FERTINNOWA

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Benchmark report

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The FERTINNOWA team is extremely thankful for the major efforts Rafael Granell Ruiz made to the benchmark report.

We are even more grateful for the opportunity to work with this warm and driven person.

We will always remember the long working hours with Rafael.

These were all the more enjoyable with his smiles and great sense of humor.

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1 Executive Summary

Fertigation is the practice of applying fertiliser to a crop via the irrigation system. In the context of horticulture (fruit, vegetables and ornamental production), fertigation is most commonly used with drip irrigation. The large, rapid and ongoing increase in the adoption of drip irrigation in horticulture has facilitated a similar on-going increase in the use of fertigation. For important crops, e.g. tomatoes and sweet pepper, closed growing systems were developed to improve water and nutrient efficiency on the one hand and to reduce nutrient losses on the other. For soil-grown crops, the solutions were directed towards improvement of irrigation and fertilisation management to avoid irrigation and nutrient surpluses. Implementing innovative technologies is considered to enable the next step towards a more sustainable use of both water and nutrients in fertigated crops. A European overview of the current implementation rate of technologies and best practices at the farms level has so far been lacking.

This Benchmark Survey has been prepared in the context of the FERTINNOWA project (www.FERTINNOWA.com) whose objective is to form an overview of the current status of technology and knowledge implementation in different European regions, growing systems, and crops where fertigation is applied. The survey aims to gather information on perceptions and behaviours regarding irrigation and fertigation management in fertigated crops. These insights are essential to have a better understanding of which technological, socio-economic and also regulatory factors hinder or support technology uptake by the growers.

In the context of this survey, the FERTINNOWA consortium has developed a questionnaire which aimed to collect information under the following main sections: (1) background information related to the grower and the farm; (2) grower perception about water source management; (3) agricultural practice related to irrigation and nutrient management; and (4) agricultural practice and perception towards minimising environmental impact due to discharge/emission of nutrient wastewater.

The FERTINNOWA consortium surveyed 371 farms, covering a total of 531 cropping systems including soilless and soil-grown crops both outdoor and covered. The surveyed farms were located in the main European horticultural production countries including Spain, Italy, France, Belgium, the Netherlands, Poland, Slovenia, the United Kingdom and South Africa. Participating farms were found through opportunistic and critical case sampling. With critical case sampling, generalisations cannot be extrapolated out to the wider population, but they can help in making logical generalisations. However, these generalisations should be considered with care. This document reflects the views of the respondents. This does not mean that the answers provided comply with the actual situation or legislation.

The following paragraphs provide an overview of the gained insights regarding the main sections of the questionnaire referred to previously.

Water source management

Ground water was identified as the most applied water source for irrigation practices, with 60% of the respondents using this source. However, some regional differences were observed. In most of the North West (NW) region, rainwater was reported as the primary water source. However these respondents reported that their farms were also set up to use groundwater. Irrigator communities provided the primary source of irrigation water to the majority of farms in Spain. A minority of the farms surveyed used surface water, mains tap water and other types of water such as desalinated water or disinfected urban wastewater.

Although water quantity problems was expected to be a serious issue in the Mediterranean (MED) region, water quantity problems were more frequently reported by the NW respondents. Farms using rainwater or groundwater or both, and farms receiving water from irrigator communities reported water shortage issues.

Water storage was considered to be important in overcoming water shortage issues. However, respondents who stored water also faced different bottlenecks: lack of space for rainwater storage, maintenance requirements, leaking, material degradation, and the presence of unwanted material in the water (e.g., algae or microalgae). Stored water was also sensitive to external particles such as sediments, leaves, bird or fish droppings, etc.

Overall, respondents believed that water availability would remain the same. However, in Spain and Poland, the majority of the respondents believed that water availability would be reduced in future.

Respondents were also satisfied with their water quality overall. The mineral water quality of rainwater and mains tap water had the highest satisfaction rates. Respondents were fairly satisfied with groundwater quality even though some differences were observed between countries. Water quality was rated lower for disinfected urban wastewater.

Interviewees mainly chose to switch towards less problematic water sources or to mix different water sources to mitigate the problem, or adjusted the nutrient inputs to the system. Few respondents chose to treat their supply water. In general low-tech solutions were preferred to high-tech solutions which could cost a lot more. Solutions would probably be adopted if less expensive and easily available.

Regarding the sanitary status of the water, the main problem reported was the growth of algae. Few technical solutions were considered satisfactory, highlighting the lack of effective solutions on the market.

In almost all water sources, except tap water, bacterial problems were mentioned. Respondents reported problems with *E.coli, Agrobacterium rhizogenes*, other *coli* forms, and *Pseudomonas* (species not specified). Fungal problems including *Phytopthora spp., Pythium spp., Fusarium spp*. were more pronounced in recirculated drain water. Other problems included *Salmonella* and biofilm formation. Disinfecting water using UV light was the most common disinfection method.

Many respondents considered their water supply to be ‘sustainable’ or ‘very sustainable,’ although the majority could not provide precise data on their annual water consumption. Respondents who were willing to shift towards more sustainable water supply considered increasing rainwater storage, recirculation of drain water or diversification of water sources.

The shift towards more sustainable water supply involves several bottlenecks, such as the need for space to build a water storage facility, and high initial investment costs, etc.

Water and nutrient use efficiency

Water and nutrient use efficiency were very dependent on the cropping system and the medium used (i.e., soil or substrate). The MED and NW region were more closely aligned in their irrigation and fertigation practices compared to the Central East (CE) region. In soilless crops, especially covered soilless crops, changes in water and nutrients can have an impact very quickly, and this was reflected by higher levels of monitoring and automation associated with this cropping system.

Precision irrigation technology, such as drip irrigation, was already widely used. Respondents seemed more aware of the day-to-day needs of the crops rather than overall annual water consumption. Most respondents relied on their own experience for when to irrigate, based on crop or substrate appearance, combined with technological tools. However, a large proportion used experience alone (CE region and soilless outdoor crops).

The majority of respondents adjusted nutrient application to crop growth stage, especially in covered crops. Generally, respondents did use tools to monitor fertigation, but again, monitoring was used much more in the MED and NW regions compared to the CE region. Generally, there was poor visibility of recommendation schemes (awareness was low), but if respondents were aware of them, then they then tended to make use of them.

The NW region was more concerned with salinity compared to other regions, and mostly in soilless covered systems. Adding water was the primary method to address salinity, based on respondents' own experience or that of an advisor. Interestingly respondents from soil-grown systems seemed to require more support with this issue than soilless systems.

Effluent management and minimisation of environmental impact

To our knowledge, the FERTINNOWA benchmark study is the first to identify multiple different discharged water streams for fertigated crops at an European level. Clear distinctions were observed amongst the different regions and growing systems.

In the case of soilless growing systems, reducing nutrient inputs, saving water, complying with legislation and reducing environmental impact were the main drivers for recycling drain water. Again, regional differences occurred.

A notable feature in the responses was the wide range of technical challenges reported by the growers, relating to recirculation of drain water, which can affect the crop quality, and which needs to be resolved: ion accumulation, high electronic conductivity, spread of diseases, growth inhibition and root exudates were reported.

Widespread adoption of recycling irrigation water could be supported through government incentives or growers' ability to pass cost increases on to customers. The benchmark survey showed that external controls, either by regional or governmental agencies as well as certification agencies can be the main trigger for growers to further reduce the environmental impact of their farms.

2 Materials & Methods

2.1 Study area and sampling protocol

The surveyed farms were located in nine countries: Spain, Italy, France, Belgium, the Netherlands, Poland, Slovenia, the United Kingdom and South Africa. The survey included the main EU horticultural production countries. In Figure 1, the locations of the study areas are presented.

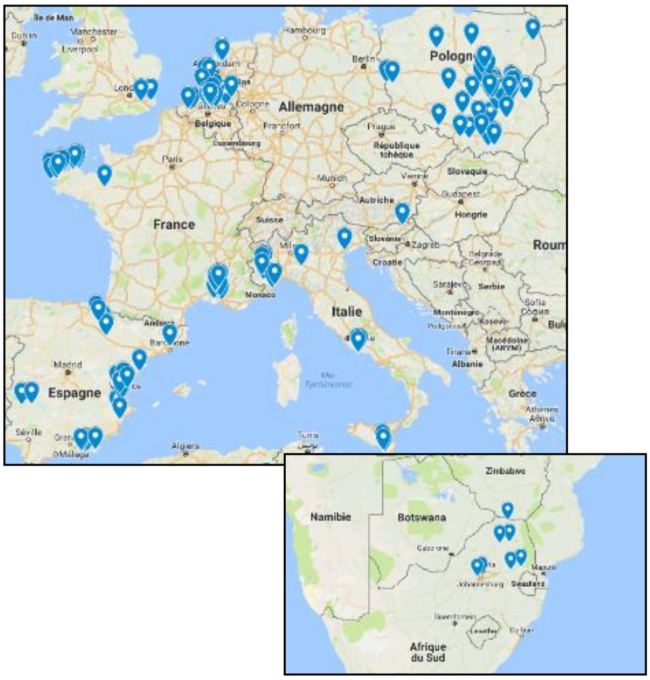

Figure 1 Geographic distribution of surveyed horticultural farms

Participating farms were found through opportunistic and critical case sampling. With critical case sampling generalisations cannot be made to population, but they can help in making logical generalisations. However, such logical generalisation should be made carefully. It was further argued that critical case sampling may be used to investigate whether a phenomenon is worth investigating further, before adopting an expert sampling approach to examine specific issues further (Lund Research Ltd, 2012).

The survey commenced on April 2016 and closed on November 2016, and we interviewed 371 farms in total. The choice of sample sizes varied across countries depending upon their respective amount of funding, resource availability, infrastructure constraints, and cultural feasibility. Figure 1 shows the repartition of the questionnaire between partners, countries and climate regions (according to Köppen classification).

Interviews lasted between 1 and 2 hours and all interviews were anonymous and sampling results were confidential. We did not include data on individual owners and locations of their properties here to comply with privacy policies

Although most of the farms surveyed had only one cropping system (70%) there were farms with more than one crop/cropping system. The benchmark distinguished the following cropping systems:

- Soilless grown outdoor (SLOD)
- Soilless grown covered (SLCO)
- Soil grown outdoor (SGOD)
- Soil grown covered (SGCO)

To understand the farm's management practices, it was important to capture information of all the factors that may influence the interviewees' choices. Therefore, all cropping systems that were present at the farm were included in the survey. In total, we investigated 531 cropping systems through the questionnaires (Figure 2), which are considered to be the main systems on the surveyed regions. Mainly farms with the following crops were selected: vegetables (leafy and fruit), fruit trees, soft fruit, ornamentals and other crops.

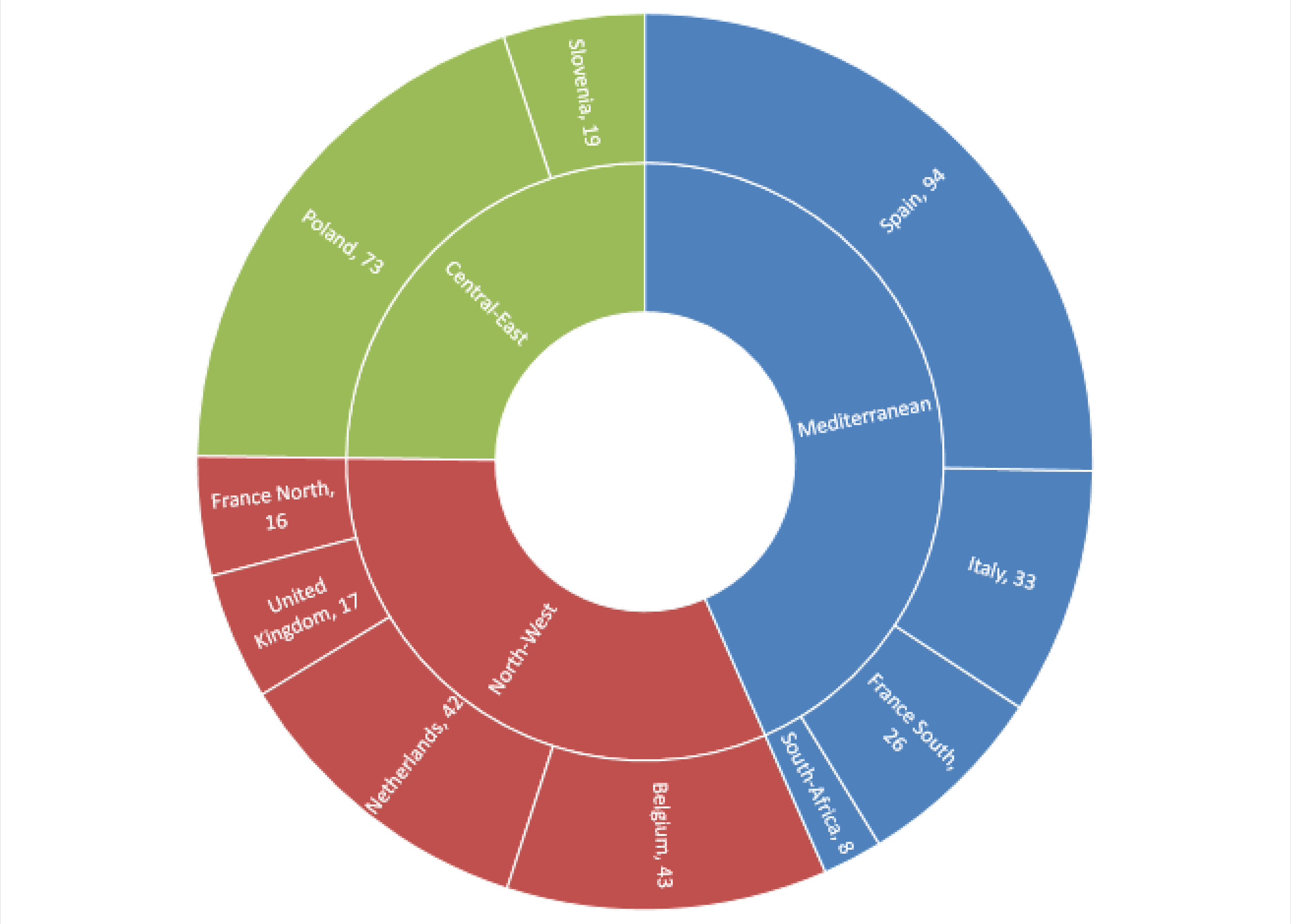

Figure 2 Number of interviews carried out by FERTINNOWA partners in each country

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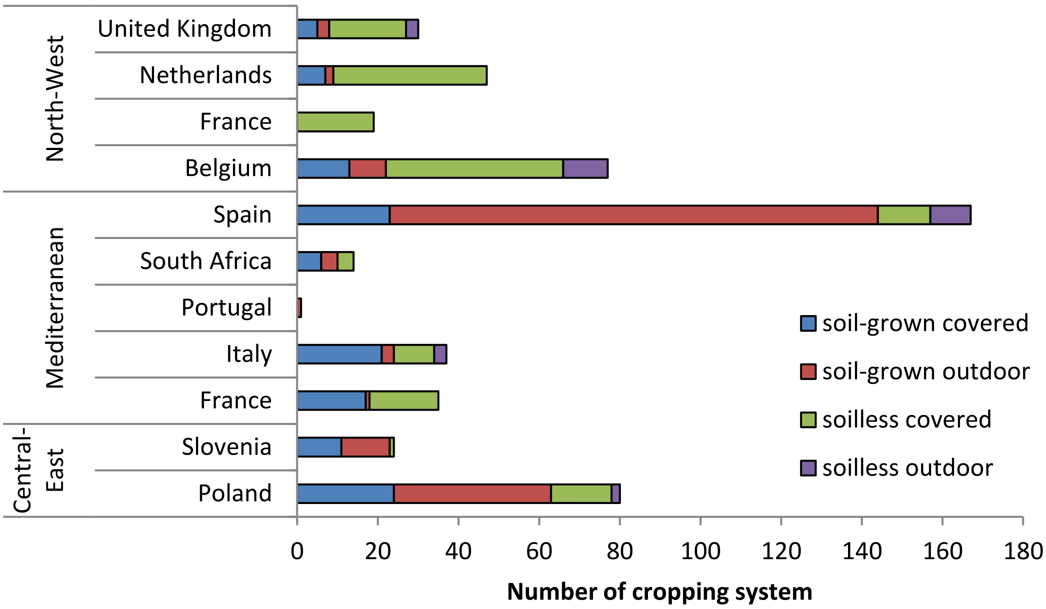

Figure 3 Cropping systems investigated per country

While we believe that the findings that emerged are far from unique to the growers interviewed, considerable caution is needed before making any generalisations to other groups. This also underscores the urgent need for expanding the research with a broader scoped study (outlined in policy recommendations).

