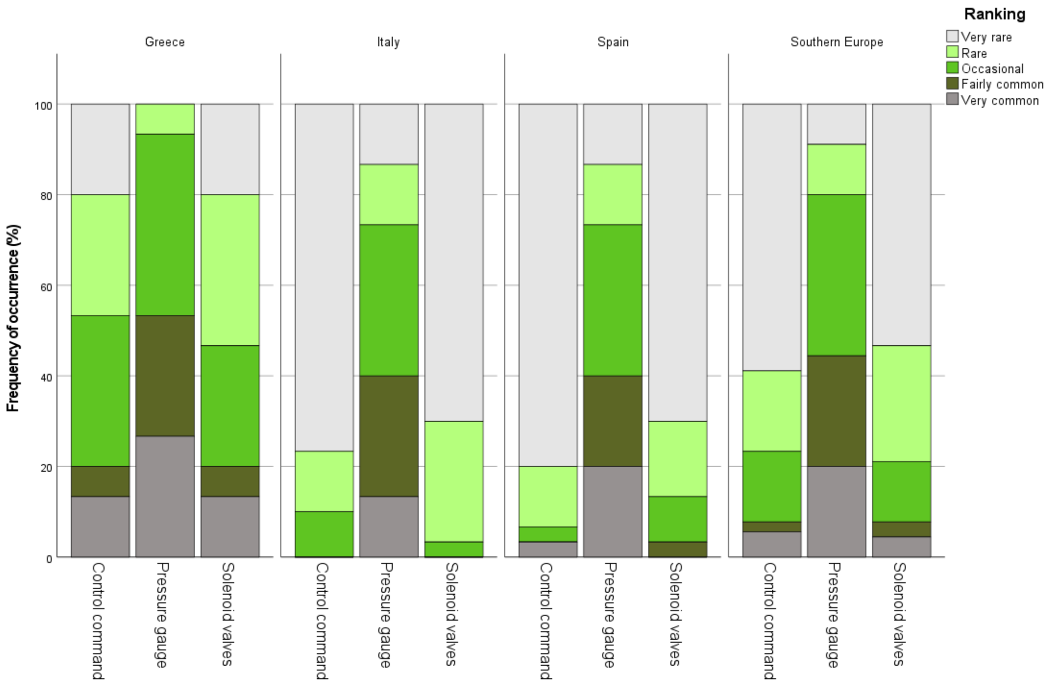

Figure 71. Occurrence for the manufacturers' answers related to the question *What other problems are the most frequent in spraying equipment?* Stacked bars show the importance range from "very rare" to "very common". SEU data is an average of the three countries.

3-D orchards

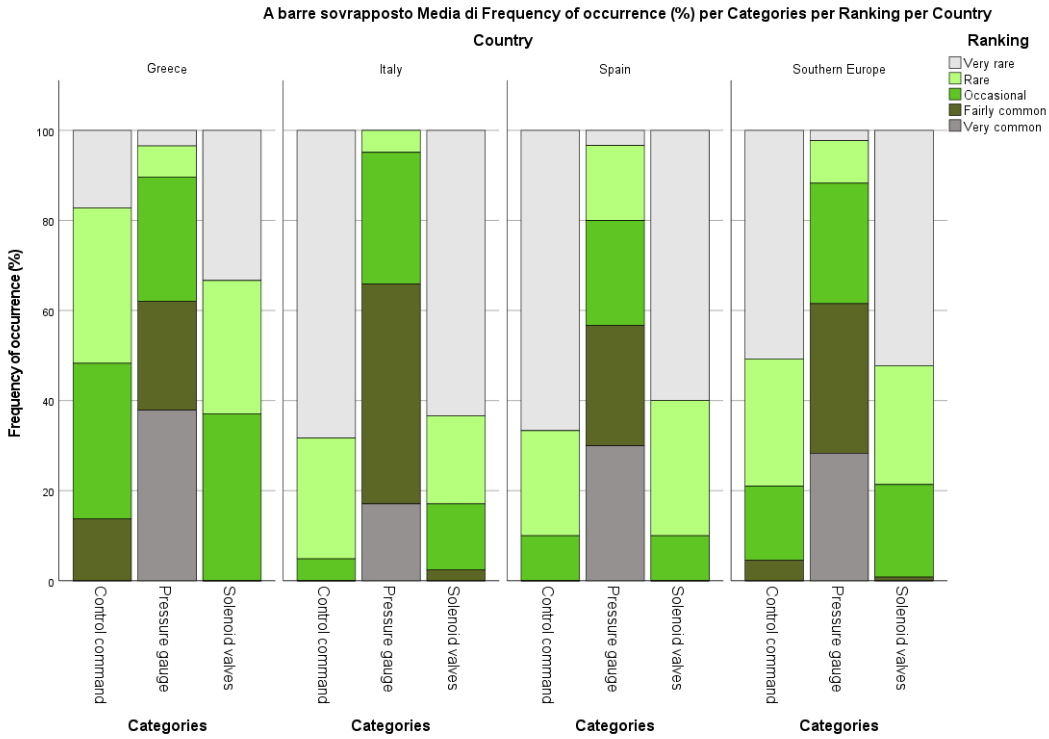

Figure 72. Occurrence for the inspectors' answers related to the question *What other problems are the most frequent in spraying equipment?* Stacked bars show the importance range from "very rare" to "very common". SEU data is an average of the three countries.

3.4.3 Topic C: Spray Drift and Use of Techniques for its Reduction

This section shows the answers to the questions from the survey related to the drift and the use of techniques and tools for its reduction carried out to the 3 target groups, farmers/technicians, sprayer manufacturers and sprayer inspection stations.

Generally, the majority of farmers and technicians declared to know what drift is (Figure 73). Comparing the answers between countries, in Italy the percentage of farmers knowing the drift concept is the highest, independent of the crop, followed by Spain, meanwhile in Greece the declared knowledge is a little bit lower. Comparing the answers between farmers of different crops, it can be observed that more than 90% of the farmers of nuts, stone fruits and oranges know about drift, in olives the percentage is a little bit smaller (around 85%) and in vineyards the percentage is the lowest, around 80%.

3-D orchards

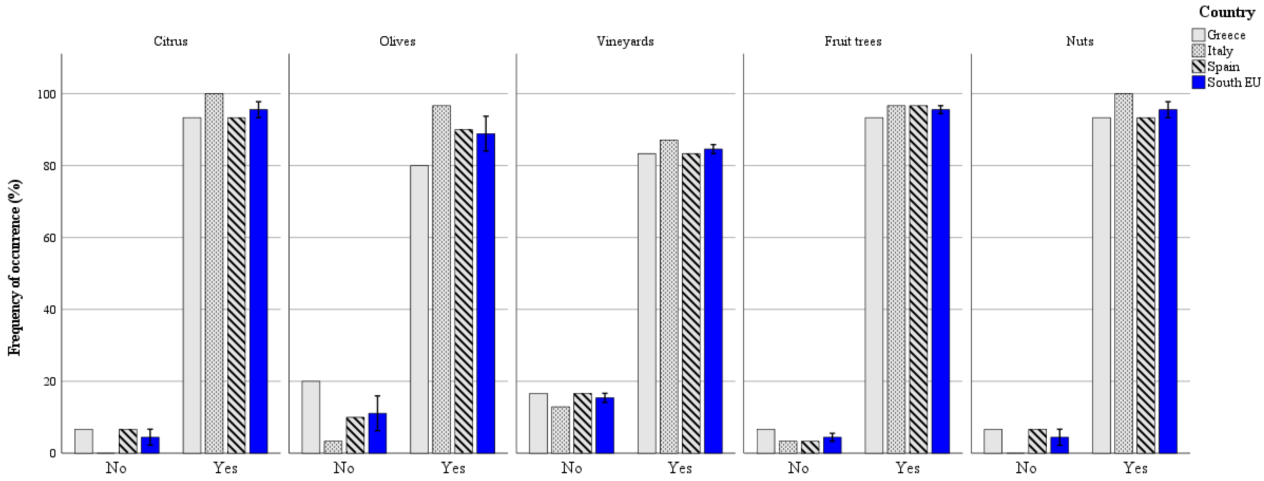

Figure 73. Occurrence for the farmers/technicians' answers related to the question *Do you know what is spray drift?*

When farmers/technicians were asked if they were concerned about drift during plant protection products (PPP) applications, the answers followed the same trend as for the drift concept question (Figure 74). The drift concern is high (80-90%) although a little bit lower than its knowledge. Italy is the country more concerned, followed by Spain and Greece. Also, in general, the growers of vineyards for the 3 SEU countries showed lower concern about drift compared to the farmers of the other crops, except for olive crops in Greece.

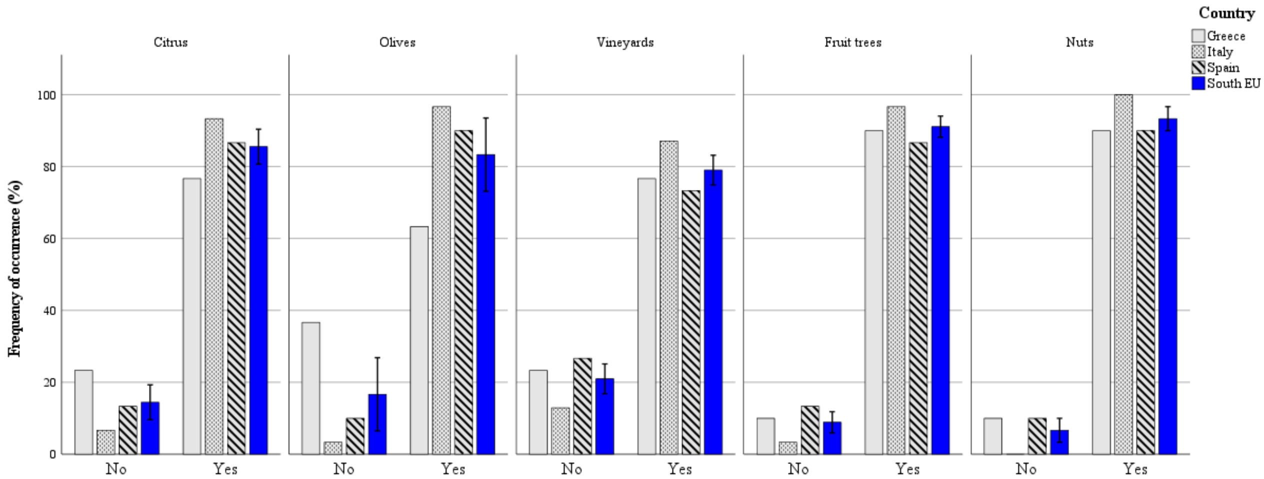

Figure 74. Occurrence for the farmers/technicians' answers related to the question *Are you concerned about spray drift during PPP application in your field?*

3-D orchards

The percentage of farmers/technicians familiar with spray drift reduction techniques (SDRT) is between 65 and 90% (Figure 75). Spanish farmers, independent of the crop, declared to be the most familiar to SDRT (80-100%), followed by Italian farmers (75-90%). However, the familiarity of Greek farmers is lower and depends on the crop; in citrus is around 82%, in nuts around 63%, in olives, vineyards and stone fruits around 50%.