2.2 Survey design

Within FERTINNOWA, a questionnaire was developed which aimed to gather information on perceptions and behaviours regarding irrigation management on fertigated crops across Europe. A detailed description of the questionnaire and its development can be found in D3.1. Therefore, only a brief description will be provided in this report. The topics to be explored were identified by combining information gathered from group discussions with few growers, technicians and researchers and a survey of the existing literature. A pilot test of the survey was performed by asking researchers and growers to evaluate the first draft. This allowed us to collect additional information and develop the final form of the questionnaire. Questions that were unclear or otherwise problematic were revised. The questionnaires were translated from English into the relevant languages.

The questionnaire collected information under the following main sections: (1) background information related to the grower and the farm; (2) grower perception about water source management; (3) agricultural practice related to irrigation and nutrient management; and (4) agricultural practice and perception towards minimising environmental impact due to discharge/emission of nutrient wastewater.

The questionnaire consisted of closed (binary, multiple choice and Likert-type scales) questions to obtain information about attitudes towards and the usage and perception of fertigation management, while open-ended questions were used to more broadly explore the socio-economic problems.

An interview guide was designed for the interviewers to avoid bias from interpreting the questions wrong.

2.3 Data analysis

Qualtrics, an online tool, was applied to collect and digitalise all answers all over Europe in a standard format. The data were checked for errors and missing values. In a second step, the responses to the open-ended questions were coded and categorised using the constant comparative method (Miles and Huberman, 1994). These open-ended responses were initially coded by two researchers who consulted regularly to ensure inter-rater reliability. One additional researcher reviewed the initial coding to further address reliability. The response codes were input into the numeric database with responses from closed-ended questions.

Given the categorical nature of most of our variables and the small size of the samples, we mainly used qualitative analysis. Sample sizes varied across analyses because of differential patterns of missing data for the dependent measures.

3 On-farm management of water resources

All over Europe, water of fair quality for irrigation is getting scarcer and growers need to question their water resource management. The management of on-farm water resources involves several aspects: selection of the water source, management of the quantity of water abstracted from this source, management of the mineral and sanitary quality of the raw water used. Water storage represents also a step in the on-farm water cycle, interacting with the quantity, quality, sanitary parameters of raw water, as well as drain water management when recirculation is applied.

The local and regional conditions regarding the availability of water are very scattered. In the North-West part of Europe, alternative sources to groundwater are promoted such as the use of rainwater, nowadays largely developed. In the Central-East, increasing constraints linked to the use of groundwater are questioning growers' current practices. In the Mediterranean area, the pressure on water resources is particularly high because of the scarcity of qualitative water and the competition for the use of water between sectors (agriculture, tourism, industry). The need for available alternatives to groundwater (whose quality is dramatically decreasing) is more and more highlighted in those regions.

The requirements linked to irrigation water (in terms of quantity and quality) are strongly related to the cropping systems type (outdoor/ indoor/ soil-grown/ soilless) and the crops. For outdoor crops, the irrigation water is an additional part of the water received naturally from the rainfall pattern. Depending on the soil mineral composition, the water quality can eventually be mitigated in the soil. However, the increasing tendency of land use intensification leads questions this statement because the soils are increasingly saline. For covered crops, the irrigation water is the only water received by the crop. In case of soil-grown crops, the soil under greenhouses is intensively used, and for substrate-grown crops, the crops usually have minor perimeters to cope with salinity because of the limited volume of the substrate. Therefore the EC and the sanitary status of the input water should be carefully monitored to enable efficient fertilisation without leading to phytotoxicity. The management of source water plays a crucial role in the whole cropping system performance.

This chapter describes the current status of the use of water resources by the surveyed growers.

The selection of the source of water used by the grower depends on several parameters: availability, quantity and quality requirements, ease of use, price, etc. We aimed at understanding the management of water sources (type of water, purpose, storage, time of use) and the bottlenecks faced by growers in terms of quantity (available volume over the time), quality (mineral composition), or sanitary status (waterborne pathogens). Growers also reported the bottlenecks faced in relation to those topics and actions they carried out to cope with them. The survey did not imply a quantification of abstracted water streams due to the diversity of local condition and cropping systems investigated.

3.1 Water sources used for irrigation

3.1.1 Definition of the water source types

The fresh water sources, further referred to as water sources frequently used in this chapter are listed in Table 1. This list is however non-exhaustive. In this survey, fresh water sources refer to freshwater inputs into the farm's water cycle. Recirculated water streams like drain water and drainage water are not taken into account in this section. More detailed information regarding the implementation of drain and drainage water can be found in section 5.1. Depending on the farm's specific situation or the applied water source, the fresh water can originate from a source at the farm's site or supplied to the grower from outside of the farm. In the latter case, the water can be provided as raw water or has passed pre-treatments phases such as a desalinisation step.

Table 1 Non-exhaustive list of water sources for irrigation practices

Water source	Definition
Community water	Referring to water provided by irrigators or water users communities. The provided water can originate from different water sources like groundwater, precipitation, surface water and in some cases desalinated water. [1]
Groundwater	Water extracted from the phreatic or artesian aquifers
Desalinated seawater	Referring to water provided through desalination plants water from the sea to supply fresh water for irrigation through a dedicated network. In some case, it can also be supplied by irrigators communities.
Disinfected urban waste water	Sometimes also referred to as grey water. This urban wastewater is coming from a treatment plant turning the urban wastewater into fresh water available for irrigation. It circulates also usually in a dedicated network.
Drain water	Drain water refers to the excess of the nutrient solution provided to plants grown in artificial substrates like rock wool, coco, peat, etc. The cases might be recycled as a water source. Drain water does not pass through the greenhouse soil before collection.
Drainage water	Drainage water refers to the excess of the nutrient solution provided to soil grown crops. This excess of irrigation water passes through the greenhouse soil before it is collected through a sub ground piping network.
Mains tap water	Referring to water provided through the regular network of potable water (civil network)

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[1] Depending on the irrigation community, the grower is not always aware about the origin of the water. Each member of the irrigation community holds water shares. Most members must pay a minimum quota per share depending on the contracted electric power, administration expenses, the amortisation of facilities, repair, and maintenance, etc., as well as the cost of the irrigation itself. A water share entitles the holder to irrigate during each of his turns with a certain water quantity. However, often the timing and the water quantity do not meet the grower's needs.

Rainwater (Precipitation)	Precipitation refers mainly to rainwater but also snow, sleet, or hail that falls or condenses on the ground or a surface (like a greenhouse roof).
Recirculated water	Refers to sources like drain and drainage water. The source is not specified.
Surface water	Refers to water coming from rivers, canals or ponds.

In this document, desalinated seawater and disinfected urban wastewater are considered as minor water sources and referred to as “other sources”.

In case the use of drain or drainage water is not specified, the general term “recirculated water” is used in this document.

3.1.2 Types of fresh water sources applied

Figure 4 shows that groundwater was identified as the most applied water source for irrigation practices in our sample. It has to be mentioned that respondents could select more than one water source in the survey as multiple water sources can be applied at the farms. This explains why the total percentage per country exceeds 100%.

On a European scale, 60% of the respondents applied groundwater as a water source for irrigation. Groundwater is the most commonly used source for the vast majority of the farms in Poland (88%), France (88%), the Netherlands (83%), Italy (82%) and South Africa (50%). It is used less commonly by the Spanish (15%) and Slovenian (42%) respondents.

Although rainwater was the primary water source for irrigation in most of the NW region (77% of the respondents reported to use it), still these respondents reported that their farms as well have the possibility to use groundwater.

Irrigator’s communities provide the primary source of irrigation water to the majority of the farms in Spain (79%).

A minority of the surveyed farms reported the use of surface water (9%), mains tap water (7%), and other types such as desalinated water or disinfected urban wastewater (2%).

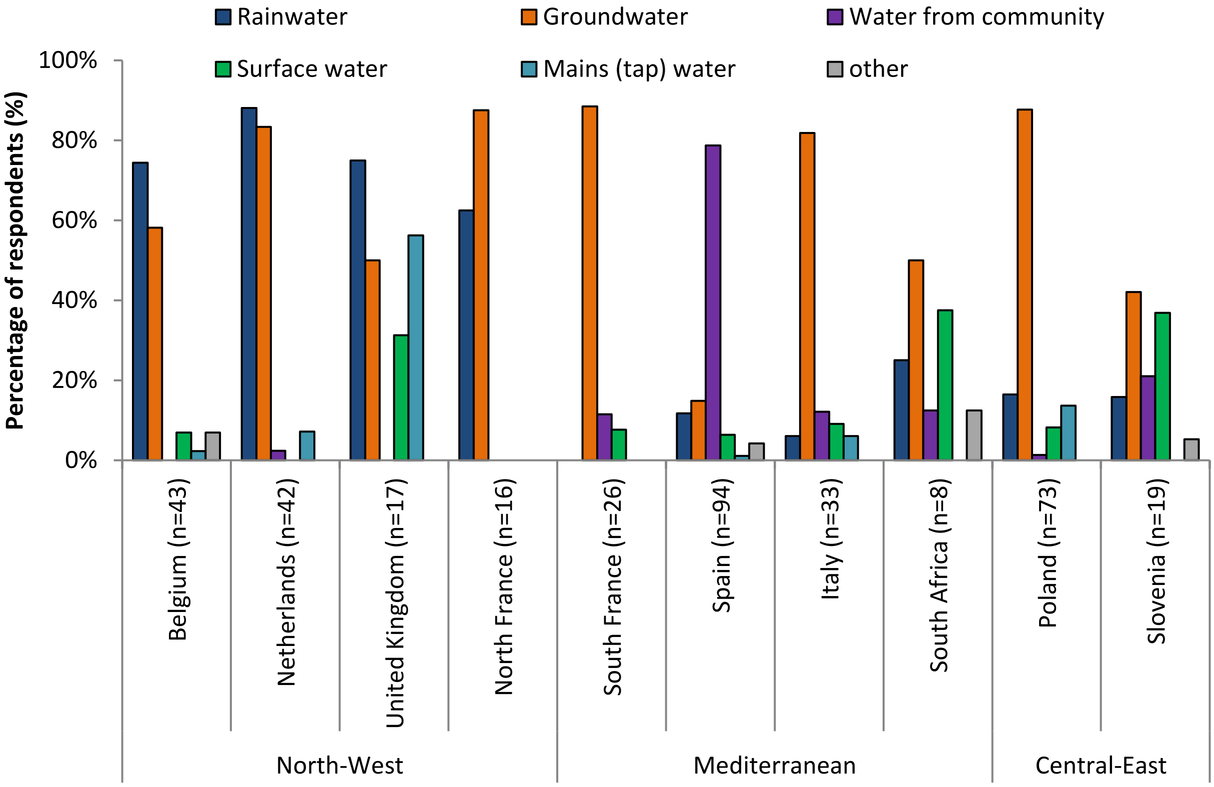

Figure 4 Type of fresh water source applied in each country

3.1.3 Diversification of water sources

Most of the respondents (62%) relied on a single water source while about 32% of the farms interviewed used 2 water sources. Only 6% of the respondents applied more than 2 water sources to fulfil the crops water demand (data not shown). There seemed a slight trend that farms with soilless grown crops rely on multiple water sources compared to farms where soil grown crops are cultivated. The regional trend is even clearer. Respondents in the NW region used more diversified water sources compared to their MED and CE colleagues (Figure 5). A possible explanation can be the fact that rainwater is used more frequently as a water source at these farms. Due to the discontinuous precipitation patterns and the limited storage capacity at these farms, a second or even third water source is present (see section 3.2.1.2).

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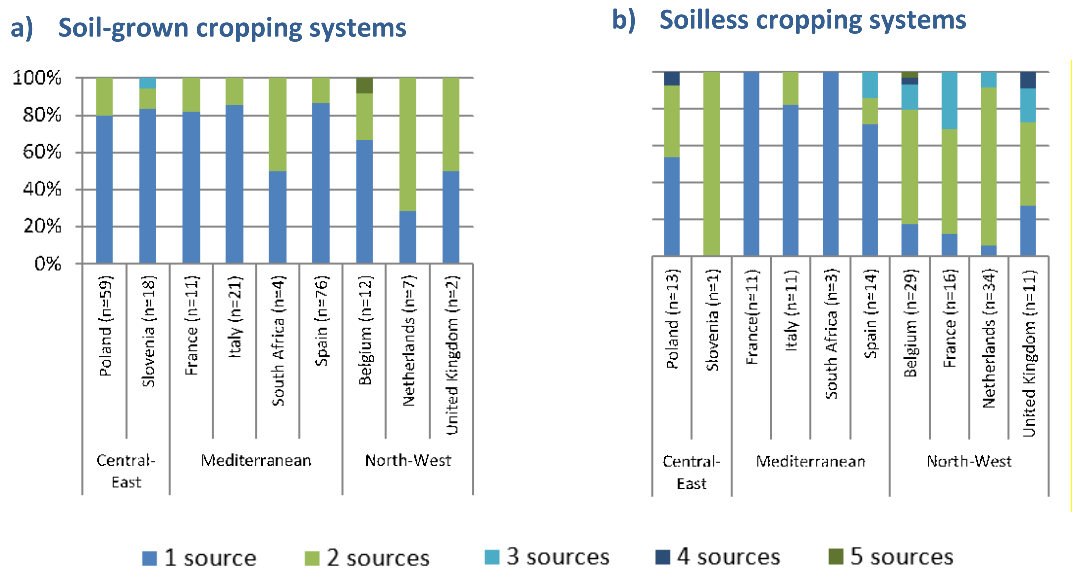

Figure 5 Number of water sources used in each farm that we investigated divided by country, with only soil-grown (a) or soilless (b) cropping systems

In the MED and CE regions, the available water sources seemed more limited. The majority of the MED and CE respondents reported using only 1 water source. A minority of the respondents reported as well the use of a second water source. The farms relying on only one or two water source are less resilient to shortage or quality problems (mineral composition and/or sanitary problems).

3.2 Problems faced regarding water supply

Part of the FERTINNOWA survey focussed on the problems faced by the respondents in the field of water supply. The questions focused on water availability, mineral composition, sanitary and chemical pollution of the water sources. The problems that the growers are facing differ not only between the regions that we investigated but within them as well (Figure 6).

Although water scarcity would be expected a serious issue in the MED regions, water quantity problems are more frequently reported by on average 50% of the NW respondents, respondents of the North of France excluded. In the MED region, 63% of the South African respondents reported problems related to water supply where this was only 43% in Spain, 21% in Italy and 8% in the South of France. Water quality problems were reported by the majority of respondents in Belgium (51%), the North of France (69%) and Italy (55%).

Problems related to chemical pollution of the water sources were reported by respondents in Spain (9%), Italy (15%) and the North of France (13%). Exceptionally Dutch, Polish and Slovenian respondents reported chemical pollution issues as well.

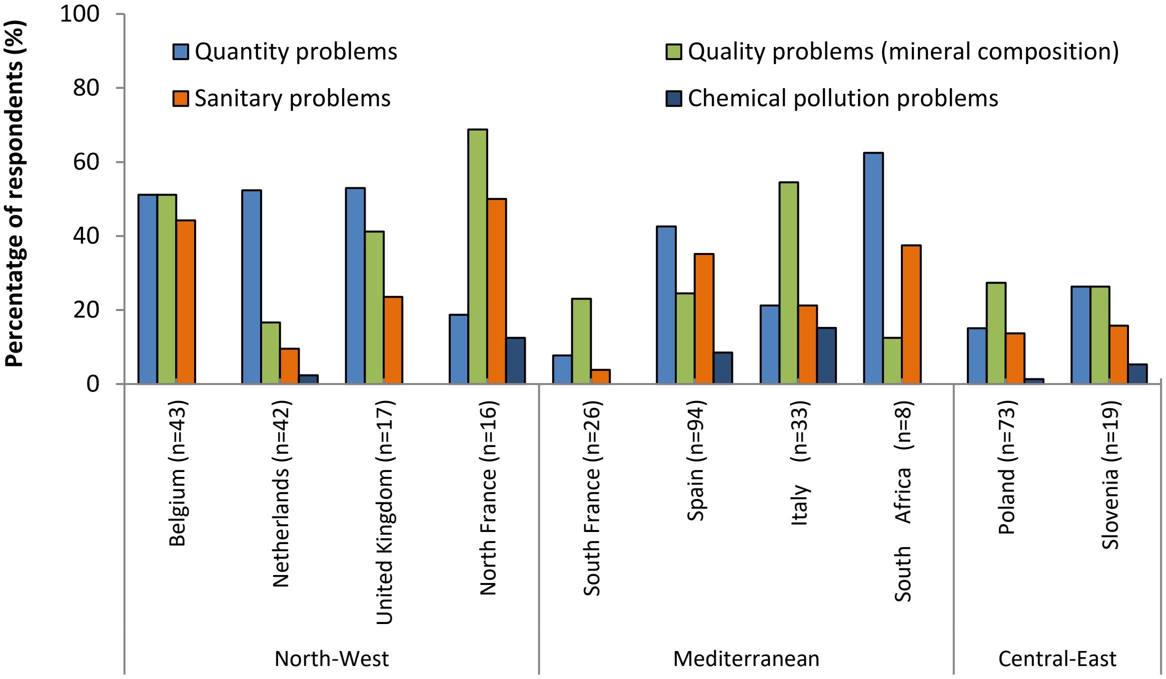

Figure 6 Overview of the problems related to the water supply that growers faced per surveyed country

3.2.1 Quantity issues related to water resource

When talking about water quantity issues one must always take into account the interaction between water availability and the crops water demand. While the latter might be more stable throughout the years, the water availability might vary significantly between years. The availability of water is highly depending on for example the climatically and hydrographical conditions of the region. Within years especially these climatically conditions, like precipitation pattern and amount can vary significantly. The crops water demand is depending on several factors as well like for example the specific crop type that is grown (tomatoes require more water compared to sweet pepper), the growing phase of the crop, the growing method (soil, substrate, outdoor or covered) and the irrigation method that is being applied (drip irrigation compared to overhead sprinklers). The irrigation water source must, therefore, be sufficient to cover the crops water demand throughout the growing season of the crop and to cover water supply variations between the years. Although water can be retrieved from several sources, some growers may have easy access to quite a few of these resources, while others experience difficulties getting sufficient water from one of them.

3.2.1.1 The occurrence of water shortage problems

On the surveyed farms applying rainwater or groundwater or both, shortage problems were reported to occur from March to September. Water shortage problems related to both sources peaked in July. Water shortage problems were reported more often by farms using rainwater (36%) (Figure 7).

Farms receiving water from irrigator communities reported to mainly experience water shortage issues in spring (March and April) which can be attributed in the insufficiency of water turns to meet the high crop water demand during the establishment. The problem then reoccurs in July with 10% of the farm having problems (Figure 7).

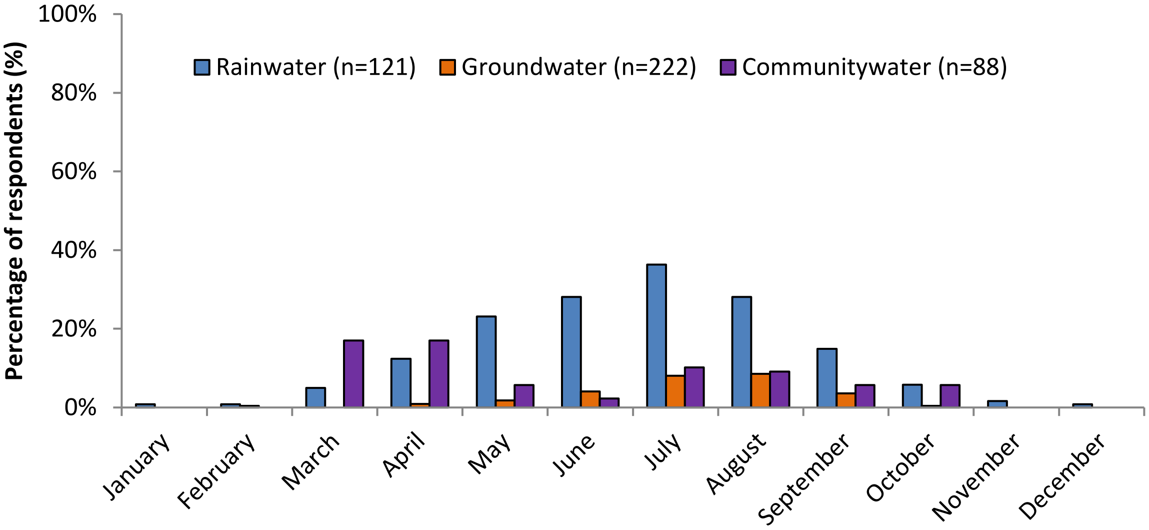

Figure 7 Water shortage periods over the year depending on water sources used by the farm

To deploy strategies for reducing the risk of water shortage it is essential to understand the causes of it. As an example, rainwater availability is highly variable over time because the annual precipitation volume might differ significantly between years. Whereas on average sufficient rainwater might be available per year, the precipitation pattern may not fit the crops water demand and thereby, periods of excess are followed by periods of deficit. As often water availability is not the sole reason behind this. Our results indicate that although water shortage was reported as the main reason for water quantity problems by 40% of farmers applying rainwater, 19% of all the farms applying rainwater harvesting, reported they experienced insufficient water storage capacity (Figure 8). Growers mentioned insufficient storage capacity for rainwater overwinter when precipitation is high. Rainfall frequency and limitations in storage capacity are two of the conditions that might be restricting a more extensive use of rainwater.

The survey revealed that growers using groundwater are suffering less from water shortage (8%) (Figure 9). Growers mentioned insufficient storage capacity for groundwater over summer when the needs for water are the highest (Figure 9). In these periods growers might opt to store groundwater at the farms as they might encounter restrictions on the abstraction volume (per day), as in some countries is regulated by legislation.

In the MED, especially in Spain and South Africa, quantity problems are mainly due to water shortages. About 17% of the cropping systems using water supplied by the irrigators communities (mostly located in MED) experienced water shortages.

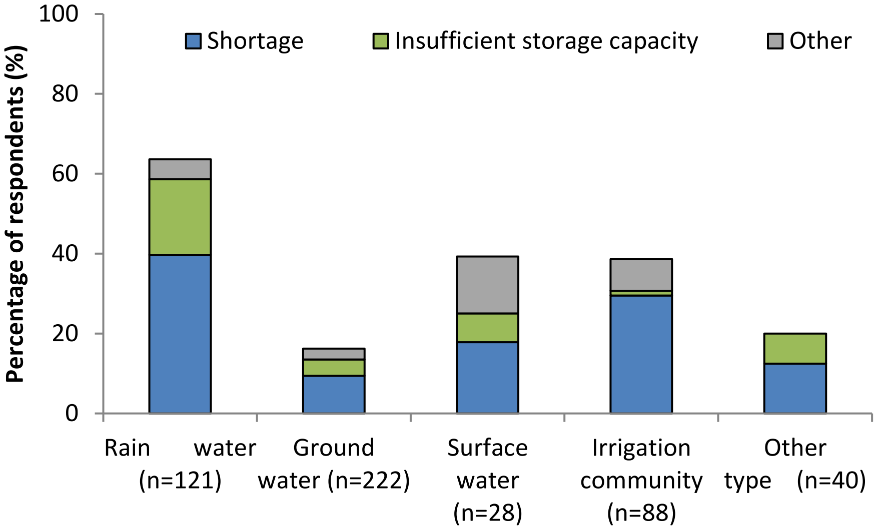

Figure 8 Reasons related to water quantity problems for different water sources

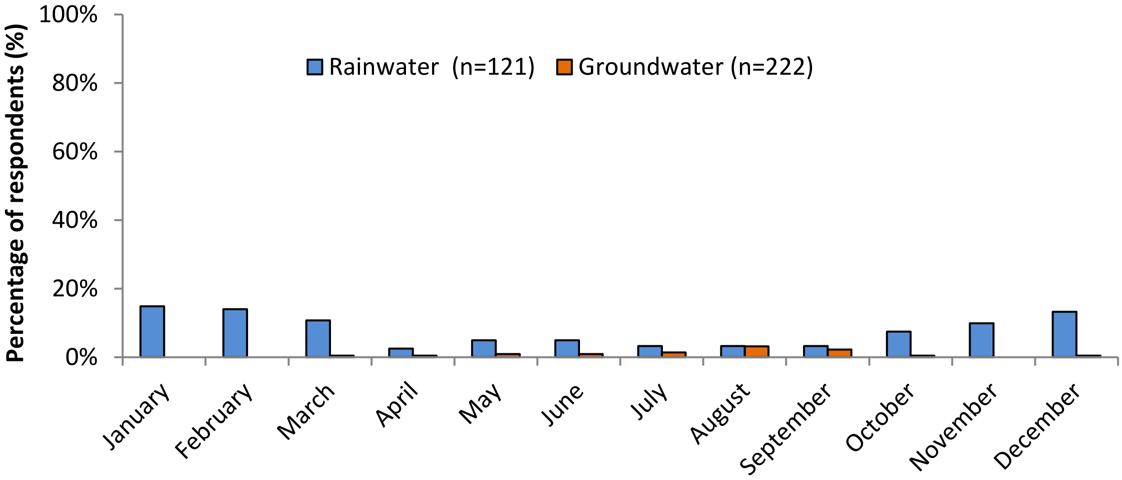

Figure 9 Periods of insufficient storage capacity over the year

3.2.1.2 Water storage

Water storage is one way to overcome water shortage issues. Therefore, part of the survey focussed on the current water storage practices at the surveyed farms.

At 61% of the surveyed farms water storage facilities were represented (data not shown). In the following section, storage of water refers to any type of water varying from rainwater to even nutrient solutions. In general, water storage facilities were provided more frequently at farms applying soilless growing systems compared to those with soil-grown crops (Figure 10).

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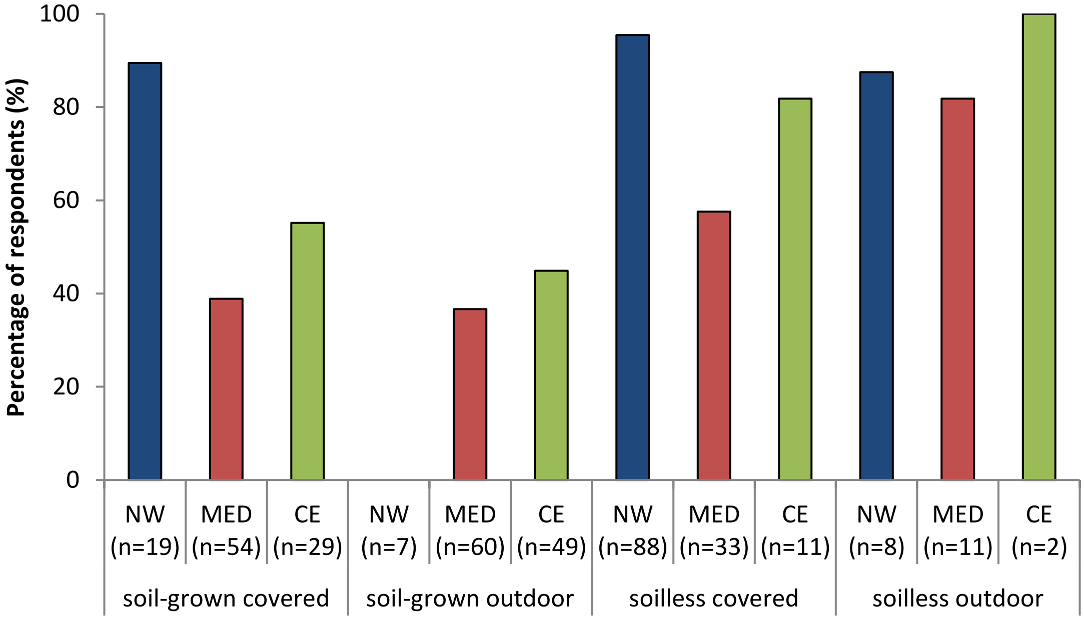

Figure 10 Proportion of farms reporting the use of at least one type of water storage by region and cropping system

The huge variety of the stored water types was as well reflected in the types of water storage applied by the respondents. In general, (un)lined water storage can be defined as larger scale water storages (more than 1.000m³) while water silos and underground tanks can be defined as smaller scale storages (less than 1.000m³). These smaller storage systems can be placed indoor (in case of greenhouses) or outdoor. A water storage system can either be built as an above ground, open-air basin or as an underground water tank. Most of the surveyed farms were using more than one type of water storage. As indicated in (Figure 101) the storage capacity extremely differed amongst the surveyed farms. As indicated above, the reason for this was the broad variety of water sources stored by the surveyed farms.

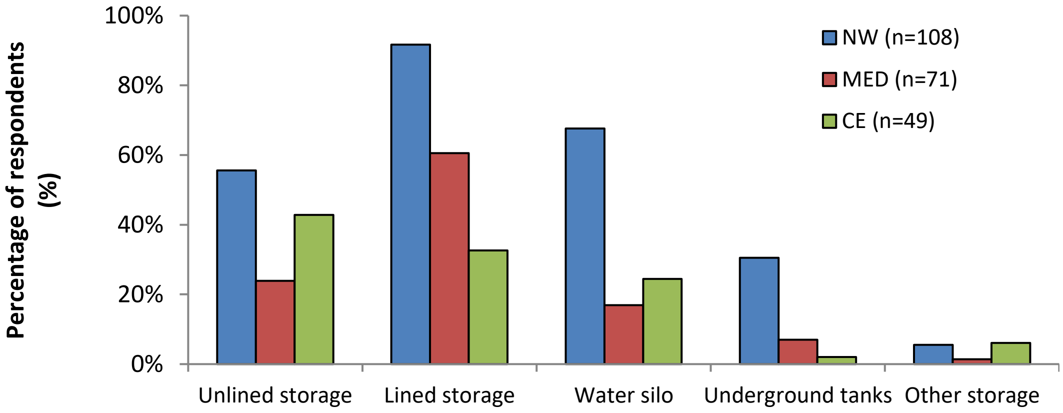

Figure 11 Proportion of respondents using the different types of water storages by region

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Unlined and lined reservoirs

Unlined and lined water reservoirs were the most applied systems according to our sample. In general, 43% of the grower reporting to store water used a lined reservoir (Figure 11). In the NW, 91% of the respondents used it. Unlined water storage or ponds were as well reported by 55% of the NW respondents and by 42% of the CE respondents. The use of larger lined or unlined reservoirs was more extended at the NW region compared to the CE and MED, which attributed to the higher use of rainwater (CFR. section 3.1.2). In the CE unlined reservoirs were indicated as the most common way to store water (42%). (Un)lined reservoirs were mainly used to store rainwater, community water or groundwater (data not shown).

Water silos

Water silos were used by 32% of the farms reporting to store water. 68% of the respondents in the NW reported to use it while less than 25% of the MED and CE respondents reported the use of water silos. Water silos were used mainly to store nutrient solutions, drain water or groundwater (data not shown).

Underground storage

31% of the farms storing water in the NW reported using underground tanks. In the other regions, this ratio is very low. They were used mainly to store drain water or nutrient solution (data not shown).