Comparing between crops, again, the vineyard farmers in general are the least familiar with SDRT.

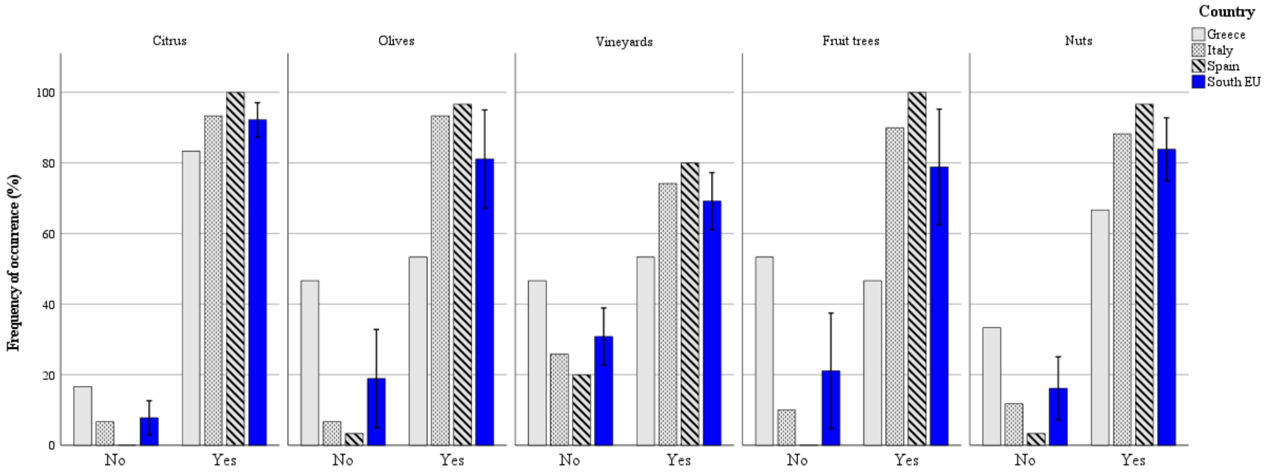

Figure 75. Occurrence for the farmers/technicians' answers related to the question *Are you familiar with any spray drift reducing techniques?*

In general, the range of importance for using SDRT was similar between farmers/technicians of different crops and between the 3 SEU countries (Figure 76). The most important reasons declared were the reduction of human risk and the protection of the environment. In second degree of importance were the following reasons: reduction of PPP consumption, reduction of PPP residues on products and the protection to the neighbours. The least important reasons were: to comply with regulations and to increase sales.

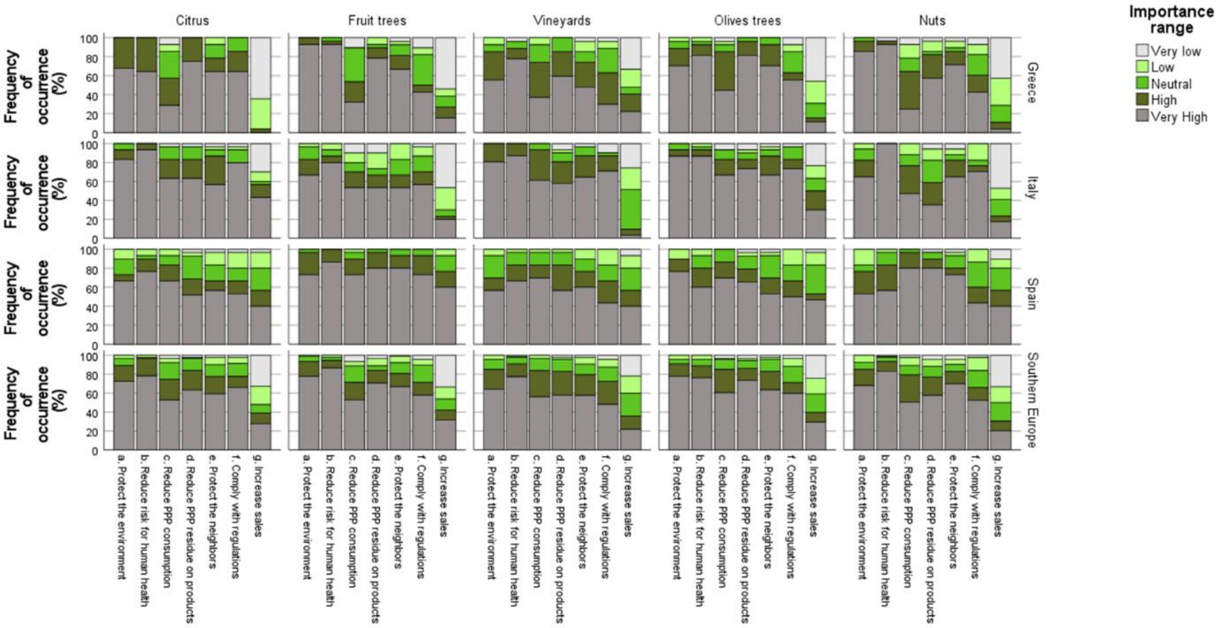

Figure 76. Occurrence for the farmers/technicians' answers related to the question *How do you rate the importance of the following reasons for using spray drift reducing techniques?* Stacked bars show the importance range from "very low" to "very high". SEU data is an average of the three countries.

Generally, between 55% and 70% of farmers declared to use drift reduction nozzles (DRN) in their sprayers (Figure 77). Farmers in Greece report making greater use of DRN in all crops except olives than Spanish and Italian farmers, unexpectedly after observing the answers of the previous questions about drift knowledge and concern. The use of DRN is similar between Italian and Spanish farmers except in vineyards where the use of DRN by Spanish farmers (62%) is much higher than for the Italian farmers (28%). In the comparison between crops, the greater use of DRN in stone fruit and nut trees is notable, on average 70%.

3-D orchards

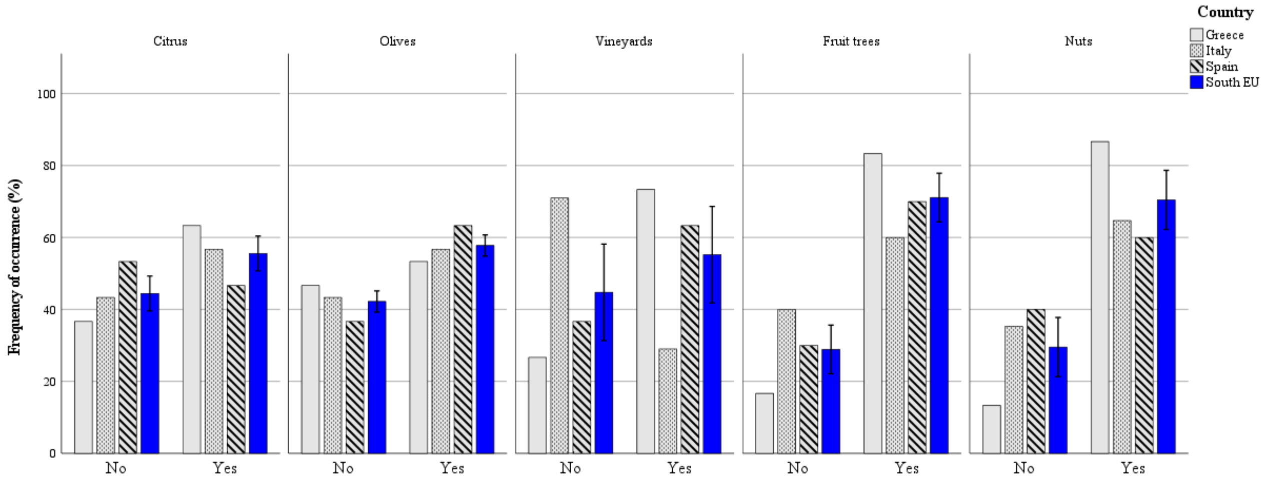

Figure 77. Occurrence for the farmers/technicians' answers related to the question *Do you use drift-reducing nozzles in your spraying equipment?*

Air deflectors of airblast sprayer are used by around 70% of farmers (Figure 78). As for DRN, in general Greek farmers make the highest use, followed by Spanish farmers. In this case, differences between crops are not remarkable.

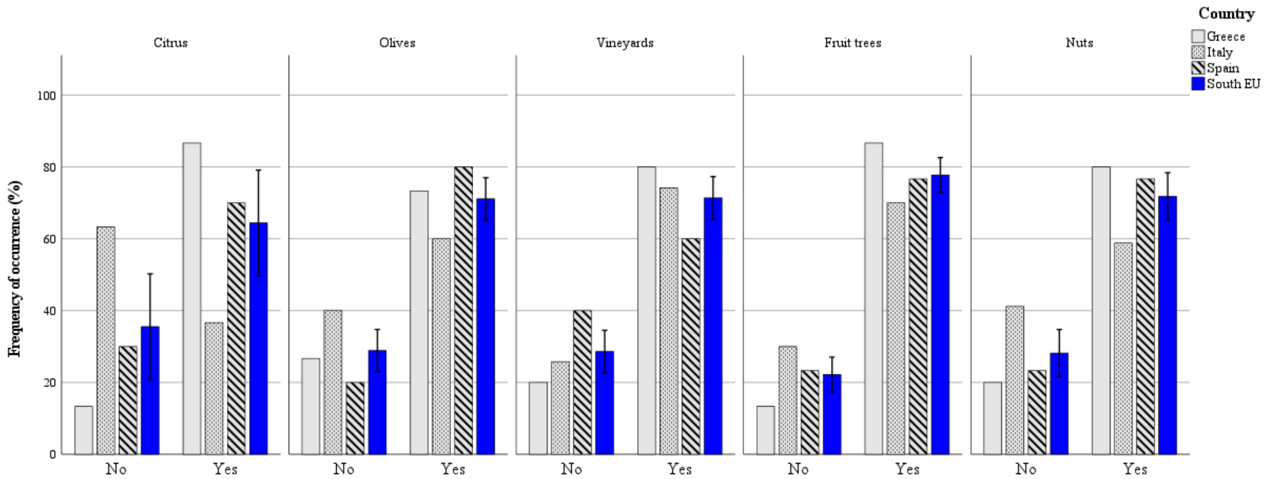

Figure 78. Occurrence for the farmers/technicians' answers related to the question *Do you use these deflectors to direct the spray to the canopy and avoid spraying above the trees/plants*?

More than 80% of farmers/technicians declared to switch off nozzles in specific situations to reduce spray drift independent of the crop and country (Figure 79).