3.2.1.3 Problems related to water storage

Microalgae – Algae

Microalgae or algae further referred to as algae, are very simple, usually small (micro) plants that grow in or near water and do not have ordinary leaves and roots[2].

The presence of algae was identified as the main problem related to water storage. Problems related to algae were reported by growers in almost all the surveyed countries (Figure 12). Algae blooming can be associated both with the water source (nutrient content) or the water storage (exposure to light) used. In Belgium, 28% of the respondents mentioned having algae problems. Frequently, the problem occurs at those farms which store rainwater in uncovered storages. In Spain, 24% of the respondents have been reporting algae problems. Discussions with experts indicated that in Spain the water supplied by irrigators communities is often transited by open canals, increasing the risks of developing algae. In Poland, the problem was associated with the frequent use of unlined water storage with 19% of the respondents reported algae problems.

When growers were questioned regarding the applied practices and technologies to overcome algae problems, it became clear that the surveyed growers acted in various ways Table 2 provides an overview with the reported practices. Practices are listed according to the frequency they were reported in the survey. 9% of the growers affected by algae proliferation in storage mentioned that they had not found any solution to the problem so far.

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[2] Definition retrieved from the Cambridge dictionary.

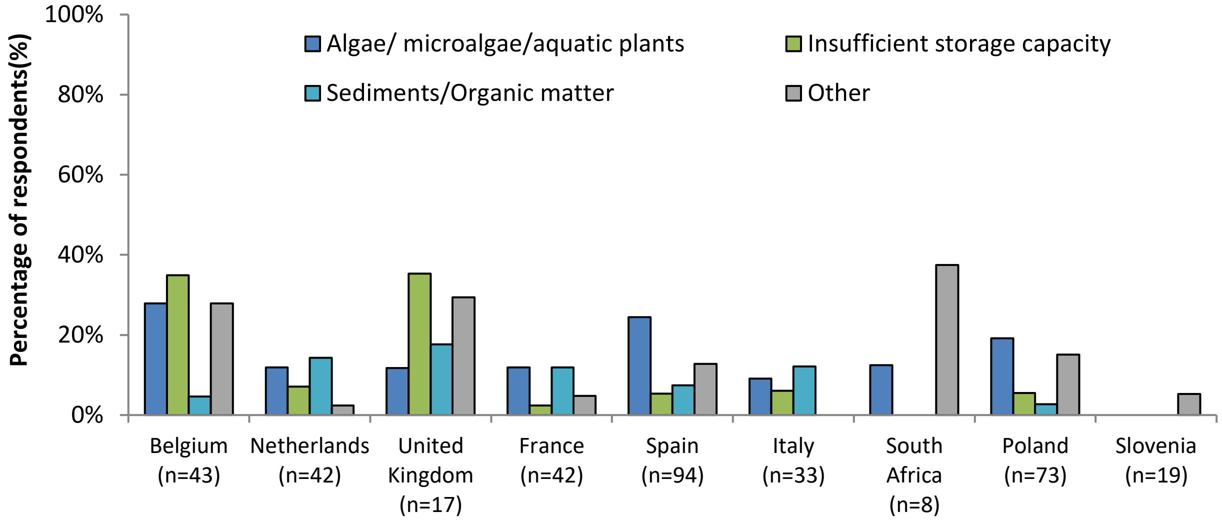

Figure 12 Percentages of respondents who expressed problems related to water storage, by country

Table 2 Overview of the practices and technologies used to overcome algae problems

Practice/technology	Evaluation by the respondents
Filtration	Filtration was the main practice used (28% of respondents) to treat algal blooms in their water storage. Although identified as the main practice, respondents had varying opinions about its efficiency. They considered filtration to be time and labour consuming as the system required frequent maintenance to avoid issues such as clogging.
Obscuring/covering	25% of respondents covered their water storage to avoid exposing the water to light. Respondents using obscuring techniques were mainly located in the NW region, and their satisfaction rate seemed higher compared to those using filtration.
Cleaning the water storage	The same percentage cleaned the water storage itself, although they considered it a tedious solution. Respondents also considered storage cleaning as time and labour consuming.
Chemicals	A minor number of respondents, especially in the MED region, applied chemical products (copper sulphate, sodium hypochlorite, chlorine, potassium permanganate, nitric acid, etc.) but use of these might be restricted by legislation.
Aeration	Systems like artificial aeration, which increase turbulence and prevent stratification or ultrasonic, were also used although mainly in the NW.
Ultrasonic devices	
Fishes	Using fishes is a known, affordable and low labour solution and was used by growers in the NW and CE regions, but interviewees also have reported some disadvantages, such as fish proliferation adding organic matter to the water via defecation).

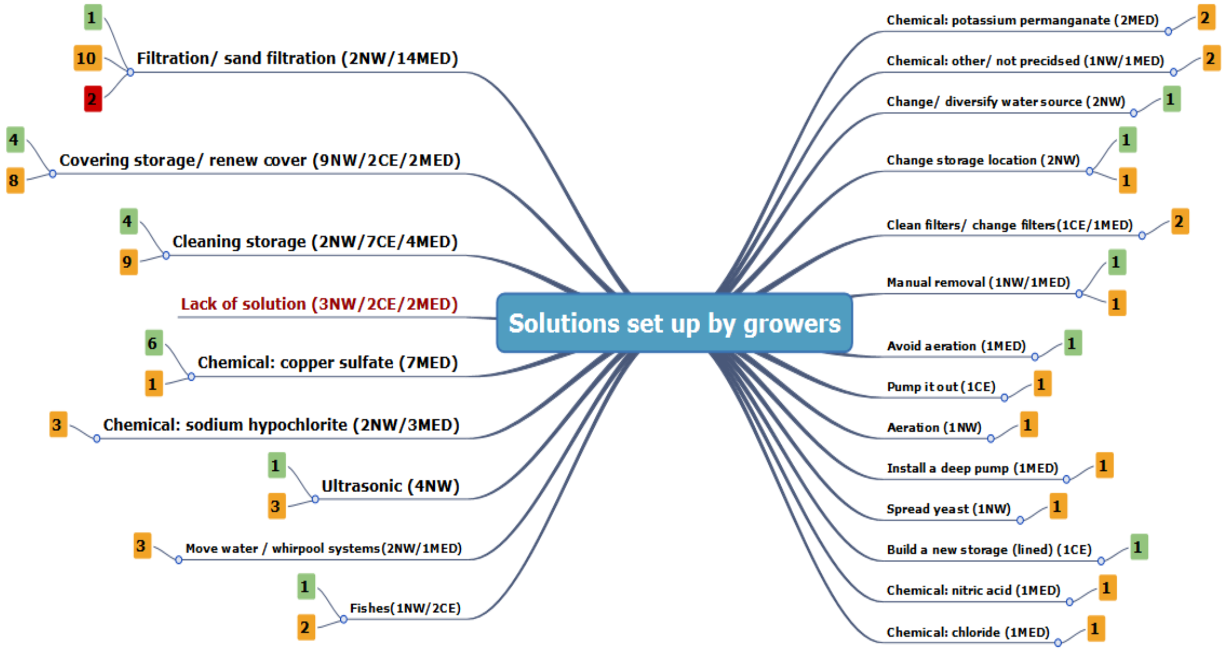

Figure 13 Solutions set up by respondents to avoid algae proliferation in their water storage. The coloured figures indicate the respondents' satisfaction rate (green: satisfied to very satisfied, yellow: moderately satisfied, red: not satisfied). The numbers in the coloured squares reflect the number of respondents per satisfaction rate

Sediments

The presence of sediments or organic matter in the water storage was also mentioned by growers in almost all the countries (Figure 12). For the problems associated with sediments and organic matter, growers were using similar solutions as those for algae. Respondents seemed to apply multiple practices or technologies to overcome problems related to sediment disposal in the water storage. 42% of the respondents reported cleaning the water storage to deal with sediment disposal. The growers applying this practice reported being moderately to very satisfied with the effect. Of the growers reporting sediment problems, 31% listed filtration as a possible solution. 66% of these growers were moderately satisfied with the effect. Installing a new liner or building a new storage was listed by 15% of the respondents. 31% of the respondents expressed not having found a suitable practice or technology yet to solve problems related to sediment disposal (Figure 14).

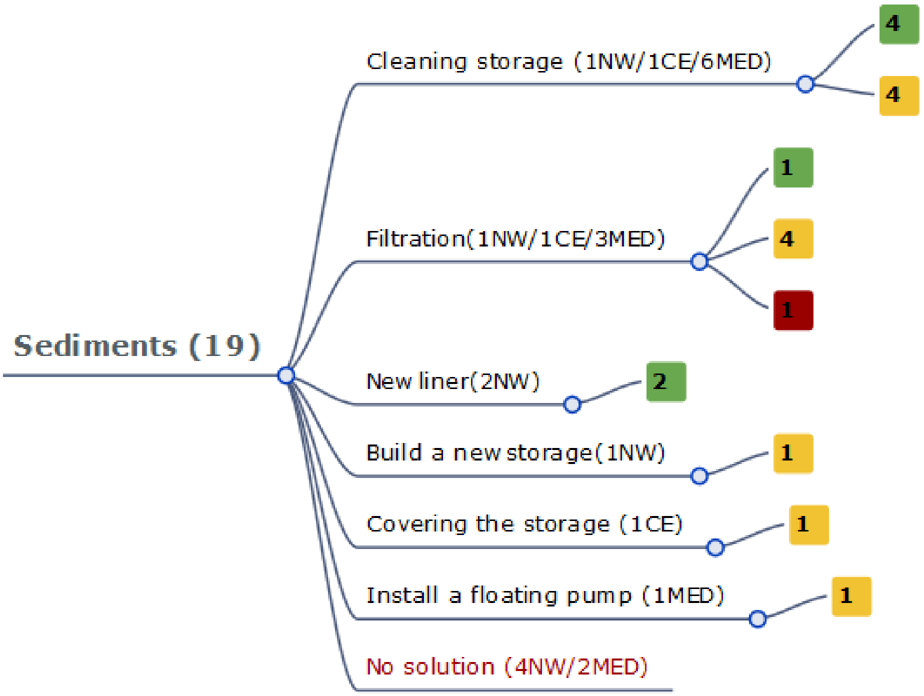

Figure 14 Solutions used by respondents to avoid sediment and organic matter issues in water storage. The coloured figures indicate the respondents' satisfaction rate (green: satisfied to very satisfied, yellow: moderately satisfied, red: not satisfied). The numbers in the coloured squares reflect the number of respondents per satisfaction rate

Other issues

A substantial number of other problems were reported by a considerable group of respondents in Belgium (27%), UK (29%), Poland (38%) and South Africa (15%).

In this category, 35% of respondents, mainly located in the MED and CE regions, considered evaporation an issue. Three growers (CE and NW regions) covered their storage to avoid evaporation losses, while another relocated the water storage (MED region). The remaining respondents did not take any further action to solve the problem. Another 12% reported other problems.

These other problems included problems with sanitary issues (other than algae), water temperature, water evaporation, leaking water storage, and fish and bird droppings (Figure 15). The solutions used were generally considered to be moderately satisfying, however, some issues are often unsolved because they are both minor and no technological solutions have yet been developed.

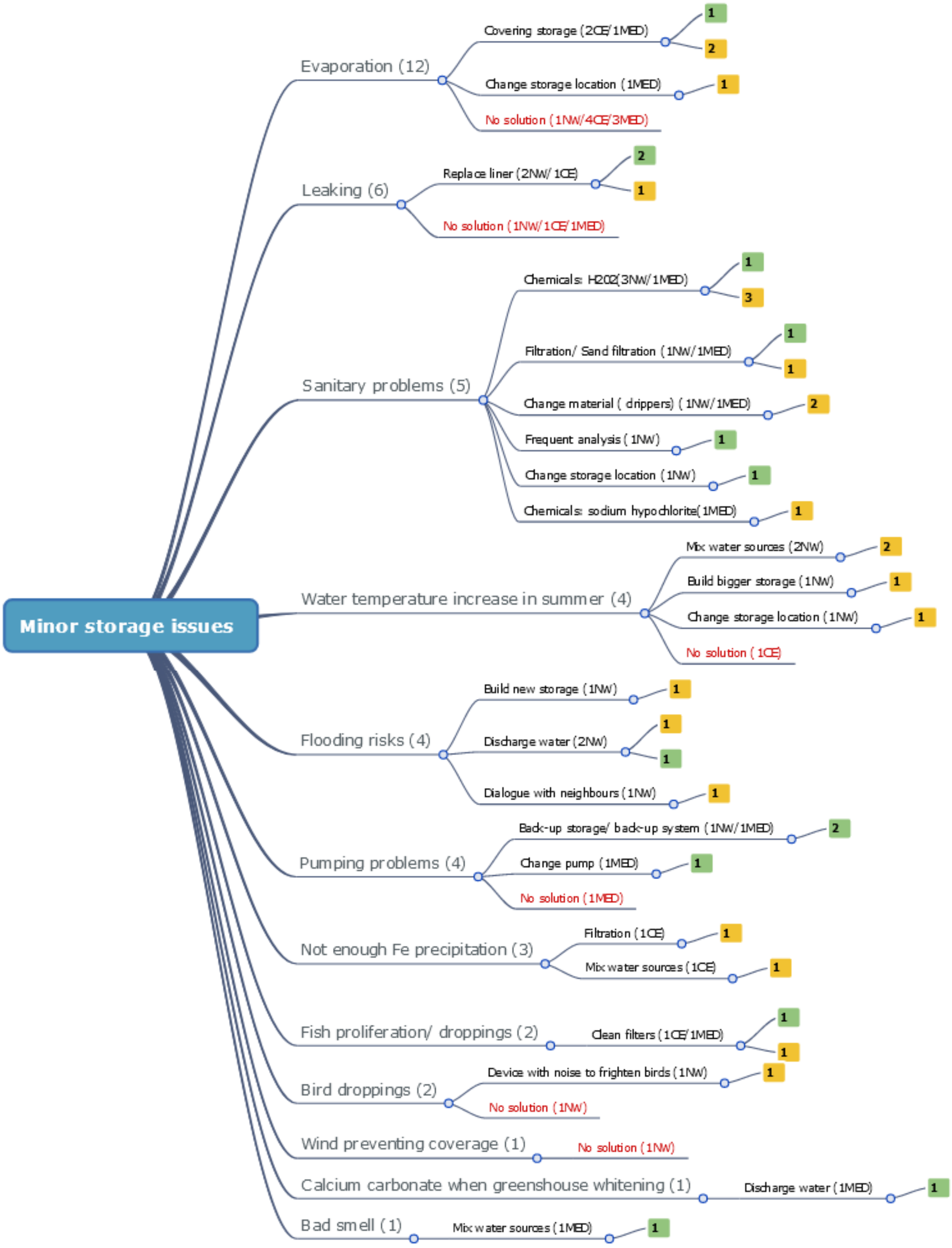

Figure 15 Minor problems that respondents are facing related to water storage. The coloured figures indicate the respondents' satisfaction rate (green: satisfied to very satisfied, yellow: moderately satisfied, red: not satisfied). The numbers in the coloured squares reflect the number of respondents per satisfaction rate

3.2.2 Mineral quality problems related to water sources

Irrigated agriculture is reliant on a suitable water supply of usable mineral quality. Water quality criteria for irrigation can vary greatly. The suitability of water for irrigation is determined not only by the total amount of salt present but also by the type (dependent on the region and water source). As the total salt content increases, various soil and cropping problems can occur, and special management practices may be required to sustain yields. The soil problems most commonly encountered were related to salinity, water infiltration rate, and toxicity, and are affected by climate, soil, and crop, as well as by the skill and knowledge of the water user.

Respondents overall were satisfied with their water quality, rated on a scale of 1-10. The mineral quality of rainwater and mains tap water had the highest satisfaction rates (on average 9). Respondents were also fairly satisfied with groundwater quality (average score of 8), even though we observed some differences between countries. For example, Spanish respondents rated groundwater quality slightly lower (satisfaction score of 7 on average) whereas Slovenian respondents highly rated it (9). Even within countries, differences occurred. Community water was rated 7,6 on average, and surface water 7,7. Respondents were generally satisfied with the quality of drain water (7), desalinated water (8,5) and other types of water as well (8). One exception was the respondents using disinfected urban water, where two out of the three respondents rated it 5 to 5,5.