3-D orchards

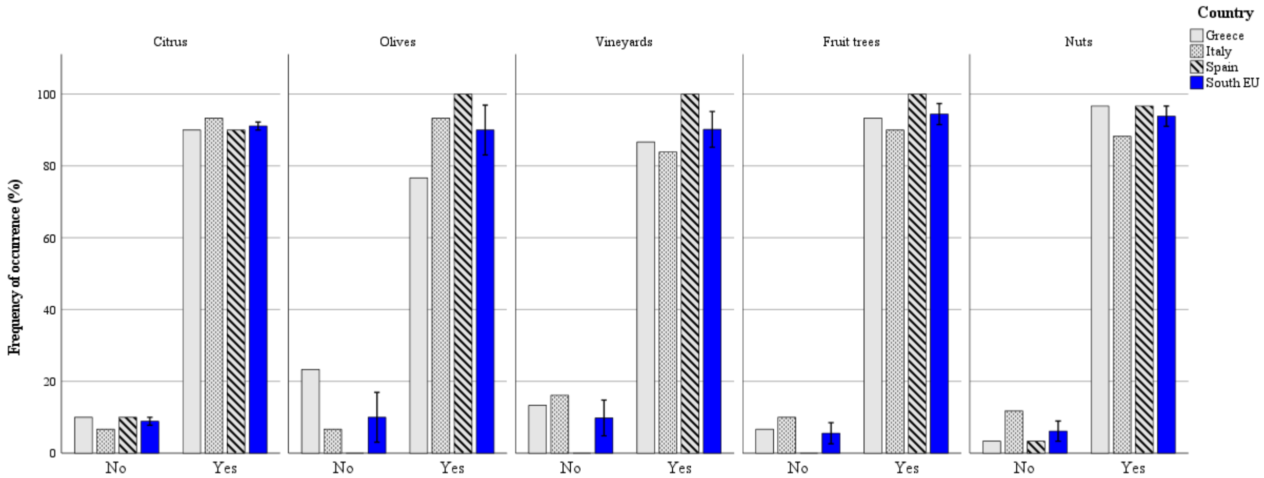

Figure 79. Occurrence for the farmers/technicians' answers related to the question *Do you swich-off/close specific nozzles in specific situations (i.e., proximity to water bodies, houses.., high wind speed, etc), to reduce spray drift?*

According to the manufacturers, DRN is the spray drift reduction technique (SDRT) mostly demanded by the customers for the 3 SEU countries, followed by the air deflectors or adjustable air spouts (Figure 80). The third SDRT more demanded differs between countries: in Greece it is the precision spraying, while in Italy and Spain is the Automatic variable rate based on forward speed.

According to the Sprayer Inspection Stations, the SDRT found in the sprayers coincides with the most demanded ones to the manufacturers (Figure 81), and also with the frequency of farmers report using SDRT when they have them installed on the sprayer (Figure 82).

3-D orchards

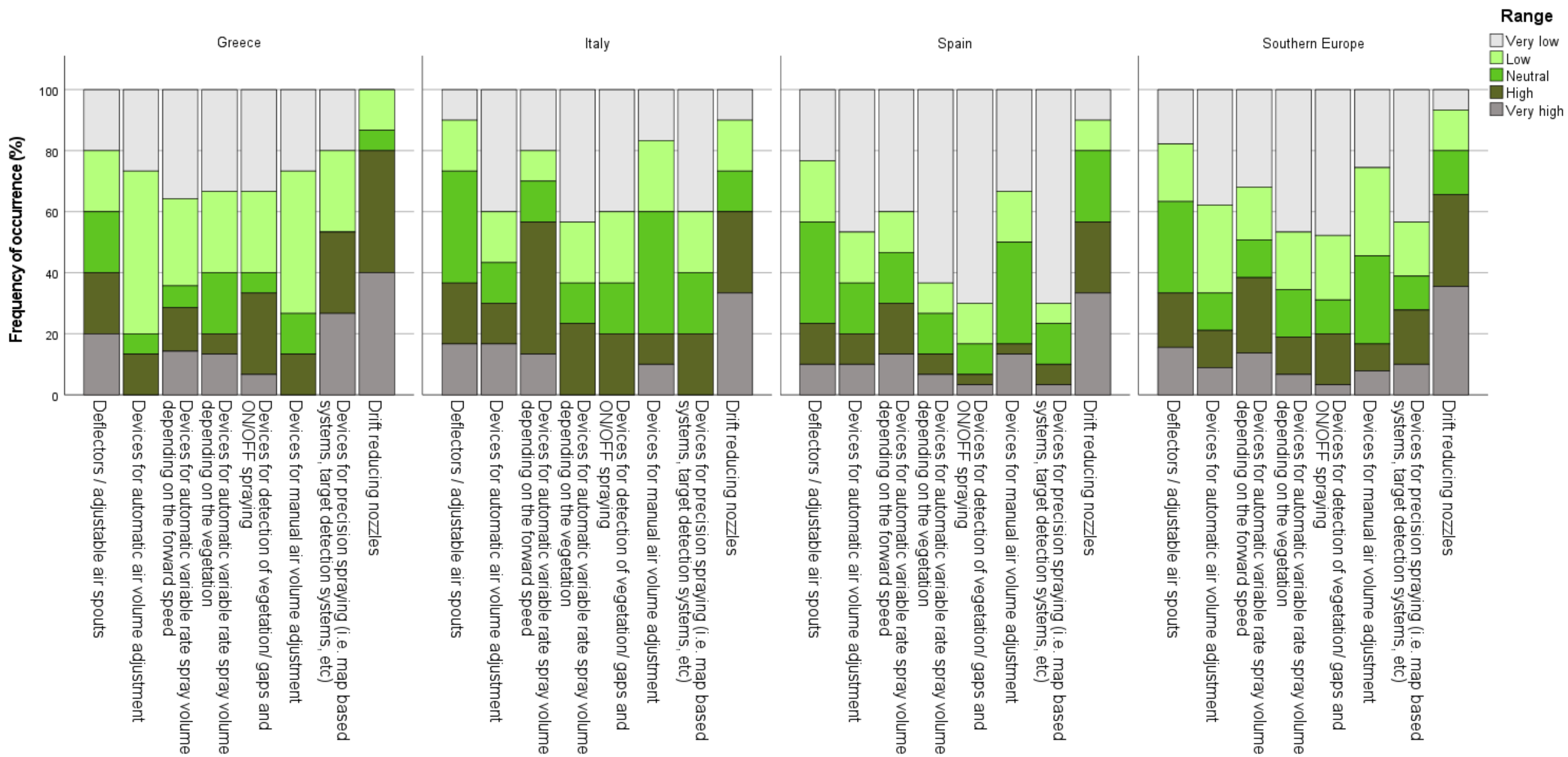

Figure 80. Occurrence for the manufacturers' answers related to the question *What is the customers' demand for the following spray drift reducing techniques in the marketed spraying equipment?* Stacked bars show the importance range from "very low" to "very high". SEU data is an average of the three countries.

3-D orchards

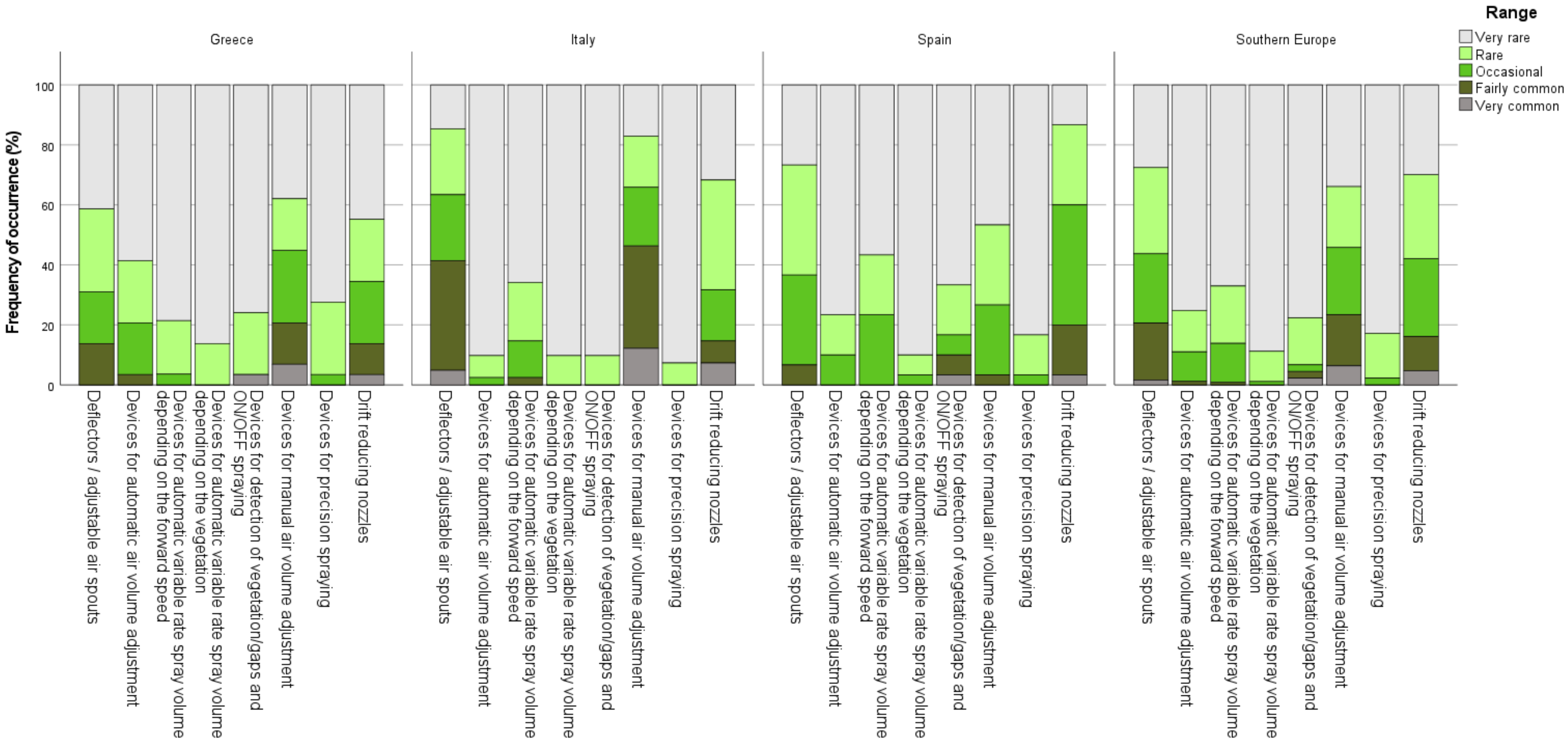

Figure 81. Occurrence for the inspectors' answers related to the question *How commonly are the following spray drift reducing techniques found in the inspected spraying equipment?* Stacked bars show the importance range from "very rare" to "very common". SEU data is an average of the three countries.