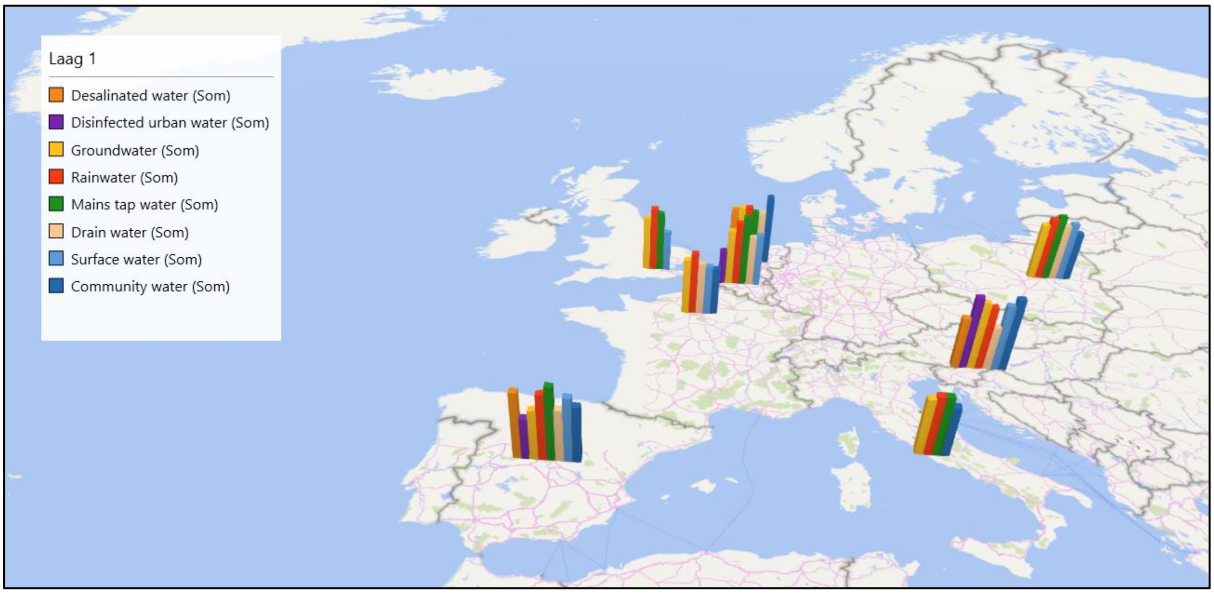

Figure 16 Average rate of the water quality on a score of 10

Only, 32% of respondents mentioned facing mineral composition problems. Most (63%) reported that the problem was minor or rare (Figure 16). Respondents using recycled drainwater encountered mineral composition problems more often than respondents using fresh water sources. Respondents who used rainwater rarely encountered mineral quality problems.

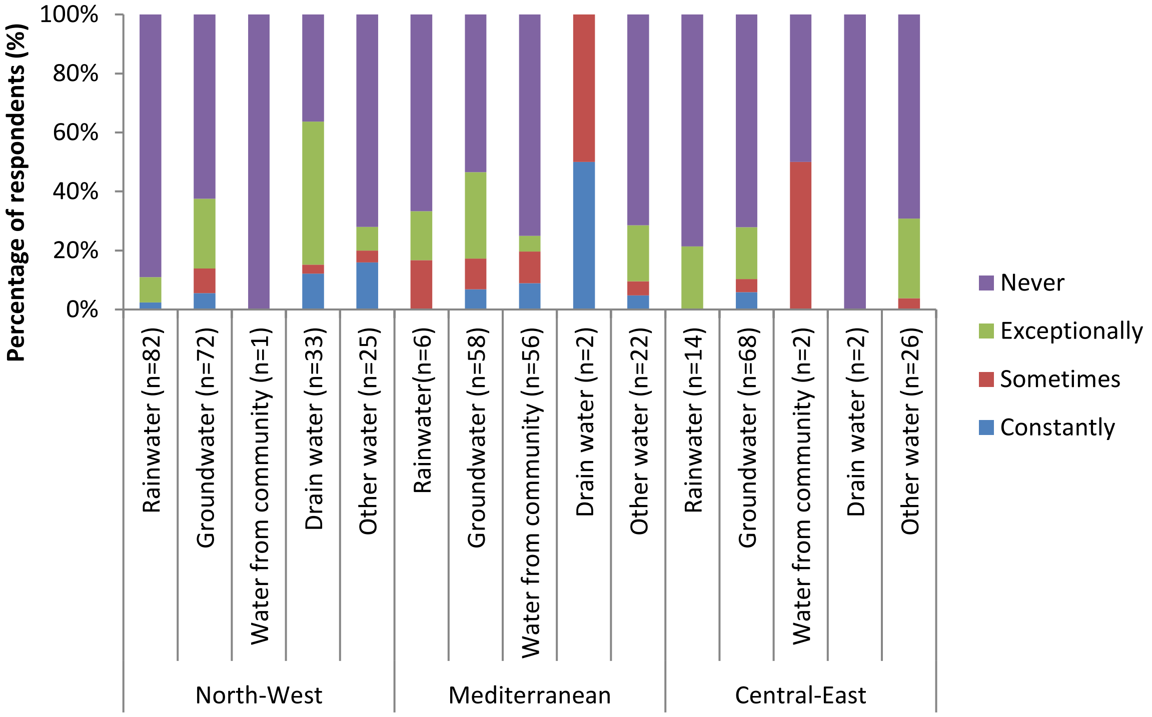

Figure 17 Proportion of responders facing water quality problems on the supplied water and frequency occurring

The growers were asked about their main mineral composition problems and the measures they were taking to resolve them.

3.2.2.1 Iron

High concentration of iron was reported the most concurrent mineral quality problem (6% of the respondents), mainly in Poland and NW region (data not shown). Figure 18 shows some of the solutions implemented by growers to mitigate its effects, as mixing water sources, adjusting the nutrient input, filtration or water treatment. The respondents' opinion about the efficiency of these techniques differed. Some growers reported a lack of technical solutions.

3.2.2.2 EC, sodium

High EC values were reported as a problem in Spain and Poland and in recirculated water (data not shown).

Respondents used different treatments to resolve mineral issues, for example, 24 systems used reverse osmosis, mainly for raw water treatment. Those respondents were mainly located in the Netherlands, and they installed the system because of their poor groundwater quality (high EC). Most respondents considered it to be highly efficient and the best available practice.

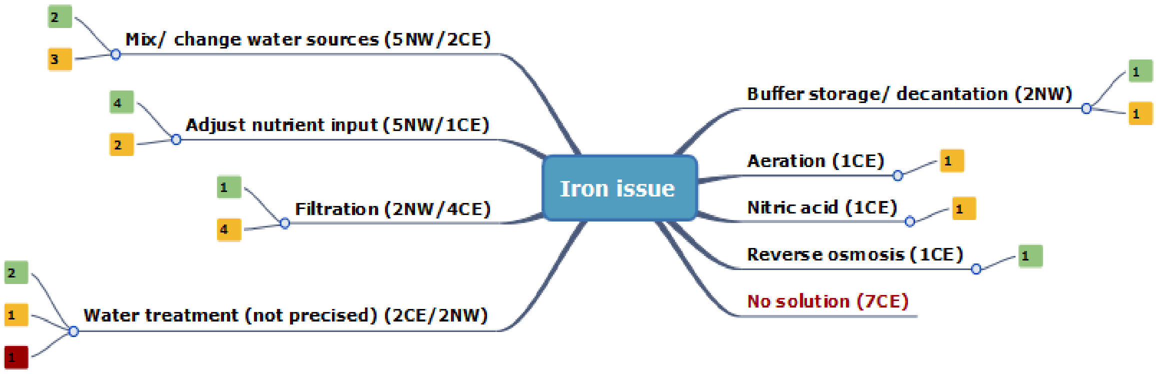

Figure 18 Solutions implemented by growers to mitigate iron issues The coloured figures indicate the respondents' satisfaction rate (green: satisfied to very satisfied, yellow: moderately satisfied, red: not satisfied). The numbers in the coloured squares reflect the number of respondents per satisfaction rate

3.2.2.3 pH and hardness

Regulation of pH and hardness were considered secondary problems, but are important parameters which may influence the composition of the nutrient solution and/or can cause dripper clogging (Figure 19). pH regulation was more of an issue for those who used rainwater (data not shown).

To address pH issues, some respondents added acid to their source water (e.g in Italy), and they considered it a cheap and safe method to avoid clogging in the system (from dissolved limestone), while also supplying nitrogen to the crop. Some respondents used Maerl filters to stabilise the pH (e.g in France).

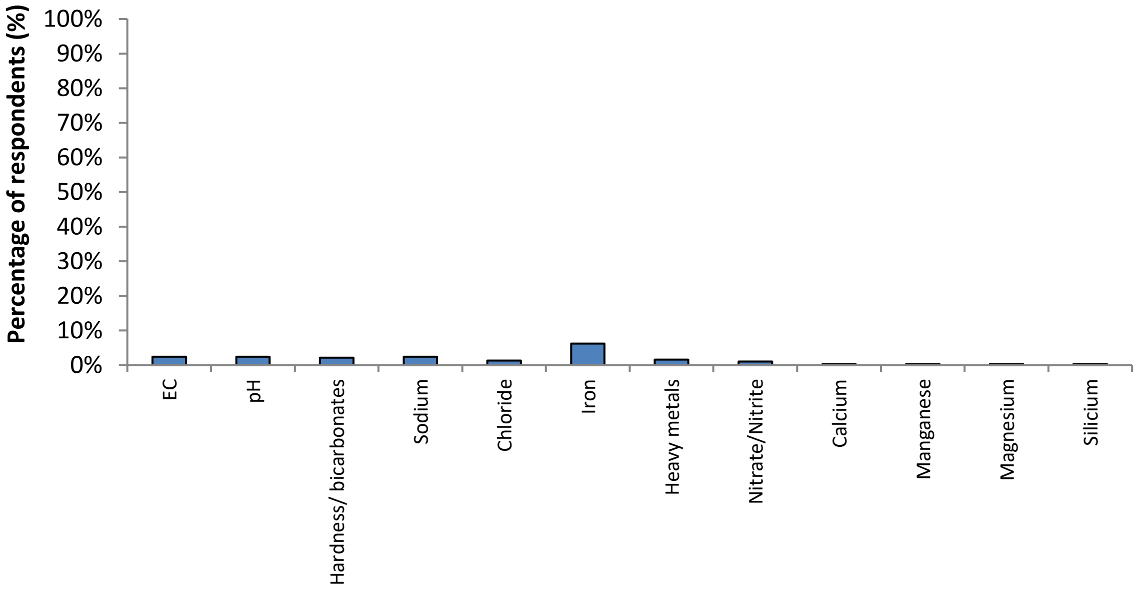

Figure 19 Proportion of respondents facing problems related to water chemical quality

3.2.2.4 Bottlenecks linked to the adoption of technologies to prevent mineral issues

Although some respondents were aware of available technologies to improve mineral water quality, several factors limiting their implementation were highlighted; respondents either considered the investment cost too high or scored mineral water quality issues as being of lower importance. This is particularly the case for adoption of deironisation techniques in the CE region and reverse osmosis in the MED region (Figure 20).

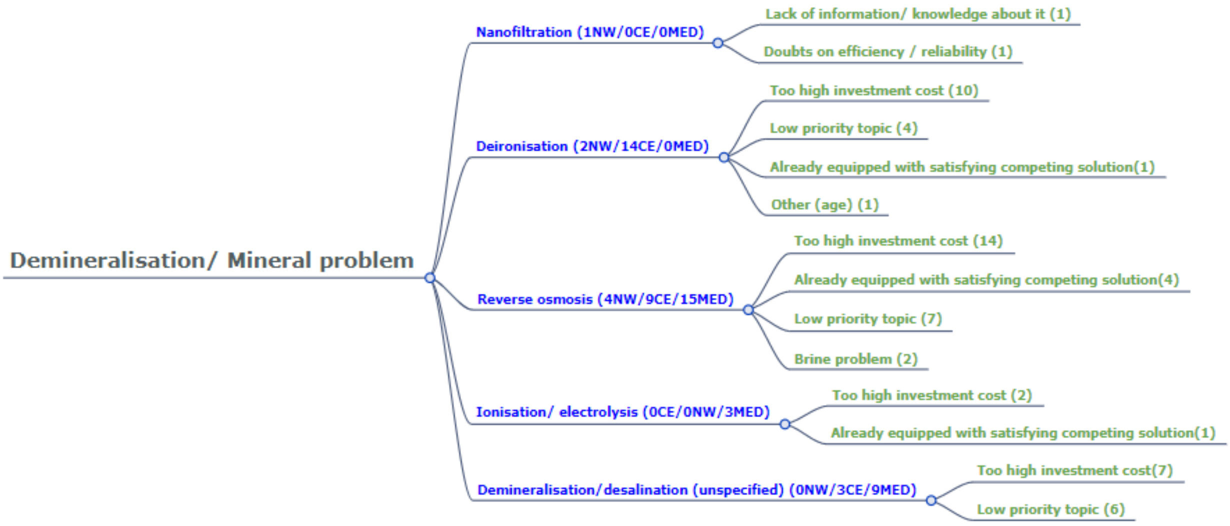

Figure 20 Reasons limiting the adoption of demineralisation treatments

3.2.3 Sanitary problems related to water resources and storage

Irrigation water can act as an inoculum source or spreading mechanism for a range of biological problems including plant pathogens, algae and biofilm-forming organisms. Plants can be repeatedly inoculated with pathogens, whether via the original water source or by pathogens entering the irrigation system at various points. Our survey allowed respondents to indicate the sanitary problems they faced and the actions taken to limit them. Of the respondents, 39% reported facing sanitary problems, even if rarely. However, in some cases, the problems occurred several times per year (data not shown). Based on the survey data, it was not possible to distinguish whether the problems were associated solely with the water source type or the storage as well. In almost all water types, except tap water, bacterial problems were mentioned. Respondents reported problems with *E.coli*, *Agrobacterium rhizogenes*, other coli forms, and *Pseudonomas* (species not specified). Fungal problems including *Phytophtora spp., Pythium spp., Fusarium* spp. were more pronounced in recirculated drain water. Other problems included salmonella and the formation of biofilms.

As mentioned before, algal blooms appeared to be the most common sanitary problem in rainwater and water supplied by an irrigation community. Irrigation water that is collected in catchment basins or irrigation recirculation systems, were characterised by elevated levels of physical, chemical, and biological contaminants that result in lower water quality, compared with other water sources (Figure 21).