3-D orchards

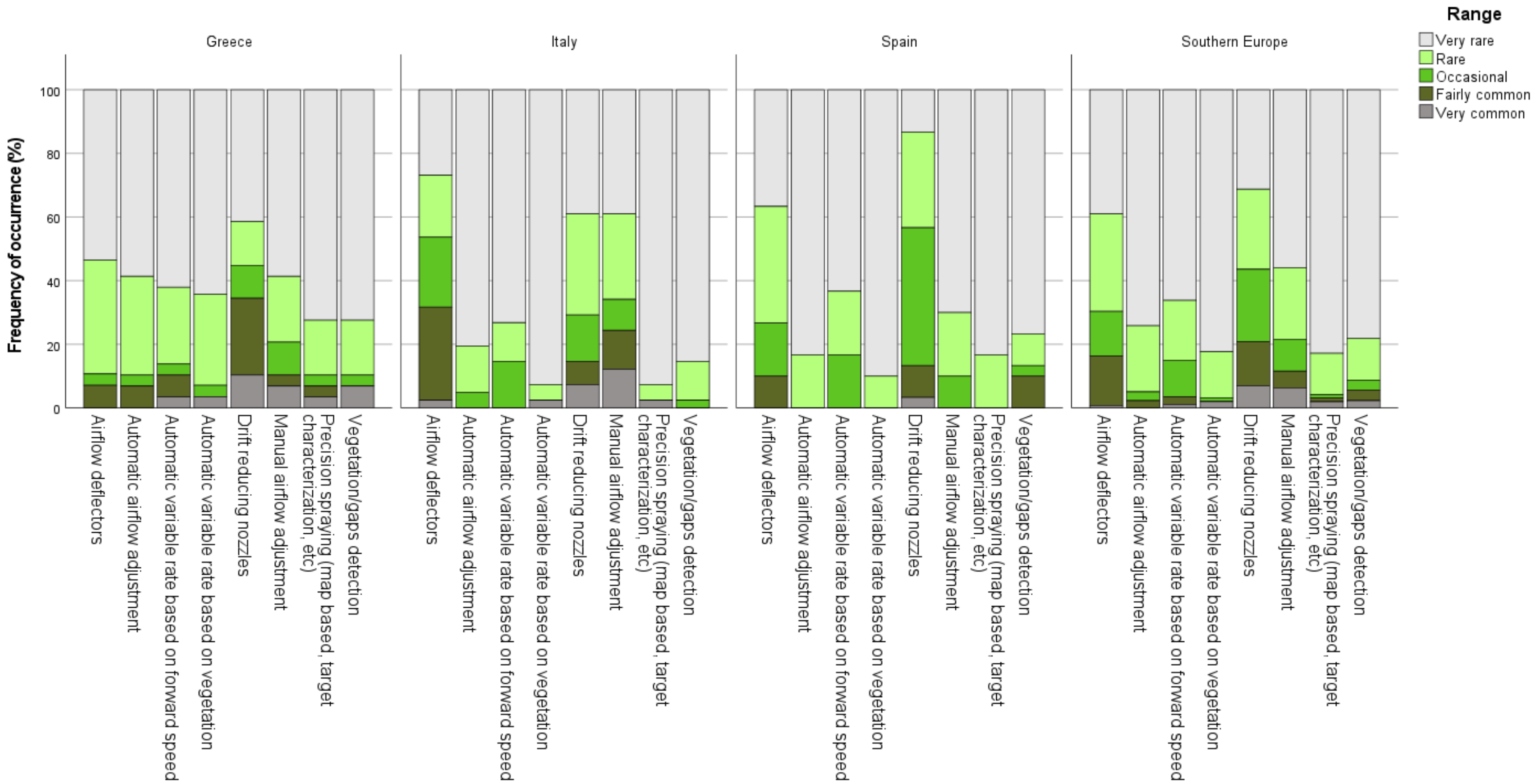

Figure 82. Occurrence for the farmers' answers related to the question *How commonly the users report they use the following spray drift reducing techniques when they have them installed in the inspected spraying equipment?* Stacked bars show the importance range from "very rare" to "very common". SEU data is an average of the three countries.

3-D orchards

In general, around 80% of farmers declared not to receive financial support from national or EU sources, and this is more pronounced in Italy (Figure 83). Furthermore, some differences are found between crops: for 3D-fruit trees, around 40% farmers of Spain and Greece answered that they had financial support.

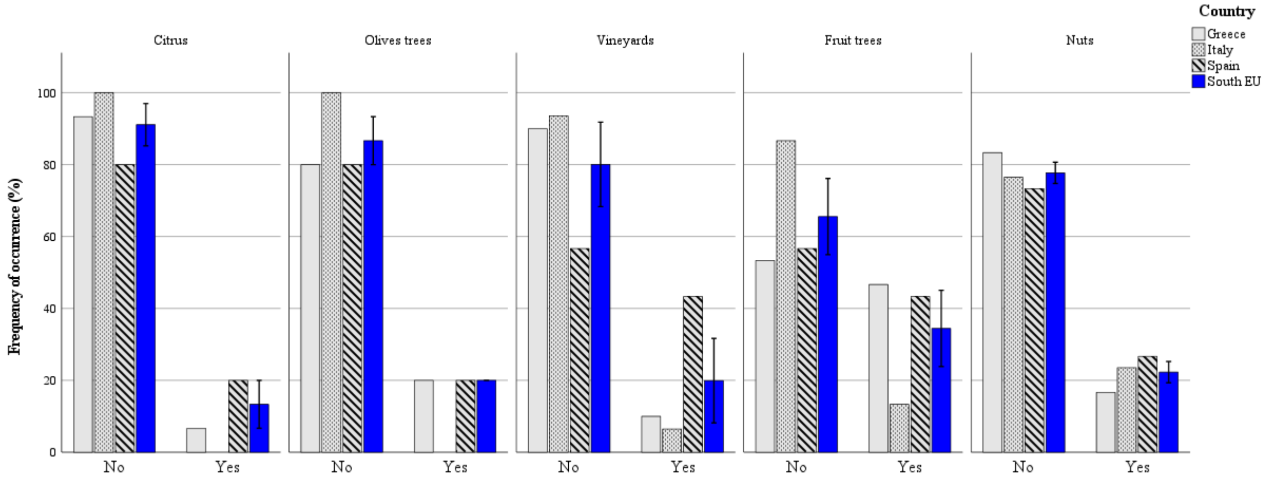

Figure 83. Occurrence for the farmers' answers related to the question *Have you received any EU or national financial support for the adoption of any kind of spray drift reducing techniques for your spraying equipment or for buying new environment-friendly sprayers?*

Regarding the questions about the use of other management practices that help to reduce spray drift, 50% of farmers reported that they use spray additives, and this is more frequent in citrus and fruit trees and less in vineyards (Figure 84). More than 50% of Spanish farmers, independent of the crop, allow to grow vegetation on the field boundaries to reduce spray drift, Italian farmers do that but in lower percentage and there are differences between crops, in olives, vineyards and nuts around 50% but in citrus around 40% and in fruit trees around 30%, meanwhile Greek farmers do not allow to grow vegetation on the field boundaries in citrus, the practice is very scarce in olives, vineyards and fruit trees but in nuts is around 45% (Figure 85). The presence of windbreaks on field boundaries is scarce in general, on average less than 15% (Figure 86). The presence of hail nets over the orchards is even lower, more than 95% of orchards are not covered by hail nets except in the case of fruit trees where around 25% of orchards are covered (Figure 87).

3-D orchards

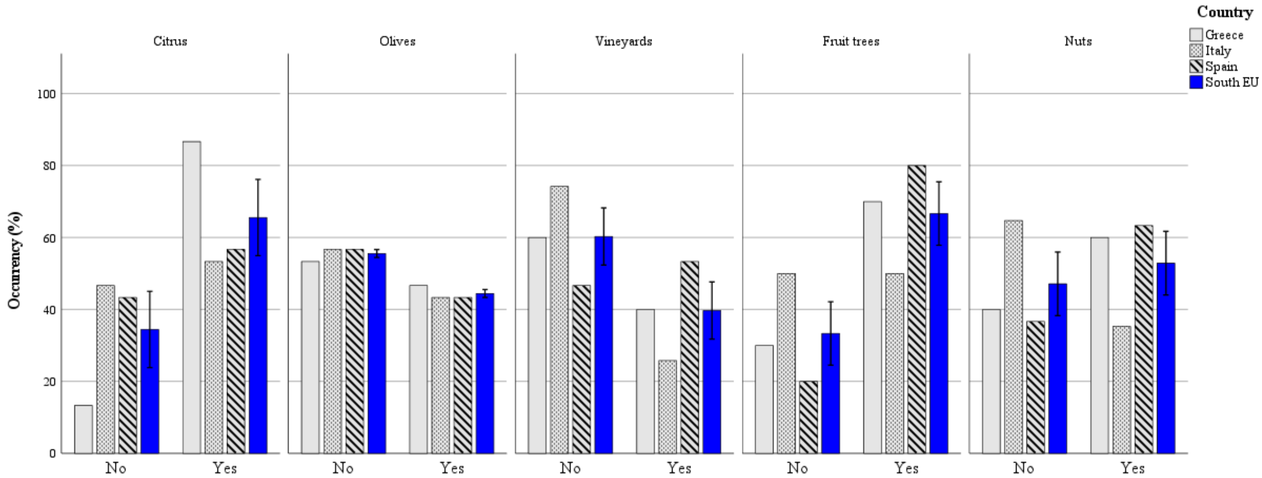

Figure 84. Occurrence for the farmers' answers related to the question *Do you use spray additives that reduce spray drift?*

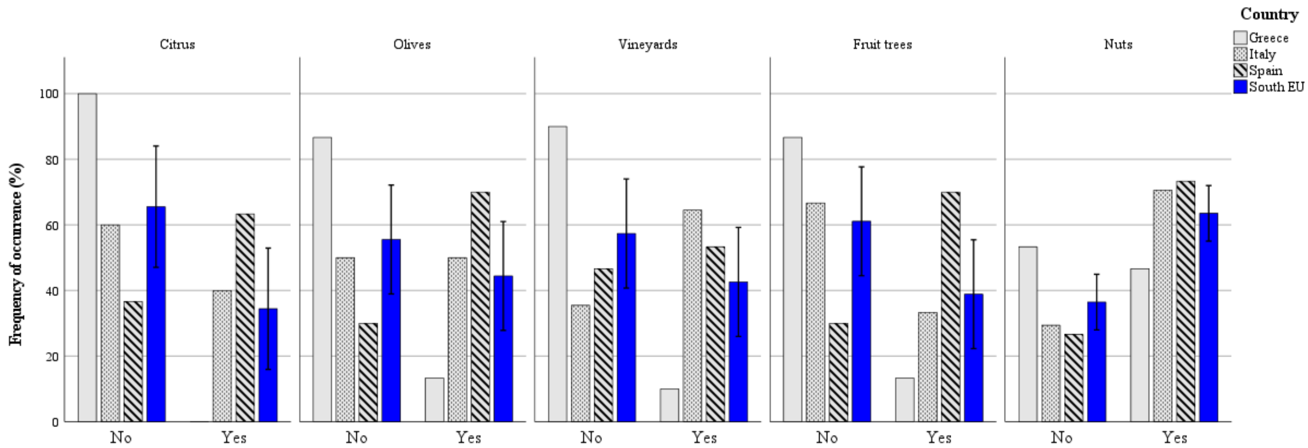

Figure 85. Occurrence for the farmers' answers related to the question *Do you allow vegetation to grow on the field boundaries to reduce spray drift into neighbouring fields or sensitive areas?*