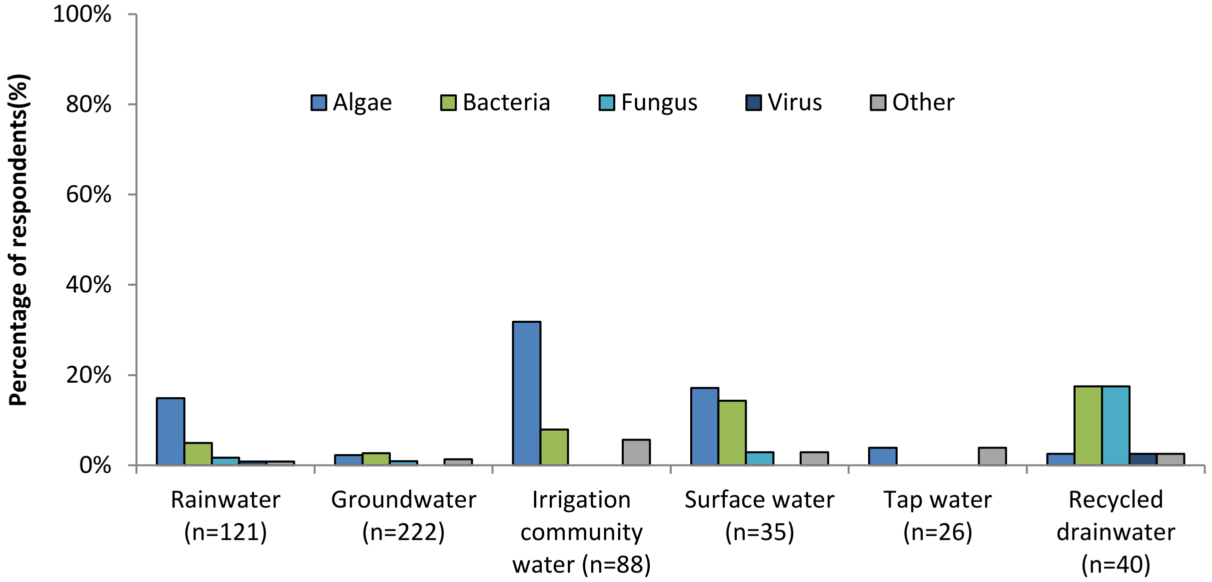

Figure 21 Types of sanitary issues faced by respondents on different water source types

Technologies to improve sanitation were incorporated into horticulture irrigation systems to i) control pathogens (human and plant), ii) improve plant health, iii) prevent the development of secondary inoculum or protective overwintering structures, and iv) prevent clogging of the irrigation system due to bacterial growth. These technologies include filtration, chlorination, ozonation, UV light, use of activated peroxides, chlorine dioxide, heat, or other technologies to treat irrigation water. (Figure 22) shows that respondents were well aware of the different treatment options, however, they often considered the investment cost to be a major obstacle towards adopting them. In general, respondents already using one of these technologies were well aware of the alternatives. These respondents were asked why they opted for their current technology above other known technologies.

- Disinfecting water using UV light was the most common disinfection method, used in 10% of the cropping systems. Respondents mainly in the NW region used this technology. It was used at several stages throughout the irrigation system: in 45% of the cropping systems using UV, it was applied to fertigation water (water including a nutrient solution), in 43% it was applied to drain water (or a mix of supplied water and drain water) and in 49% of systems on the supply water itself (raw source or mix of sources). Respondents who used UV disinfection were generally satisfied with the technology (data not shown). The respondents considered UV light to be one of the most efficient disinfection techniques as it is free from chemicals and considered safe. Some respondents also appreciated its compactness compared to biofiltration, its lower price, and the possibility to have continual disinfection using automatic measurement and adjustment. However, there were respondents who doubted its efficiency and mentioned its restricted flow capacity.

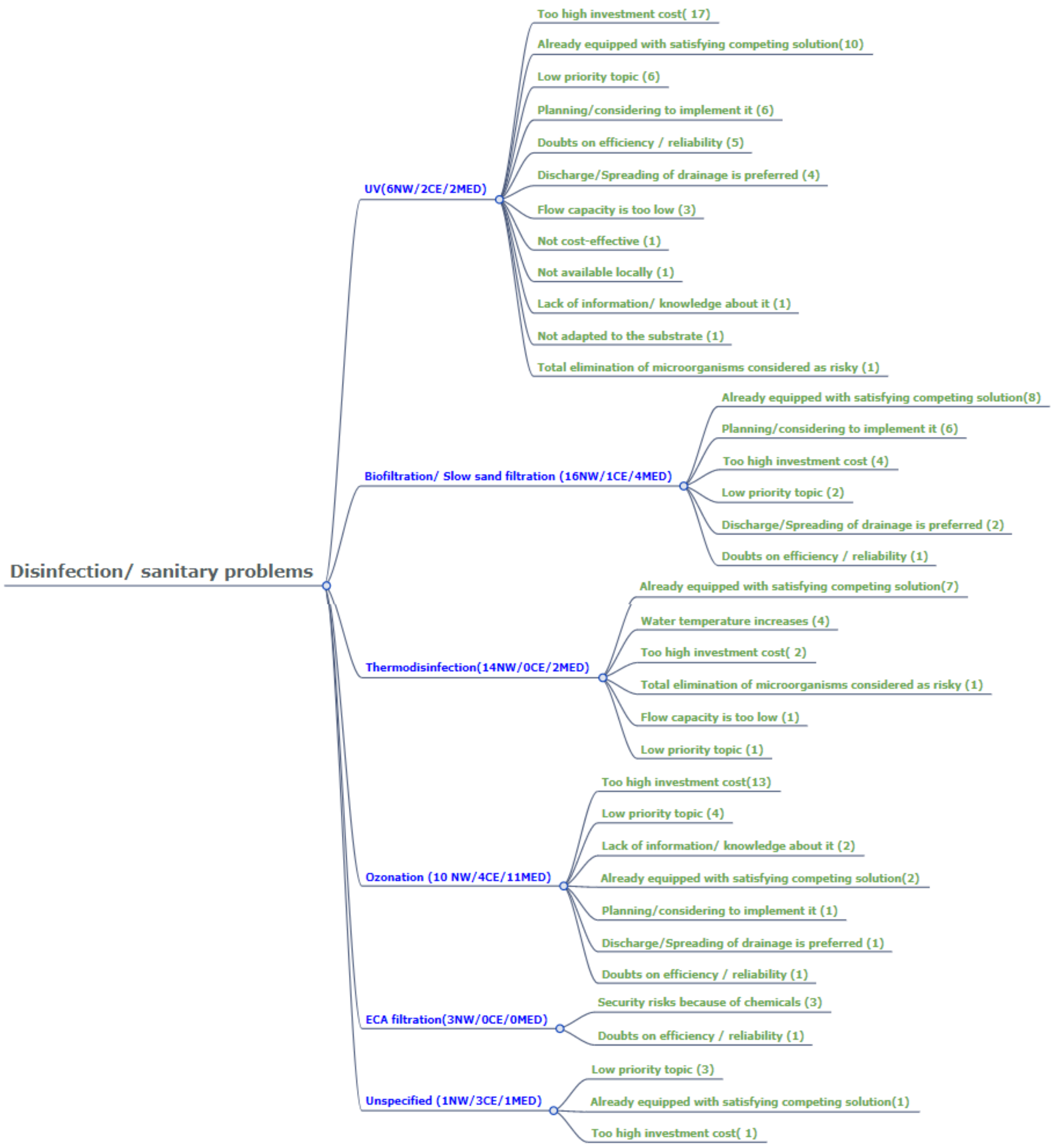

Figure 22 Bottlenecks towards the adoption of disinfection technologies

- Biofiltration and/or slow sand filtration were used in 1,9% of the cropping systems specifically for their drain water, mainly in Brittany, Belgium, the Netherlands, and South Africa. Some respondents mentioned that they preferred to maintain a balance of microorganisms instead of completely disinfecting the water. Respondents reported it to be a reliable, low maintenance and simple to manage (no technical and human constraints) compared to other disinfection systems, even if quite a lot of space is needed.
- Thermodisinfection was used by only three respondents (0,8 % of the sample) to treat drainage water in Belgium and the Netherlands. Two of the respondents believed that

it is more effective than using UV light. A third specified that UV disinfection is not 100% efficient against bacteria if particles remain in the water.

- Ozonation was used by only four respondents, mainly in the Netherlands. Although reported to be efficient, the respondents did not give further information.
- The use of chemicals to disinfect water was reported by a lot of respondents. However, they preferred not to use them due to the high cost and associated safety risk (Figure 22)

Hydrogen peroxide was used in 8% of the cropping systems. It was used either on the supply water, the fertigation water, or the drain water. It was used as a security measure to prevent drippers clogging, and to keep the systems clean. It was considered a cheap solution by respondents which can serve as a solution to different problems.

Chlorination was used by 5% of the respondents and was used to treat the raw source water (raw or mixed), the drain water, or in the nutrient solution. Few respondents used it more than one stage of the irrigation system. Again it was considered to be a cheap and efficient way to keep the water clean as it is also easy to adjust. Some respondents mentioned that they preferred to use alternatives for chlorination and were contemplating a shift to these alternatives in the near future.

Figure 23 Bottlenecks towards the use of chemicals to disinfect water

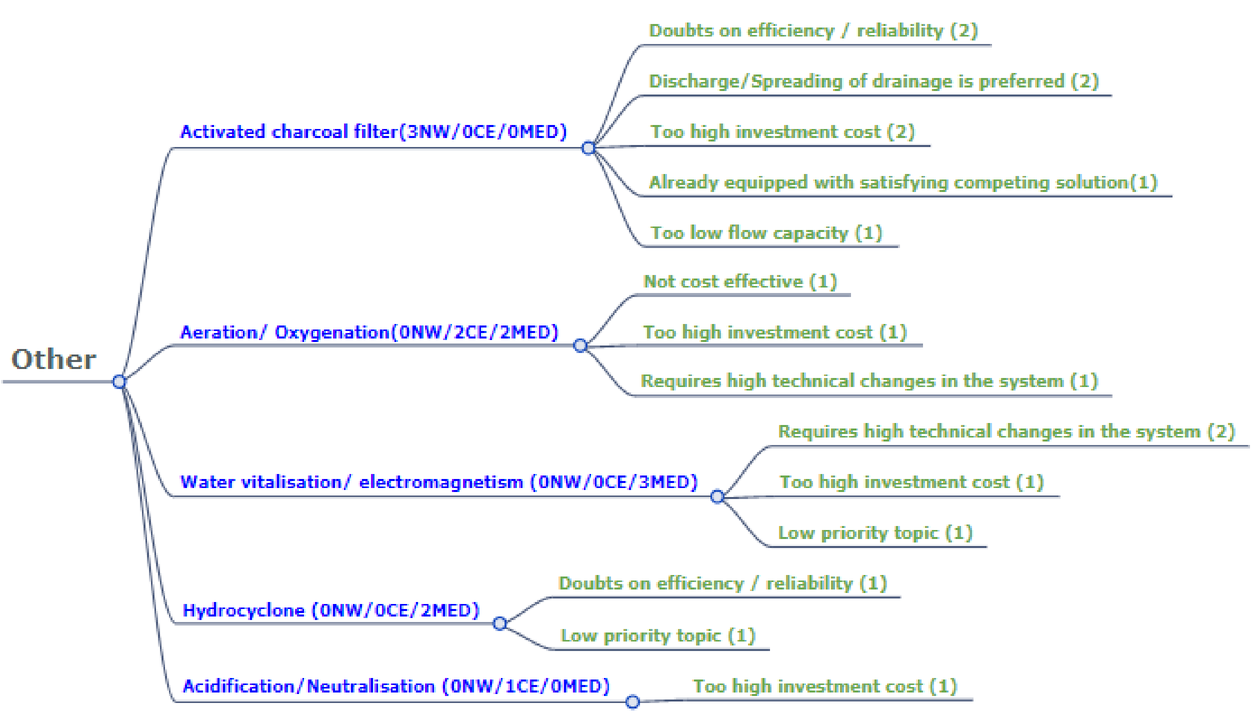

Figure 24 Bottlenecks towards the adoption of other water treatment

- Other treatment options included electrolysis which was used by only two respondents (from Belgium and the Netherlands); they gave positive feedback on the method. They were advised by researchers on how to use it. Activated charcoal filters were used by only four respondents in Belgium, and they remarked that they could physically see the effects of the filter, especially when dealing with iron. (Figure 24) shows that other treatment solutions are known to respondents, but they needed more evidence of the efficacy of the treatment and finding these other solutions was often considered a low priority.

3.3 Socio-economic aspects

3.3.1 Impact of an individual or collective water supply

Water supply management is strongly related to socio-economic parameters. Irrigation water supply (choice of the water source, quantity monitoring) is either managed individually by respondents (NW and CE regions) or collectively by local irrigation communities (MED and CE regions). This influences the level of control that growers have on their water use and their water management practices.

In regions where water was managed by the growers (at farm level), precise and reliable water consumption data were not always recorded (e.g. in case of groundwater or rainwater use). However, in regions where water was managed by irrigation communities, water consumption data were stored (because the grower has to pay the irrigation community). In the case of irrigation communities, any actions (addition of fertilisers, number of water turns) were decided collectively.

3.3.2 The cost of water

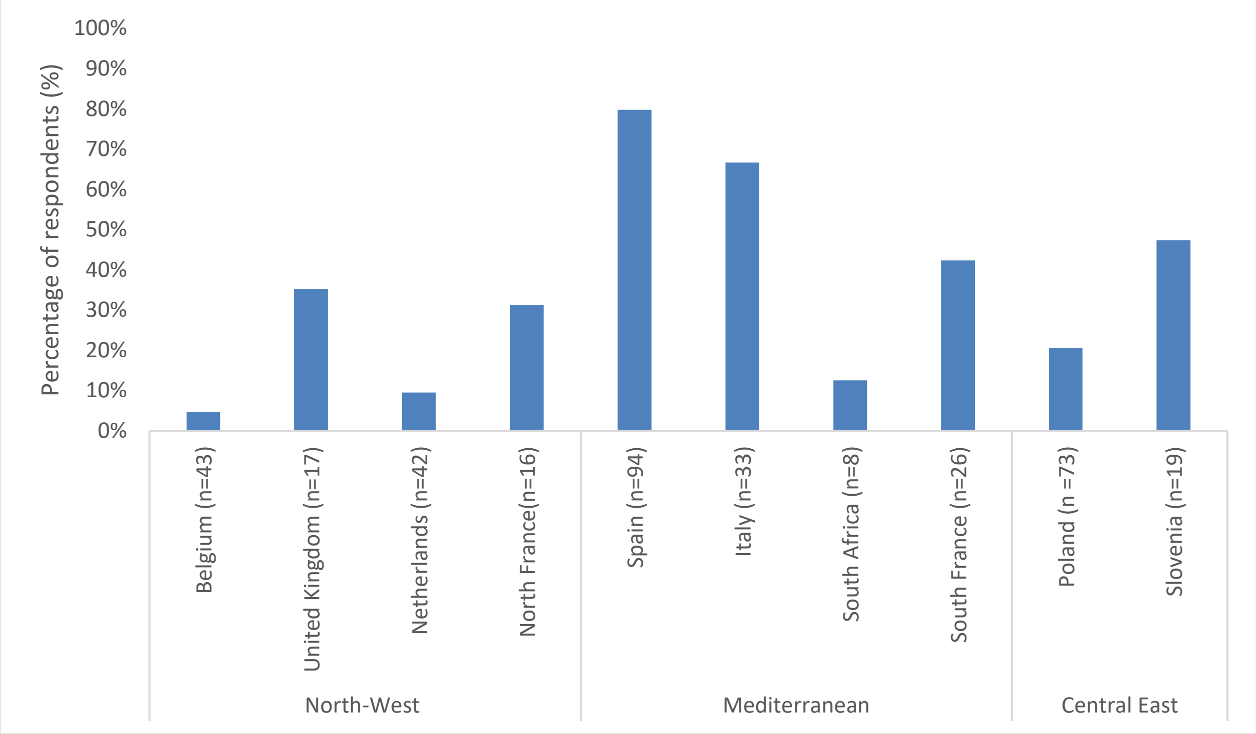

Figure 25 Overview of the percentage of respondents that provided an indication of the cost of water

Rainwater

Although rainwater was the primary water source for irrigation in most of the NW region (section 3.1.2) only 1 grower provided an indication for the cost of rainwater. While 3 growers indicated this water source as a costless water source (data not shown). Growers did not refer to the initial investment costs for water storage.

Groundwater

30% of the respondents, provided an indication of the cost per m^3 of withdrawn groundwater. The reported prices differ strongly between countries but even within countries (Figure 26). In Poland, for example, prices ranged between €0,05 to 0,93 per m^3. From the respondents answers, it was not always clear if costs for post treatments of the groundwater were included in the reported prices.