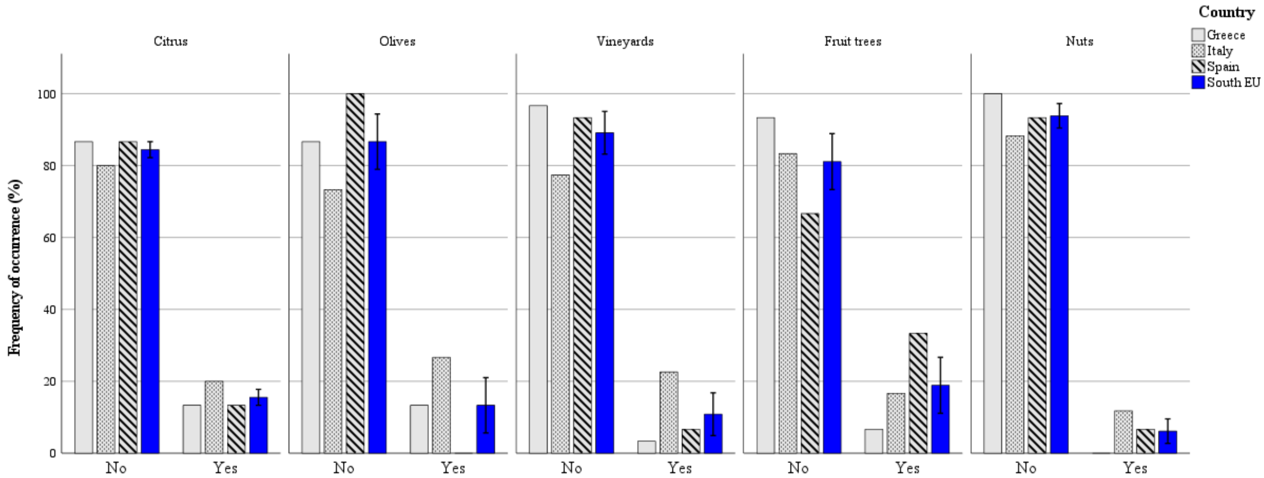

Figure 86. Occurrence for the farmers' answers related to the question *Do you have windbreaks on the field boundaries?*

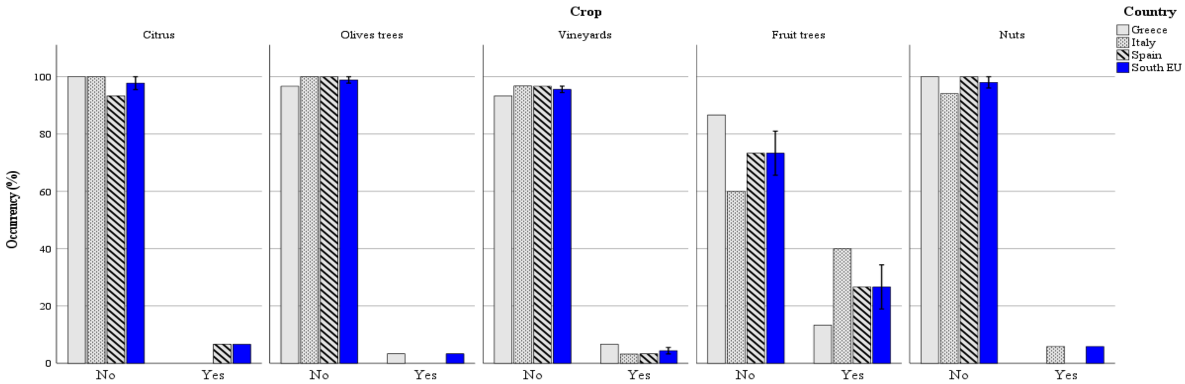

Figure 87. Occurrence for the farmers' answers related to the question *Do you have hail nets over your fields?*

When the growers were asked if they take into consideration safety distance from sensitive areas, the answers depended on the country and crop. In general, the majority of Spanish farmers said yes (>95%) but, because of the fact that nobody answered "not applicable", maybe this result is not that reliable, as can be observed for Italian and Greek farmer answers, where about 40% of citrus growers declared "not applicable", and around 25-30% in the case of olives and fruit trees (Figure 88).

3-D orchards

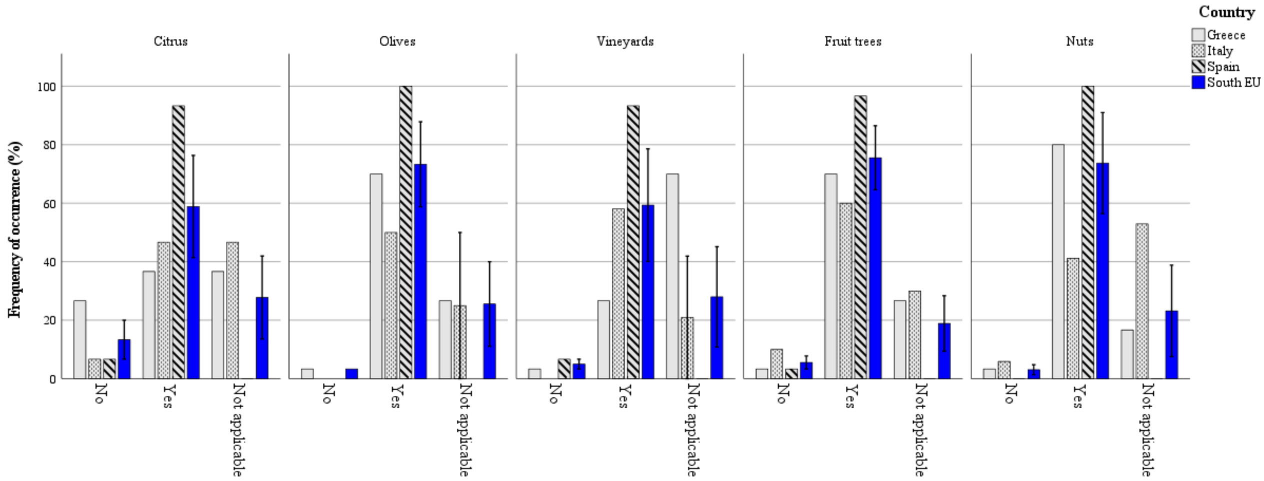

Figure 88. Occurrence for the farmers' answers related to the question *During spraying, do you take into consideration safety distances from water bodies, houses, hospitals, schools, parks etc.?*

A similar trend is observed in the answers about the adoption of buffer zones; the majority of Spanish farmers, more than 90%, declared "yes" but none "not applicable". Meanwhile, between 10 and 30% of Italian and Greek farmers, depending on the crop, indicated "not applicable". Except in fruit trees and nuts crops, around 50% of Greek farmers reported that they do not adopt buffer zones (Figure 89).

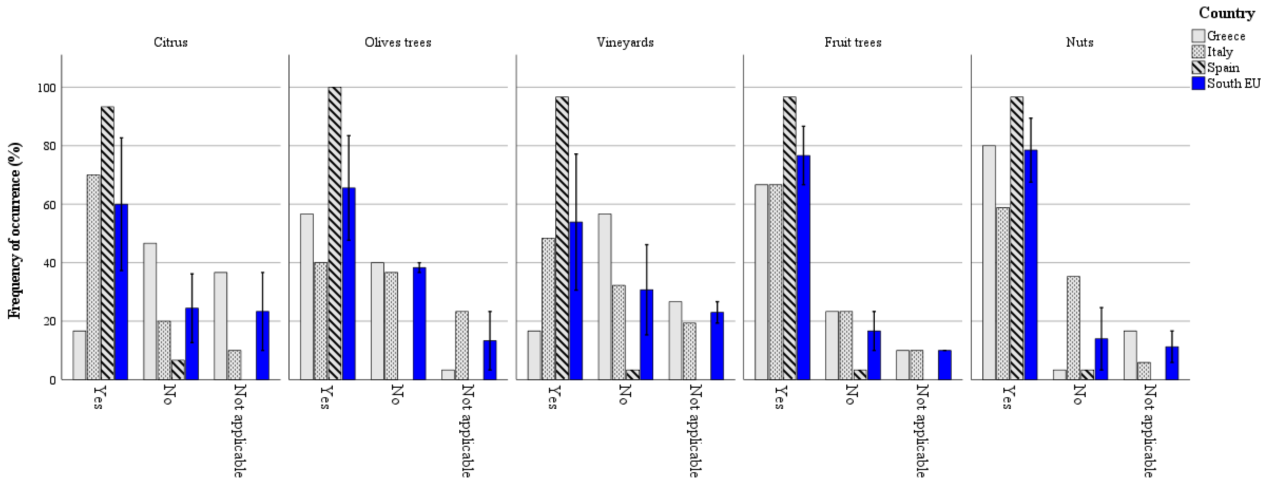

Figure 89. Occurrence for the farmers' answers related to the question *Do you adopt a buffer zone if the spraying is done near sensitive areas (organic fields/surface water/irrigation channels etc.)?*

Because weather conditions highly influence spray drift, farmers were asked about which meteorological conditions they consider to check before PPP application. In all crops and countries, rain and wind speed were the parameters more considered, and the temperature was the third in importance (Figure 90).

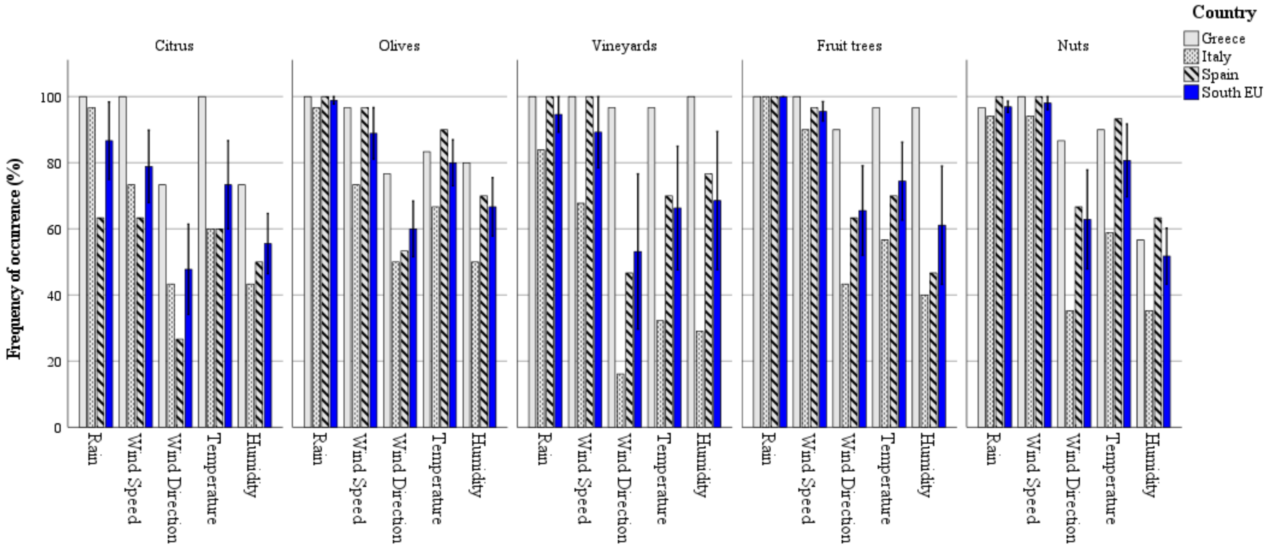

Figure 90. Occurrence for the farmers' answers related to the question *Do you take into account the weather conditions before spraying?*

3.5 Literature search

From the TIM system suggested by EFSA, 3 datasets were obtained:

- The first dataset, which refers to pesticide drift in 3-D crops, produced 136 documents
- The second dataset which refers to pesticide drift and spraying techniques (airblast sprayer, etc..) – without specifying the type of crop, produced 117 documents.
- The final one, which is the combination of the above two, yielded very few results: 5 documents.