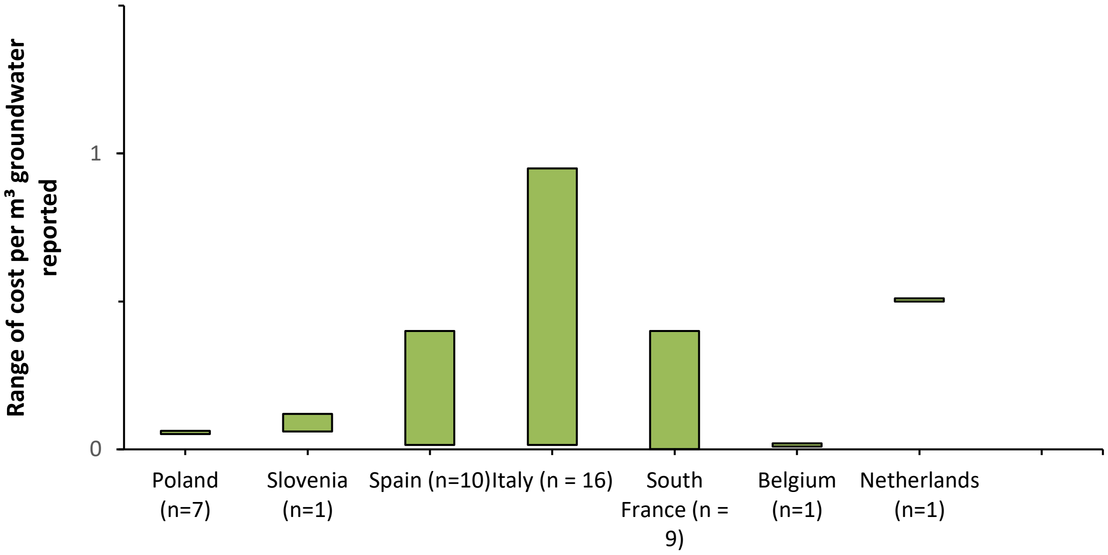

Figure 26 Range of reported prices in euro per m³ for groundwater

Community water

As indicated in the previous section, growers applying community water register very well the consumed amounts of fresh water. This is as well reflected Figure 25. In Spain, where growers apply mainly water provided by irrigator's communities, 84% of the Spanish respondents provided an indication for the cost of the water provided by irrigators communities. Prices per m³ of retrieved water varied from €0,01 to 0,72 per m³ (data not shown).

Mains tap water

10% of the interviewees provided an indication for the cost for mains tap water. The cost for mains tap water varied from €0,22 per m³ reported by an Italian respondent and €2,3 per m³ as indicated by a UK interviewee (Figure 28).

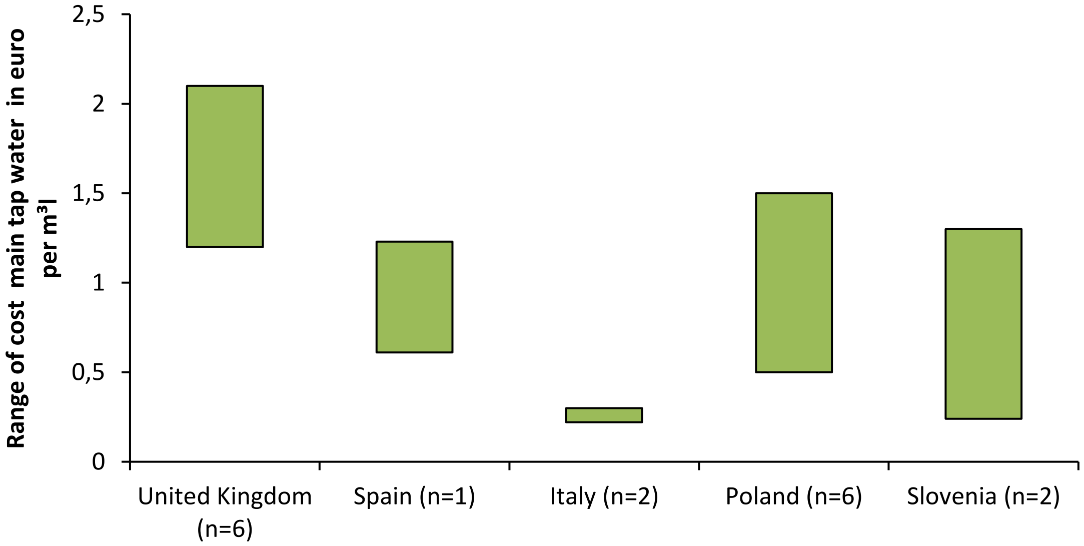

Figure 27 Range of reported prices in euro per m³ for mains tap water

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 689687

3.3.3 The evolution of water availability and quality over time

The reliability of water supply is an important factor in many irrigation decisions. Whether or not a given water source is reliable is dependent upon the source of water, the application system, and the crop grown. Therefore to understand better their choices we asked growers to rate how the water availability and quality may change in the future (Figure 28).

Respondents from different regions and even within countries had different perception regarding the future of their water supply. Overall, respondents believed that both the water availability and quality will remain the same. However, in, Spain and Poland the majority of the respondents believed that water availability will be reduced in the future. Respondents from the MED region were more concerned that the water quality will decrease in the future.

Regarding water availability, respondents in the NW were confident in their water supply (except for the UK, where the majority felt that availability would decrease), however in the CE and MED regions, more than half of respondents were concerned that water availability would decrease.

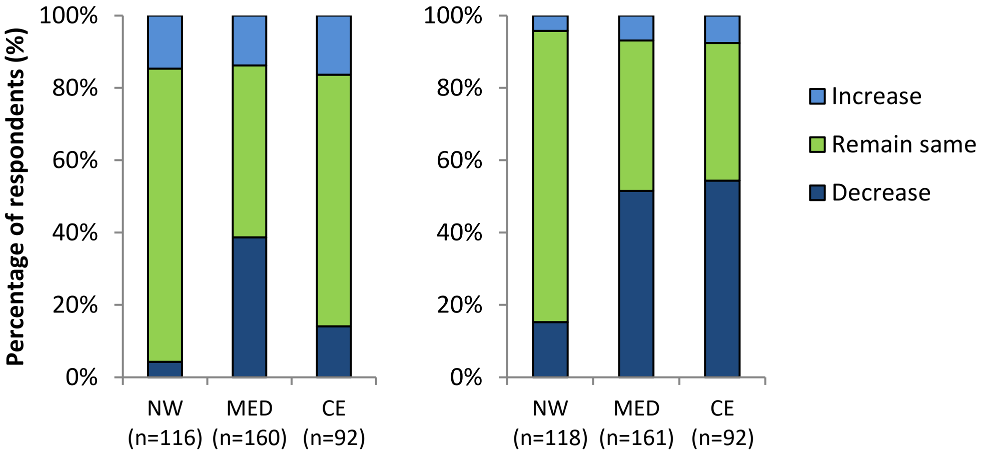

Figure 28 Respondents' perception about the evolution of a) water quality and b) water quantity or availability in the future

3.3.4 Sustainability of water supply, willingness to improve it and bottlenecks faced

Growers were asked to rate the sustainability of their water use. The majority of respondents considered their water use to be "sustainable" or "very sustainable" (Figure 29). This was particularly the case especially in the CE region where 73% of respondents considered their water supply as "very sustainable," but the same tendency was observed in almost all countries.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 689687

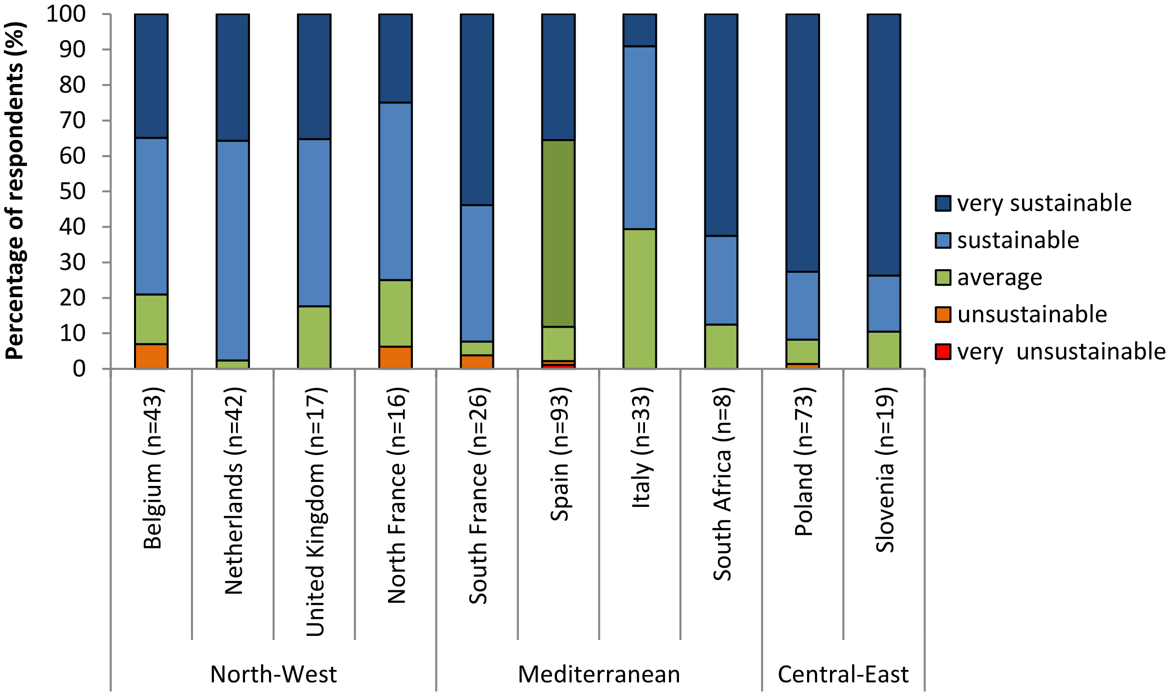

Figure 29 Rating of water supply sustainability by the respondents

Figure 30 shows the proportion of respondents planning to shift toward a more sustainable water supply in the next few years. Respondents were willing to shift supply but seemed far less willing to modify their actual management of a water source. However, some regions within countries showed a clear interest in adopting more sustainable water sources, such as Extremadura, Sicily, the western part of Poland, and also countries, particularly the UK. Local concerns surrounding water availability could explain this interest and maybe a driver for change.

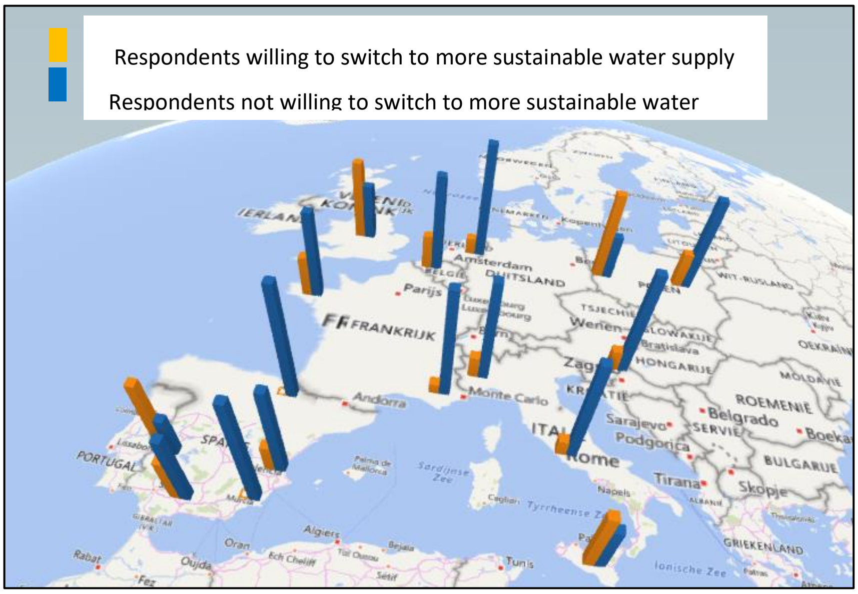

Figure 30 Graph showing the willingness of respondents to switch to more sustainable water sources (South Africa excluded)

Growers were asked for the reasons behind whether they would, or would not, change their water supply management:

3.3.4.1 Respondents planning to modify their practices to manage water supply

Respondents who considered changing to a more sustainable water source generally considered rainwater collection and installing drain water recirculation (Figure 31). This was the case across all regions. Several respondents in the CE region were considering using additional on-farm boreholes to improve their water supply. Improving water storage was also seen as a good way to increase the water sustainability (NW and CE regions). In the MED region, respondents prioritised methods that decrease water consumption to improve the overall sustainability of their water management, e.g. through a better irrigation monitoring (sensors, automation, etc.). In Spain, some respondents would consider using a more sustainable water source but a lack of alternative water sources hindered any change in practice.

Generally, respondents interested in shifting to more sustainable water sources were concerned about the difficulties that they may encounter. The high investment costs associated with using more sustainable water sources were the main bottleneck to changing. Other problems associated with using rainwater are the lack of space, or unfavourable climate conditions (lack of precipitation, unfavourable precipitation pattern).

Some respondents also explained what drives them to change practices. Economic reasons were again highlighted. Saving on water and fertiliser costs was considered an important driver to start recycling drainage water. Rainwater was considered a cheap water source by respondents from the NW and CE regions, but was also used for environmental reasons (e.g. avoiding nutrient-rich wastewater discharge into the environment in the NW region).

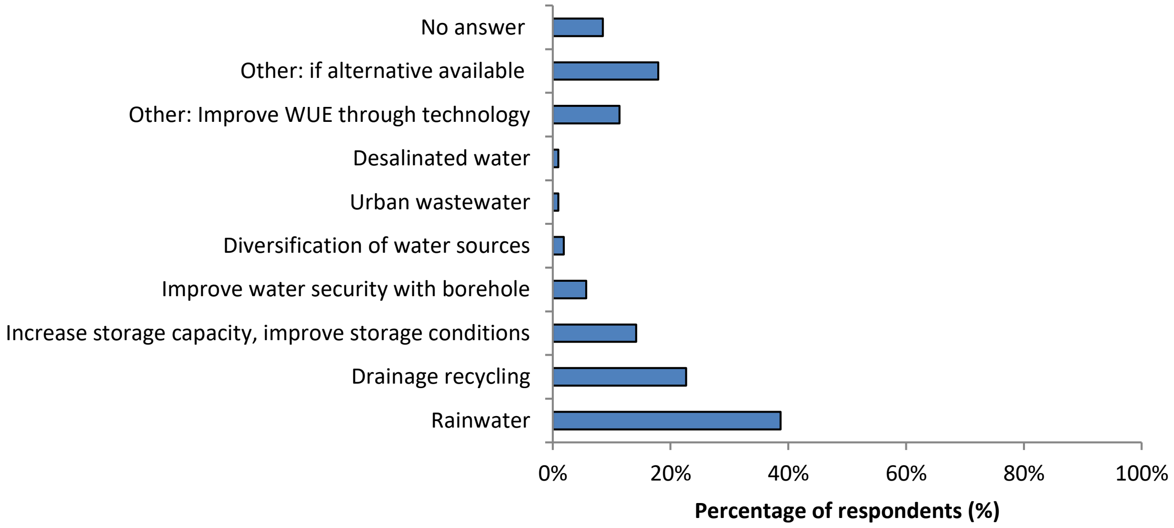

Figure 31 Planned actions of growers willing to increase the sustainability of their water supply (n=106)

3.3.4.2 Respondents not planning to modify their practices to manage water supply

It is worth noting that a lot of the respondents who weren't considering using more sustainable water sources did not provide explanations about their choice. Those that answered reported that: i) they did not experience any problems with their water supply and, therefore, saw no reason for the change, or ii) they already used the most sustainable water source available. Some respondents would consider more sustainable water sources, but high investment costs were limiting, especially for growers in Spain and Italy. They also experienced technical or practical limitations due to the design of their irrigation systems. Respondents interested in using rainwater often lacked the space to install the necessary reservoirs. In the MED region particularly, rainwater was not considered a viable water source due to the precipitation pattern (high volume and low frequency) which would require a large storage facility. In some cases, respondents lacked information on how to collect rainwater (e.g. in Poland). They also considered the sustainable water source (rainwater in the case of Poland) as being more difficult to manage (sanitary status, pH, etc.).