After the elimination of double/triple titles, 188 articles remained.

Each partner collected articles through their own systems. After the elimination of double/triple titles, all articles dealing with agriculture in Asia, Africa, Australia, and America were discarded. Then, articles were assessed through title and/or abstract: all articles whose subject was clearly out of scope, were discarded.

The total number of articles remaining after this check was 193. The list is available in Appendix E.1.

After the check of the abstract, the number was reduced to 35 (list available in Appendix E.2).

These articles were analysed with the full manuscripts and the ones referring to the three main crops under assessment (vines, olives and citrus) were selected. After this check, the articles considered suitable for further assessment were 21. Then, the articles were assessed with respect to ISO 22866 requirements (see table of parameters reported in § 2.2.7). The specific assessment for each article is reported in Appendix E.3 for vines, Appendix E.4 for olives and Appendix E.5 for citrus.

After this last screening, 6 articles were identified as relevant: 1 for olive, 3 for vines, and 2 for citrus.

Olives:

- First attempts to obtain a reference drift curve for traditional olive grove's plantations following ISO 22866 (Gil, E., Llorens, J., Gallart, M., Gil-Ribes, J. A., & Miranda-Fuentes, A.) - *Science of the total environment* 2018, 627, 349-360. https://doi.org/10.1016/j.scitotenv.2018.01.229

The goal was to obtain drift curves for olive trees in traditional plantations, following the ISO 22866 requirements. The field trials were carried out in Spain measuring both spray drift ground sediments and airborne spray drift. Drift curves were obtained and differences from existing curves for other crops were explored and emphasised; however, major difficulties in obtaining repeatability of experiments due to the nature of olive trees were discovered, and the need for the update not only of the drift curves, but also of the ISO 22866, to consider the specific characteristics of other crops, was concluded.

Citrus:

- Studies on pesticide spray drift in a Mediterranean citrus area (S.M. Meli, A. Renda, M. Nicelli, E. Capri) - *Agronomie* 2003, 23, 667–672. https://doi.org/10.1051/agro:2003044

According to the authors' statement, the goals of this study were to measure the spray drift in citrus crops in a Mediterranean setting, to evaluate the influence of the main agronomic factors influencing the process, and to assess the suitability of the Ganzelmeier data. Even if weather conditions were reported separately for each trial carried out, data seems reliable. The weather data were not analysed according to the acceptable conditions required by ISO22866: 2005 because the experimental study was conducted before the publication of the standardised method. The trials were carried out in Italy testing two spray application techniques (manual spray lance vs. airblast sprayer) in four different locations; in total eight trials were carried out deriving that trials were not replicated. Even if authors want to assess the suitability of Ganzelmeier curves (Rautmann et al., 2001) for citrus they measure spray drift ground sediment up to 7 m distance from the sprayed area. The total sampled distances are not adequate to capture the total spray drift and therefore to provide a reliable figure about spray drift generated during spray application in citrus. Indeed, it is well known that spray drift can travel long distances in air masses resulting in a consistent amount at larger distances, e.g. at 40 m distance from the applied area (Torrent et al., 2017). Based on these premises, the data reported by authors are not fully comparable with data obtained by other authors strictly applying the ISO22866:2005 methodology (trials conducted before the official publication of ISO22866:2005).

- Comparison between standard and drift reducing nozzles for pesticide application in citrus: Part I. Effects on wind tunnel and field spray drift (X. Torrent, C. Garcerá, E. Moltó, P. Chueca, R. Abad, C. Grafulla, C. Román, S. Planas) - Crop protection 2017, 96, 130-146. http://dx.doi.org/10.1016/j.cropro.2017.02.001

3-D orchards

The goal of this study was to evaluate and to compare spray drift potential and field spray drift from pesticide application in citrus orchards carried out mainly comparing standard nozzles with drift reducing nozzles. The data related to the potential spray drift measurements are not relevant to obtain a reference spray drift curve meanwhile those related to the in-field spray drift measurements are fully relevant. The field trials were carried out in Spain measuring both spray drift ground sediments and airborne spray drift, by applying the standardised methodology ISO22866:2005. Authors compared two spray application technologies (conventional vs. air inclusion nozzles) in two different locations. The trials were replicated five times, and for each replicate a complete report about weather conditions was provided also in relation to the acceptable conditions requested by the ISO22866:2005.

Vines:

- Ground Deposition and Airborne Spray Drift Assessment in Vineyard and Orchard: The Influence of Environmental Variables and Sprayer Settings (M. Grella, M. Gallart, P. Marucco, P. Balsari and E. Gil) - Sustainability 2017, 9(5), 728. https://doi.org/10.3390/su9050728

The goal of this study was to obtain drift curves for the combination for different spray application technologies (e.g. conventional vs. air inclusion nozzles) and sprayer settings (e.g. high vs. low fan airflow rate) in order to quantify the possible drift reduction achieved by the drift-reducing technologies. Furthermore the effect of environmental conditions, especially wind speed, on the spray drift generation for the different technology and settings tested were evaluated. Tests were conducted in Spain measuring both spray drift ground sediments and airborne spray drift. In all cases the weather conditions required by the ISO22866:2005 were accomplished making the spray drift results reliable.

- Toward a new method to classify the airblast sprayers according to their potential drift reduction: comparison of direct and new indirect measurement methods (M. Grella, P. Marucco and P. Balsari) - Pest management science 2019, 75, 2219-2235. https://doi.org/10.1002/ps.5354

The goal of this paper was to compare the spray drift measurements results obtained by applying the standardised methodology ISO22866:2005 with those obtained by applying a new method for the evaluation of potential spray drift by using an ad hoc designed test bench method. Even if the data related to the potential spray drift measurements are not relevant to obtain a reference spray drift curve those related to the in-field spray drift measurements are fully relevant. Indeed, the paper presents results deriving from tests conducted by using the same sprayer with the same technologies and settings as presented in Grella et al., 2017 but tested in different contexts (Italian vineyard) and under different conditions (e.g. vineyard variety and weather conditions). Also in this case, the weather conditions required by the ISO22866:2005 were fully accomplished making the spray drift results reliable and fully comparable with previous presented in Grella et al., 2017.

- Development and Field Evaluation of a Spray Drift Risk Assessment Tool for Vineyard Spraying Application (G. Bourodimos, M. Koutsiaras , V. Psiroukis, A. Balafoutis and S. Fountas) - Agriculture 2019, 9(8), 181. https://doi.org/10.3390/agriculture9080181

The goal of this paper was to develop and evaluate a spray drift evaluation tool based on an existing model by TOPPS-Prowadis to improve the process of plant protection products' application and to mitigate spray drift for specific meteorological conditions that are determined, based on weather forecast, by reassessing the limits for wind speed and direction, temperature, and air relative humidity set in the tool. The paper reports results for a single sprayer and configuration tested by applying ISO22866:2005 methodology under three different weather conditions categorised by authors as low, medium, and high risk of spray drift. The trials were conducted in Greece measuring both spray drift ground sediments and airborne spray drift. The weather conditions required by the ISO22866:2005 were fully accomplished making the spray drift results reliable.

3.5.1 General comments to the olive, citrus and vineyard cases

In general, the papers above reported and commented are considered reliable because they fully accomplish the standardised methodology reported by the ISO22866:2005 both in terms of field trials layout, sampler types and tracer used to determine the spray drift at different distances from the applied area and also acceptable weather conditions and their measurement frequency (except Meli *at al*., 2003).

Concerning the acceptable weather conditions these are fundamental to define if the measurements reported in the scientific literature are reliable or not; the selected papers report detailed data about weather conditions. In some papers initially considered, and after check discarded, authors reported just a general sentence where they state that the weather conditions during the trials accomplish the requirements set by ISO22866:2005. This type of statement is not sufficient for a comprehensive evaluation of spray drift data. Indeed, for a comprehensive evaluation of data reliability of drift study, weather conditions measured at the time of application need to be reported for each replicate in a dedicated table; in this regards, also the ISO22866:2005 specify that a complete report about weather conditions is part of the protocol.

To check that environmental conditions during the field trials met ISO22866:2005 requirements, the following needs to be reported for each replicate: (a) number of wind measurements less than 1 m/s (outliers) must not exceed 10%; (b) mean wind direction must be perpendicular to the sprayer track in order to create downwind conditions for the area where spray drift samplers are placed; (c) frequency of wind direction > 45° to the spray track (not centred) must not exceed 30%; and (d) mean air temperature must be between 5 °C and 35 °C.

Even if the spray drift data derived from reliable selected literatures are not enough to build a strong spray drift models/curves. For the vineyard case, Grella *et al*. (2017) attempt a comparison of their results with the reference spray drift curves (Rautmann *et al*., 2001) (Figure 91) and interestingly it can be noticed that probably the vineyard late-growth-stage reference curve does not fit the worst case for the South Europe conditions. The 90th percentile curve obtained from experimental data is higher than those obtained by Rautmann *et al*. (2001) -official curves- at all downwind distances from the applied area (up to 30m from the applied area). No comparison about experimental data and reference drift curves are available in literature as to date no ad hoc reference curves are available for olive and citrus. Indeed, for regulatory purposes, values derived from curves referred to other crops are used also for olives and citrus even if the context, spray application conditions and technologies used are not comparable (e.g. orchard reference curves used) and also the weather conditions.

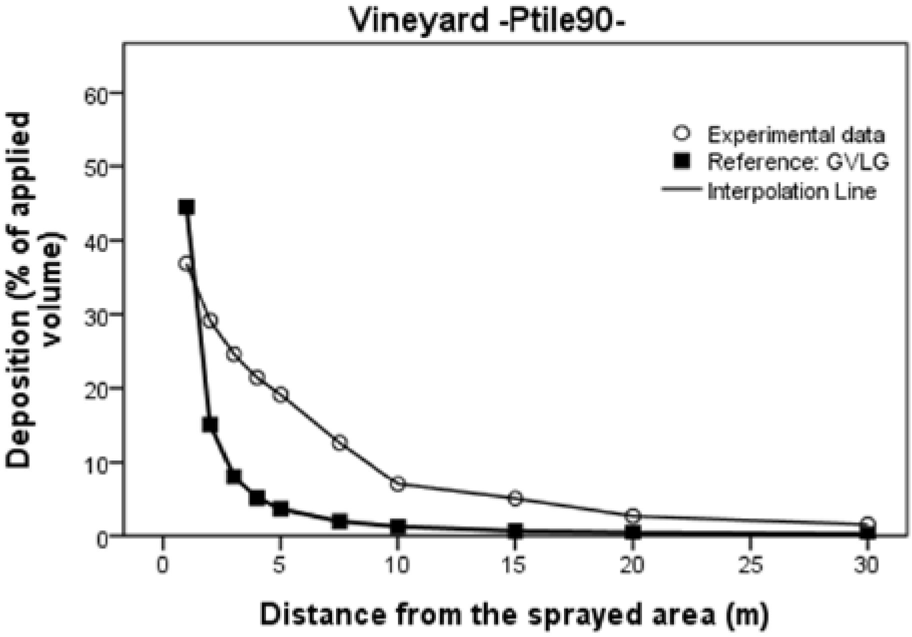

Figure 91. Comparison of experimental data of drift in vines (Grella et al. 2017) with the reference spray drift curves of Rautmann *et al*. (2001)

Another important aspect that can be derived from the literature selected, is the increasing attention deserved by authors to the airborne spray drift. Indeed the reference curves provided by Rautmann et al. (2001) provide values only for spray drift sediments measured on the ground. Recently, several authors found higher values for airborne drift compared to drift ground sediments measured at the same sampling distance. Also, in some cases the drift amount increases by increasing the sampling height (Grella *et al*., 2017 - Figure 92), remains stable at the different heights or slightly decreases by increasing the sampling height (Torrent *et al*., 2017 - Figure 93 and Miranda *et al*., 2018 - Figure 94).

Anyway, in all cases huge amount of droplets remain suspended in the air with the potential to travel long distances without exactly knowing for how much time and distance they can remain airborne. Authors agreed about the importance to measure both ground sediment and airborne spray drift in order to obtain a comprehensive overview of spray drift phenomenon in relation to both the weather conditions and spray application technology under evaluation.

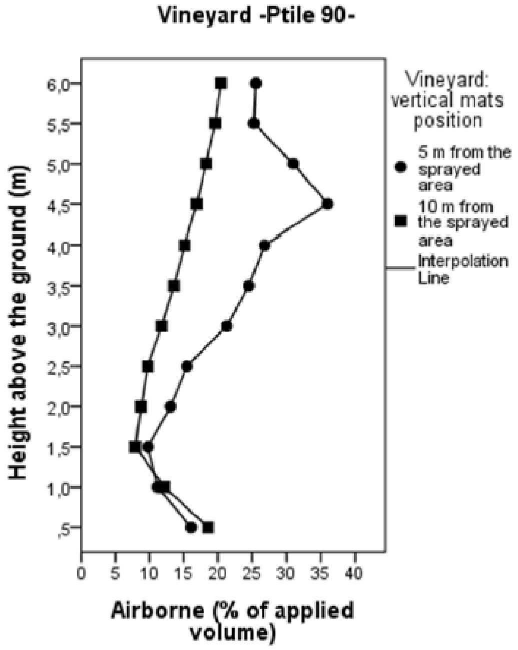

Figure 92. Experimental data of drift in vines at different height (Grella *et al*. 2017)

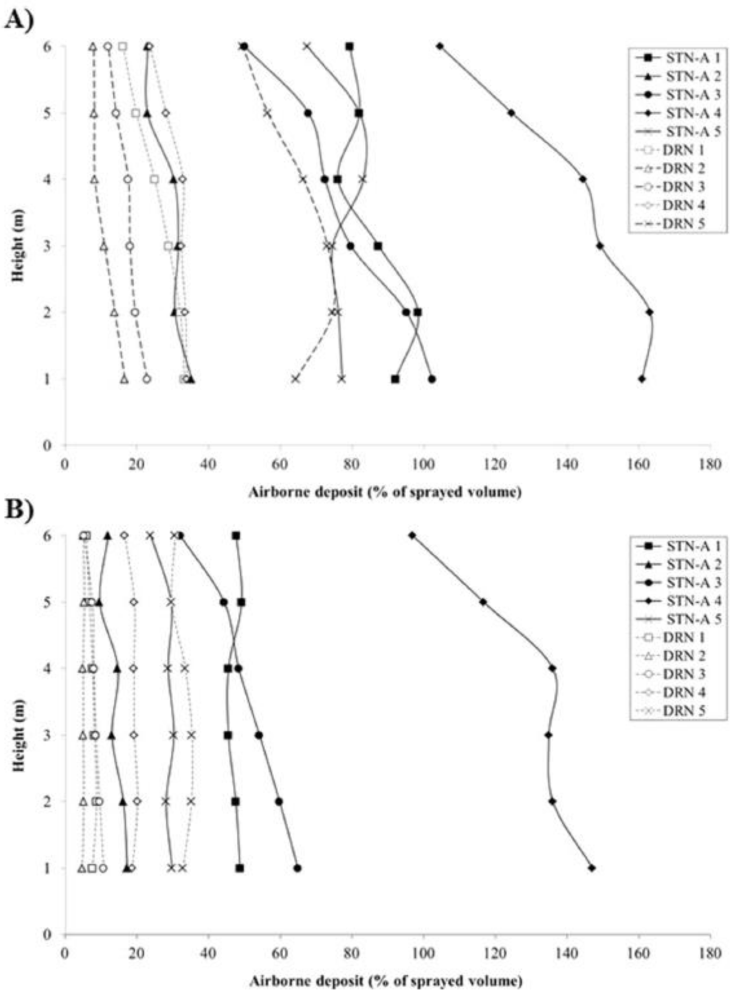

Figure 93. Experimental data of drift at different height (Torrent *et al*. 2017)

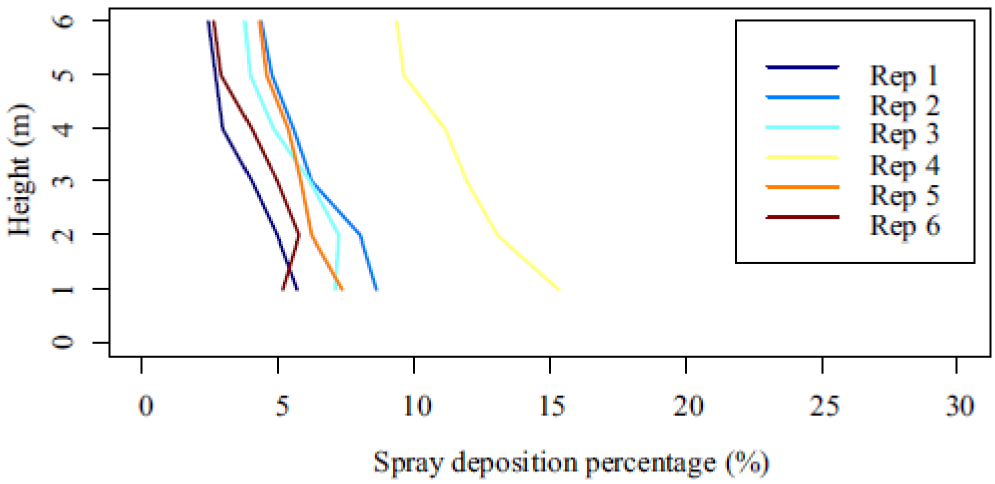

Figure 94. Experimental data of drift at different height (Miranda *et al*. 2018)

3.6 3-D orchards and spraying technologies versus exposure models

In the registration process of PPPs, risk assessment is performed through exposure modelling. Models consider drift as one of the principal routes of contamination for different compartments/organisms/populations. Actually, drift is not modelled itself but makes reference to value derived from field studies, where spray drift measurements are performed under a range of reference conditions to assess the amount of applied spray volume blown downwind of a treated area and deposited on the soil surface next to the field.

These spray drift curves used for risk assessment are those described by Rautmann *et al*. (2001) that substantially are the integrations of well-known curves proposed by Ganzelmeier *et al*. (1995). These curves were based on results of 119 drift trials conducted between 1989 and 1992 (Ganzelmeier *et al*., 1995) plus 50 arable crops trials and 72 fruit growing trials done between 1996 and 1999 (Rautmann *et al*., 2001), all of them carried out under agro-climatic conditions of Germany. These values have been used for the calculation of the drift 90th percentile in the application of PPP to four crop types, namely field crops, grapes, fruit crops and hops.

Beside the fact that these reference drift curves have not been updated in the last 20 years, the current drift curves used for fruit crops refer to apples, a fruit crop widely spread in Europe. However, those apple crops used in drift tests were managed as usual in Central and Northern Europe, following a spindle training system, forming a vertical wall of vegetation, with very low leaf density and width. And this scenery is completely different from apples managed in SEU and noticeably from other typical crops of Southern countries like citrus, olives and fruit crops like kiwi, peach and apricot, that are characterised by having large canopy size, different shape, higher leaf density and being bulkier. Furthermore, the climatic conditions are remarkably different as well as the spray application technology and practices.

In modelling, drift is expressed as a percentage of applied dose reaching the compartments/organisms/populations depending on distance; in orchards/vines just two values of drift are considered to address early and late crop growth stages. To better discuss this point, Appendix F collects a series of images of 3-D crops typical of SEU: the difference in shape, training systems, height, foliar density, and dimension is so huge that the reliability of just 2 values of drift to be used in the exposure assessment for the entire group of 3-D orchards is highly questionable.

Drift tests for the current drift table used in Europe were mainly conducted in Northern Europe, where crop training systems and layout are very different from those used in the South. Furthermore, in Northern Europe, PAE and climatic conditions are different from the ones in SEU. To better clarify this point, Appendix D collects images of the major equipment used in 3-D orchards in SEU: the variability in equipment is very high, with different equipment for different crop (airblast for citrus different from airblast for vines) but also with different equipment for the same crop and different equipment depending on land characteristics.

Considering the extension of the area cultivated with 3-D orchards in Southern Europe and the peculiarity of equipment used to apply pesticides on these crops, it is clear that spray drift deserves specific attention.

Another point to be considered in dealing with drift is what comes out from surveys: air deflectors are widely used in Southern EU, together with automatic variable rate based on forward speed, and nozzles are normally switched-off in specific situations. Therefore, when addressing exposure assessment, information on technique and equipment cannot be disregarded.

The literature search performed during this project, as already described above, did not provide enough information to produce new drift tables to possibly substitute the curves currently used in risk assessment. Nevertheless, even in the absence of such quantitative data, a lot of qualitative information is available to show how 3-D orchards present peculiarities which are not typical of pome fruit grown in Central-Northern Europe, the crop and scenery used to simulate orchards up to now.

As already highlighted above, from the available studies the vineyard late-growth-stage reference curve used for risk assessment does not fit the worst case for the South Europe conditions, since the 90^{th} percentile curve obtained from experimental data is higher than those obtained by Rautmann *et al*. (2001) at all distances from the applied area (up to 30m). This fact may be considered a sort of "warning": if vineyard for SEU is assessed with an underestimated exposure, being the same type of crop assessed on Rautmann curves, what may be the situation of other 3-D crops, like citrus and olives, which were never, or scarcely, assessed with experimental data?

The other key point raised by the literature search which can greatly impact on risk assessment procedures is the airborne spray drift. As already stated in the previous paragraph, the reference curves used for modelling provide values only for spray drift sediments measured on the ground while new studies report higher values for airborne drift compared to those found at ground level for the same sampling distance. Since the droplets remain suspended in the air, they have the potential to travel long distances and few information is available on how long they can remain airborne and how much they can travel.

A comprehensive overview of spray drift phenomenon in relation to both the weather conditions and spray application technology is needed to update what is currently used for risk assessment. Both a new set of data to characterise 3-D orchards different to apple and pear growth at Central European conditions and a clear picture on where drift exposure really occurs, whether more on ground or on air, is needed.

Furthermore, considering the quick and high development of PAE used in agriculture, it has to be considered whether data collected more than 20 years ago might still be considered reliable or need some integration and update to comply with the recent improvements in application techniques which might have affected the phenomenon of drift.

Last but not least, the increasing interest in precision farming and drones is opening new scenarios of exposure which might need a complete revolution of what has been considered a standard situation up to now.

Considering the high variability in crop cultivations and training, in pesticide application techniques, in equipment and in new evolution of agriculture, it is clear that risk assessment cannot pretend anymore to exclude agronomists from the process. Even if models in different compartments and risk assessment of different organisms/populations need specific expert, the global vision of what is reliable in field, which application make sense, which mitigation measures may be applied, what the behaviour of farmer might be in specific situation, all these are information that just people acting in field might have and share.

4 Conclusions

- In general, in all crops, 80% of the surveyed farmers were professional but still 20% were part-time farmers with the exception of olives, where part-time farmers increased on average to around 35%. It has to be taken into account that this percentage of part-time farmers could increase if orchards of less than 1 ha were included in the study. Also, farmers themselves are frequently in charge of the spray application, especially in Italy and Greece. In Spain, the percentage of professional applicators increases between 35-62%, depending on the crop. Furthermore, in all the SEU countries, the integrated farming system is widely the most adopted, regardless of the type of crop considered.

- On the other hand, in all the 3 SEU countries, more than 60% of the farms are in plain land, 80% in the case of citrus, although there are some special regions where crops are cultivated in hills, something that is really noticeable in olives for the 3 countries and nuts for Italy and Greece, and this influences directly the spray technology used. Generally, small and medium size orchards between 1 and 50 ha with traditional or extensive training systems stand out, except in the case of vineyards where the trellised system is the most common. Moreover, the majority of orchards did not have interconnection with sensitive areas, and in the case they have, the suburban areas are the most frequent ones, with the implication that this may have for human health.

- Regarding the PAE and PPP practices, the airblast sprayer is widely the most common equipment, its age mostly ranged between 1-20 years old and, in general, they are approved by the inspection stations. Consequently, this equipment type is the most inspected and the most sold by manufacturers.

- The most relevant criteria for buying a new sprayer for farmers and technicians is the efficacy, followed by operator safety and precision application, which are in agreement with the trends declared by manufacturers and inspection stations. The majority of farmers declared to be familiar with technology and innovation, although sprayers with high levels of automation are not demanded. The adjustment or calibration of the sprayer is more frequent, although not high (lower than 40% on average), at the beginning of the season, but currently, on average, around 20% of farmers declare that they never perform such actions. Therefore, it is important to continue the efforts to educate and train farmers about the importance of this practice in order to improve efficacy while reducing environmental and human risks, as well as the cost of PPP application. On the contrary, almost all of the farmers report to maintain constant speed during the spray application and to modify the volume rate and the spray pressure along the vegetative season, but a limited number of them use decision support tools for spray volume adjustment, which would increase the efficiency of PPP application, as it has been demonstrated, for example, in the LIFE PERFECT project (https://perfectlifeproject.eu/es/).

- The spray application timing is decided by taking into account the advice of plant scientists or based on the personal experience of the growers themselves and most of the farmers declare to spend between 0.5 to 1 hour to spray one hectare, depending on the equipment. Each type of crop follows a specific pattern related to the month when the spray application is made, although in general spring is the most usual period, followed by summer or autumn.

- Regarding the use of PPE during application, almost all farmers use them during the spray application and the most used PPE are gloves, mask with filters and coverall. On the other hand, most of the farmers use cab-less tractors or tractors with cab with filters.

- In Spain, spraying equipment is more regularly maintained by the manufacturers than in Italy and Greece and a similar trend is observed when farmers go to technical services for repair.

- During maintenance and repair, it seems that the most problematic parts are the pump, the nozzles, the measurements, control and calibration systems, and the filters, with a high consistency between the 3 countries. However, in the case of inspection there seems to be a high differentiation particularly with the tank in the case of Italy, and with the power transmission parts in the case of Spain. This leads to the conclusion that these problems do not force the owners to bring their sprayers for repair, and that maintenance is not performed regularly. On the contrary, pump problems are much less frequent during inspection than during maintenance and repair, leading to the conclusion that problems in the pump are timely repaired when they occur.

- In general, most of the farmers/technicians of the 3 SEU countries know the drift concept and they are concerned about it. They are familiar with SDRT although Greek farmers are somewhat less familiar with it than their Spanish and Italian counterparts. The main reason for using SDRT declared by farmers is due to the reduction of human risk and the protection of the environment.

- The use of easy SDRT is at intermediate level, DRN are reported to be used by around 50% of farmers/technicians and approximately 70% of farmers who have air deflectors reported using them. A more common practice reported by farmers is to switch off nozzles in specific situations to reduce spray drift, in more than 80% of cases. Sprayer manufacturers and inspection stations agree that the most commonly used SDRT are DRN and air deflectors. Other SDRT are rarely used.

- No National or EU financial support is received by farmers for the adoption of SDRT or for buying new environment-friendly sprayer.

- The use of other management practices that help reduce drift is around 50% in the case of adding spray additives, very scarce in the case of presence of windbreaks and hail nets and depending on the country in the case of presence of vegetation in the field boundaries, in Spain more than 50% in all crops, in Italy lower than 50% and depending on the crop and in Greece very scarce.

- In general, farmers of the 3 SEU countries take into consideration weather conditions before spraying, and the parameters most considered by them are rain and wind speed, followed by air temperature.

- Crop and orchard characteristics in SEU are different in comparison with apples grown in Central-Northern Europe. Moreover, the sprayers and PPP practices are also different.

- There are not enough data in published literature to develop a robust spray drift model for the different 3-D crops, therefore it is necessary to obtain new data to create a sufficiently large database taking into account the main European scenarios, that, in the case of 3-D crops, must include the agro-climatic conditions of SEU, as 95% of these cultivations are grown there.

5 Recommendations

Drift field studies should be implemented to characterise 3-D crops scenarios with a specific attention on where drift exposure really occurs, whether more on ground or on air.

Considering the quick and high development of pesticide application equipment used in agriculture, the data collected more than 20 years ago should be integrated with new data to check whether improvements in application techniques might have impacted on drift phenomenon and to which extent.

The increasing interest in precision farming and drones is opening new scenarios of PPP exposure: there is a need to collect experimental information also on drift/exposure that might occur in the field using such novel spray application techniques.

The high variability in crop cultivations and training, in pesticide application techniques, in equipment and in new evolution of agriculture, clearly requires the involvement of agronomists with expertise in field activity in the upgrade of risk assessment methodologies, to account for real practices, habits and procedures in the development of exposure scenarios.

A comprehensive study aimed at collecting spray drift data, taking into account at least the most relevant 3-D crops scenarios with special regard to SEU context, would be necessary in order to generate more reliable and up to date drift reference curves to use for PPP risk assessment. The experiments should be carried out in parallel in different areas and 3-D crops, applying a well-defined common methodology (e.g. referred to ISO 22866), in order to collect a broad and homogeneous database. This would be useful to achieve robust spray drift models to apply in all the specific 3-D crops scenarios.

6 Dissemination plans

The activities, results and recommendations of the present project will be promoted and communicated to reach out multiple audiences, directly or indirectly, potentially interested in the project activities, such as peers in the research field, industry, other commercial players, and policymakers.

Knowing that one of the main results of the project highlighted is the need of a harmonised revision of drift data in orchards, with a specific attention to 3-D orchards, activities have been and will be conducted also in the future to disseminate the project results at EU level, by:

- Informing national Focal Points of EFSA advisory forum;
- Attending:
    - Scientific and standing committees closely related to drift exposure assessment and management of PPP;
    - Working groups aimed at implementing methodologies and guidance for drift exposure;
    - Member States zonal and non-zonal forums for discussion and harmonization on implementation of EU directive and regulations on pesticides active substances and PPPs.

Besides disseminating the project outcomes and raising awareness for the identified data gaps for exposure assessment, these actions aim to gather evidence on the priority of EU programming in implementing a harmonized regulatory approach (zonal, non-zonal) for exposure assessment PPPs.

In addition to the above activities, the project outcome has been and will be disseminated in congresses and scientific societies, at national and international level, to reach a scientific audience close to the drift exposure of PPPs.

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Glossary [and/or] Abbreviations

AR	Application Rate
BBA	German Federal Biological Research Centre for Agriculture and Forestry
BBCH	Biologische Bundesanstalt,Bundessortenamt and CHemical industry
BfR	German Federal Institute for Risk Assessment
BG	Bulgaria
BPI	Benaki Phytopathological Institute
BVL	German Federal Office of Consumer Protection and Food Safety
BW	Body weight
CAP	Common Agricultural Policy
CRD	Chemical Registration Division
CTGB	Dutch Board for the Authorisation of Plant Protection Products and Biocides
CY	Cyprus
D	Drift
DA	Dermal Absorption
DEFRA	Department for Environment, Food and Rural Affairs
DFR	Dislodgeable foliar residue
DRN	Drift Reduction Nozzles
EFSA	European Food Safety Authority
EL	Greece
ELGO-DIMITRA	Hellenic Agricultural Organization "DIMITRA" / Institute of Soil & Water Resources / Dept. of Agricultural Engineering
ELSTAT	Hellenic Statistical Authority
ENTAM	European Network for Testing of Agricultural Machines
ES	Spain
EU	European Union
EW	Emulsion, oil in water
FAO	Food and Agriculture Organization
FAOSTAT	Food and agriculture data of FAO
FOCUS	FOrum for the Co-ordination of pesticide fate models and their USe
FSDS	Fixed Spray Delivery System
FR	France
GD	Guidance Document
GIS	Geographical Information System
GR	Granule
HR	Croatia
IPM	Integrated Pest Management
IT	Italy
IVIA	Agroengineering Center of Valencian Institute of Agricultural Research

ISTAT	Istituto Nazionale di Statistica (National Institute of Statistics)
MAPA	Ministerio de Agricultura, Pesca y Alimentación
MS	Member State
MT	Malta
NTA	Non-target arthropods
PAE	Pesticide Application Equipment
PPE	Personal Protective Equipment
PPP	Plant Protection Product
PT	Portugal
RA	Risk Assessment
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
SAE	Spray Application Equipment
SDRT	Spray Drift Reduction Techniques
SEM	Structural Equation Modelling
SEU	Southern Europe
SOP	Standard Operating Procedure
UBA	German Environmental Protection Agency
UK	United Kingdom
UMIL	Università degli Studi di Milano
UNITO	Università degli Studi di Torino
UASS	Unscrewed Aerial Spray System
US EPA	United States Environmental Protection Agency

Appendices

Appendices A, B, C, D, E, F are provided as separate reports at https://zenodo.org/records/10477854.