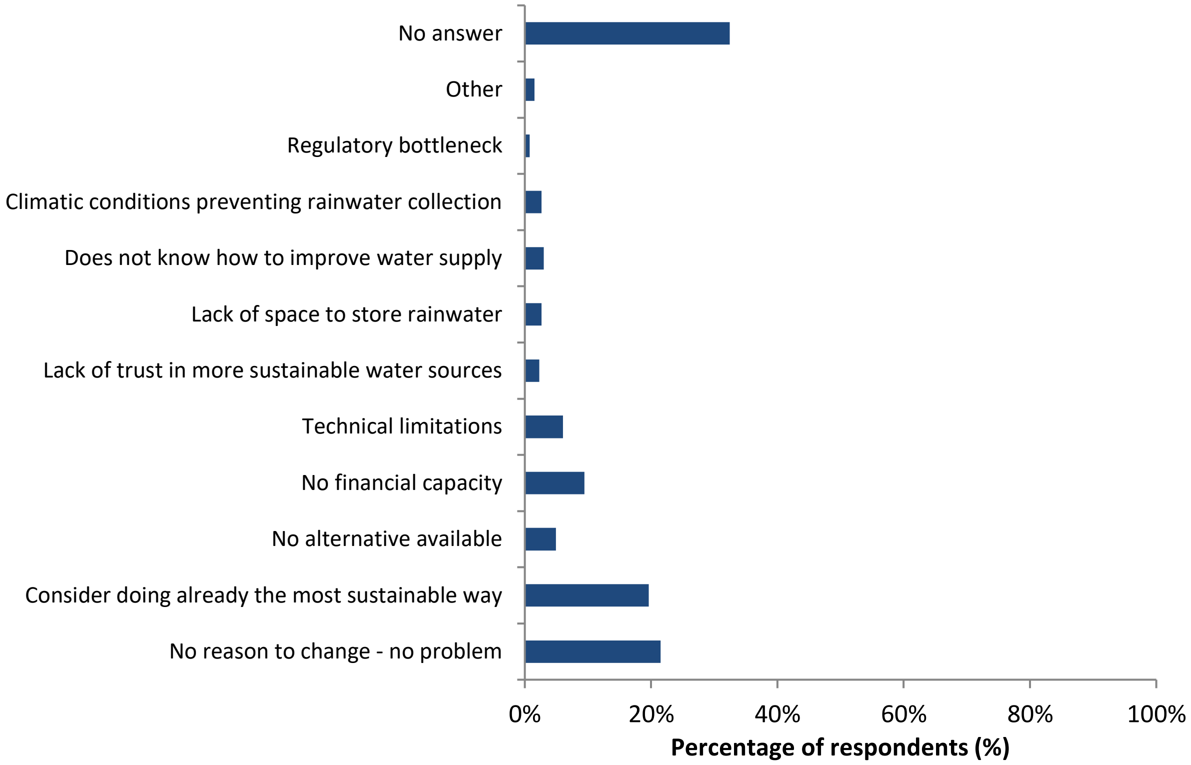

Figure 32 Respondents who expressed reasons for not changing water supply towards more sustainable water sources (n=265)

3.3.4.3 Drivers for changing to a more sustainable water supply

Respondents mentioned several factors that might convince them to change to a more sustainable water source (Figure 33). Generally, if a problem appeared on the farm (such as a water shortage or decrease in quality) a respondent was more willing to change his practices (especially in Spain and France). Some respondents highlighted that financial support would help them to adapt their practices, especially in the MED region (Spain and Italy).

Respondents also sought cost-effective practices or technologies (especially in Spain). For CE respondents, the cost of water was the deciding factor, whereas technical considerations such as availability and efficacy of technologies were the deciding factor for Spanish respondents. Some respondents wanted more technical support. The legislation was also considered an influential factor, with some respondents (particularly Italian) only willing to change if they were forced to do so.

If the farm changed or expanded, that would drive change in sustainability practices, but a large proportion of respondents would not be convinced by any reason to adopt more sustainable practices (some were already considering using the most sustainable methods).

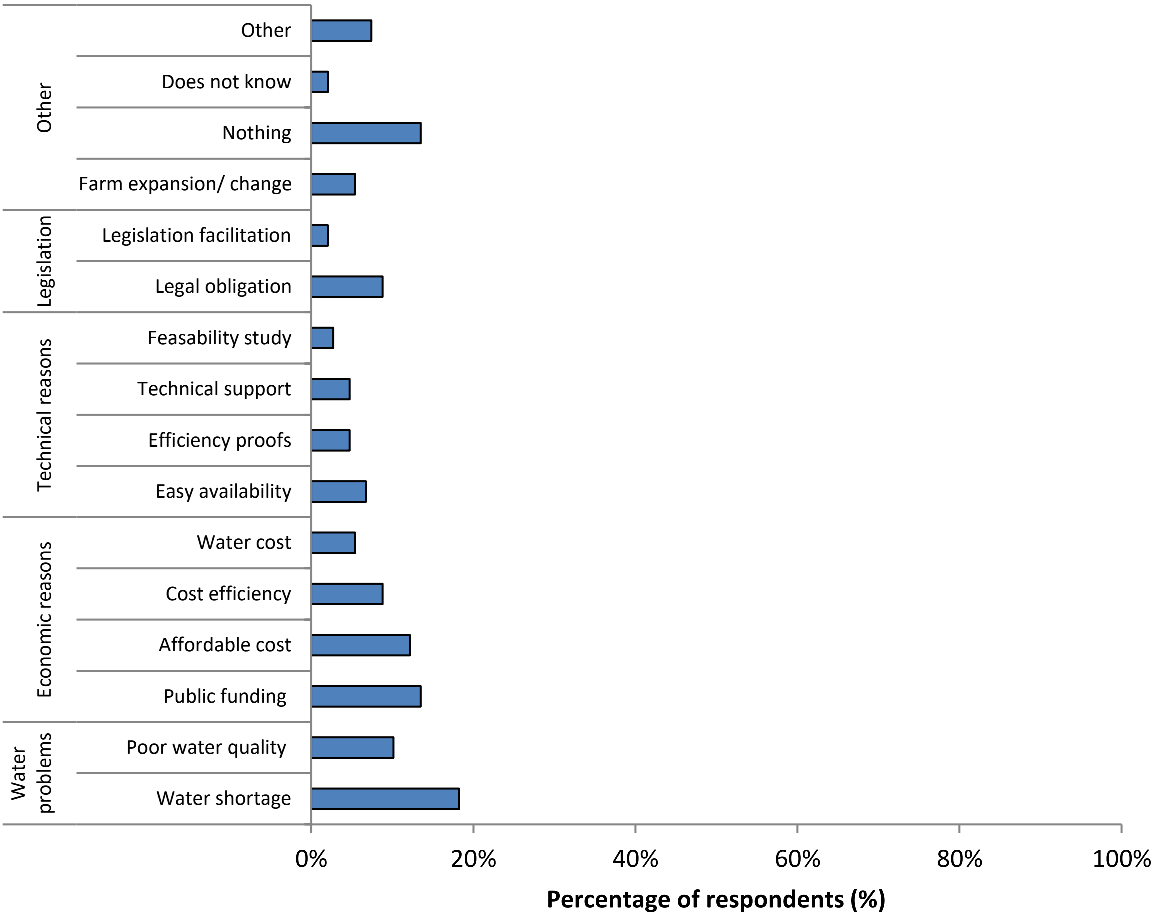

Figure 33 Reasons that growers considering as convincing to shift towards more sustainable water supply (n=148)

3.3.4.4 Respondents expectations regarding public authorities

Figure 34 shows the expectations of respondents regarding public bodies, across the different countries. Respondents mainly expected flexibility and administrative simplification. Laws were considered to be very restrictive and not accommodating of particular circumstances. Respondents preferred positive incentives (whether financial or not) rather than restrictive actions, which can have a negative impact on the relationship between respondents and the authorities. Clear guidelines were expected as i) respondents were not particularly aware of the legislation and subsidies available etc.; ii) they wanted to stop the introduction of new laws which make on-farm adaptation difficult; and iii) respondents wanted incentives, subsidies and technical support to help them comply with existing rules and adapt to new rules or advice. In countries where water networks are managed by public authorities, respondents wanted to see a greater involvement of authorities in the maintenance and improvement of the water supply infrastructure, and a stable or lower price for water, which seems to continually increase.

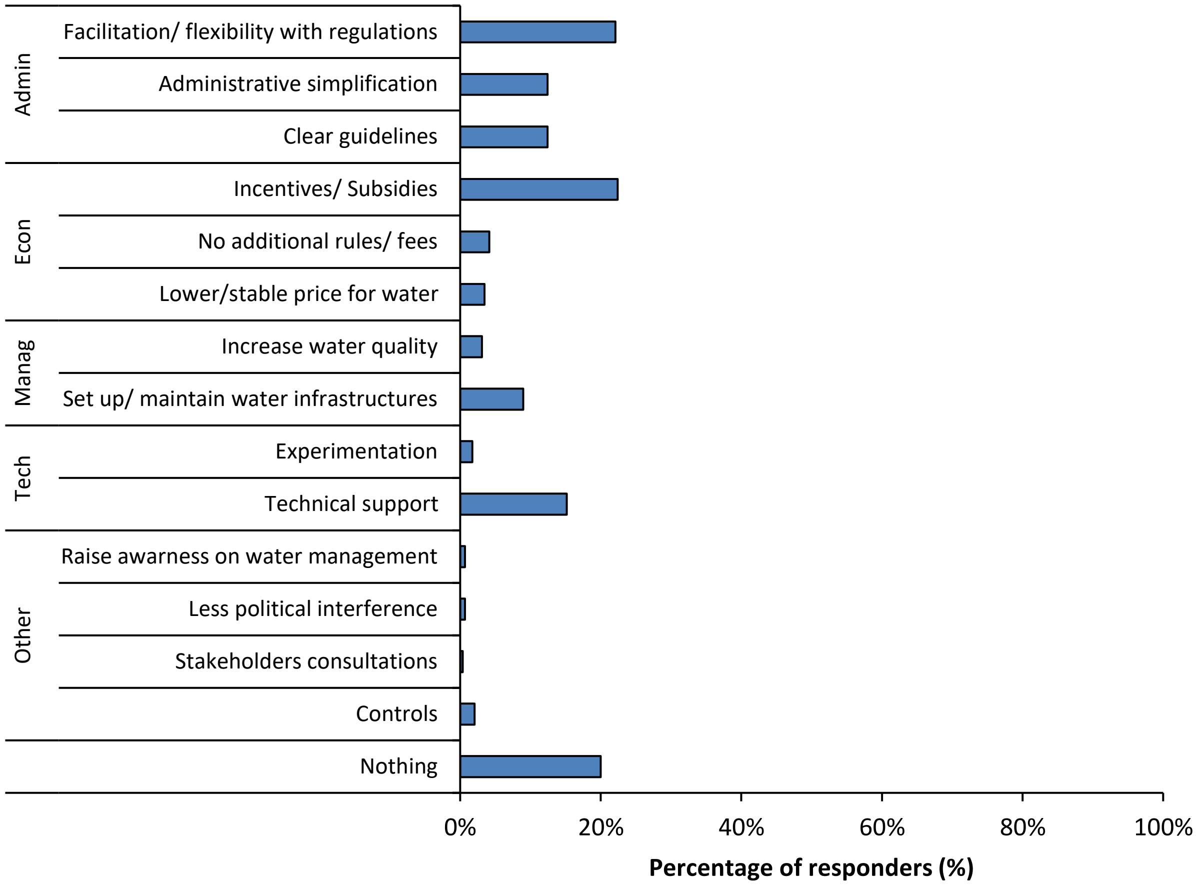

Figure 34 Expectations expressed by growers towards public bodies (n=290). Tech: Technical, Manag: Management, Econ: Economic, Admin: Administration

3.4 Regulatory aspects

Regulation in the surveyed countries and regions was very variable. In some regions, respondents were compelled to measure and report their water consumption to the authorities. This also depended on the water source used. As previously mentioned, fees are sometimes set up by the government to encourage a reduction in water consumption.

Figure 35 shows the percentage of respondents for whom water consumption was controlled by external authorities. The situation within countries could differ (e.g. if the respondents are located in a protected area).

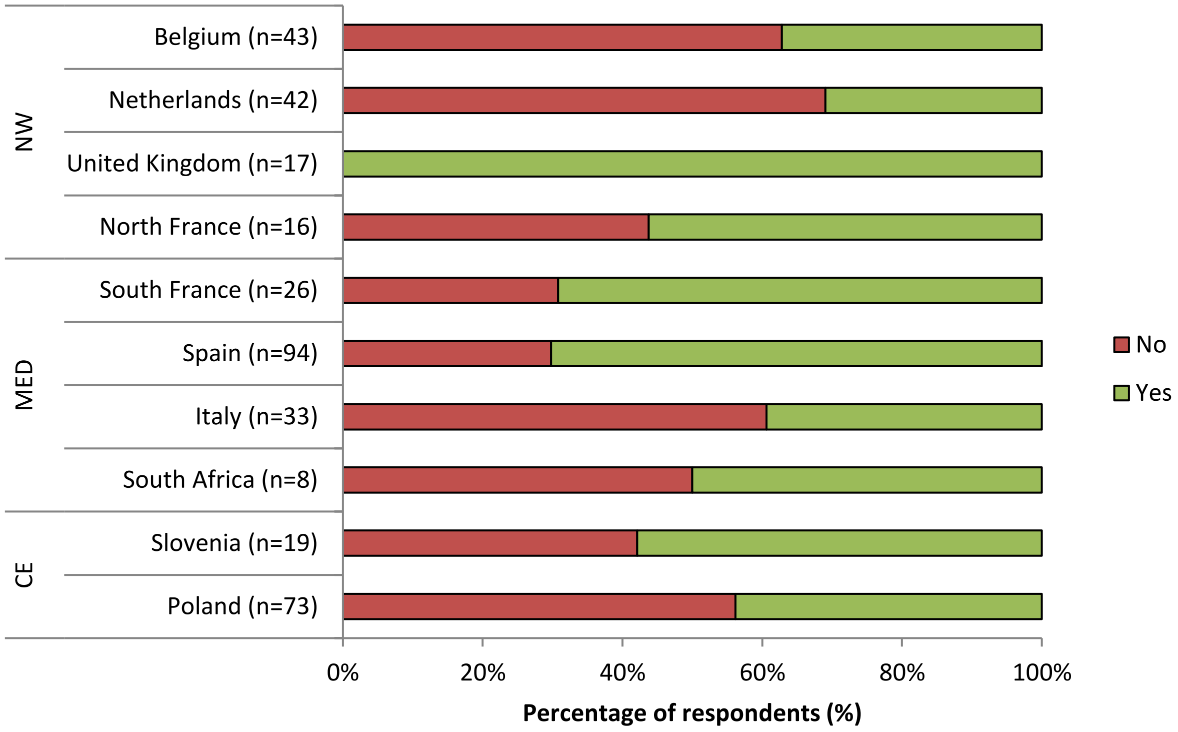

Figure 35 Answers to the question "Is water consumption controlled by external bodies?" (CE = Central East, MED = Mediterranean, NW = North West)

Respondents were asked about regulation surrounding the building of a water storage on their farms, as an example of the regulation around water supply. In the NW region, 92% of respondents answered that they would need the authorisation to build water storage, while 88% of CE respondents and 82% of MED respondents would need authorisation (data not shown).

The survey also asked about the availability of subsidies for building water storage. Only 23% of the respondents in the CE region mentioned that they could access subsidies to build water storage, while 54% (NW region) and 67% (MED region) could access subsidies (data not shown). In the NW region, these subsidies were mainly to support rainwater storage, while in the CE and MED regions those subsidies seemed to be available for any kind of water storage.

Finally, the survey asked if respondents considered legislation a bottleneck restricting change to a more sustainable water supply (Figure 36). They mainly answered that legislation is not a problem. However, CE and MED respondents considered legislation more of a bottleneck (27% of the respondents in both regions) than growers from the NW (9%).

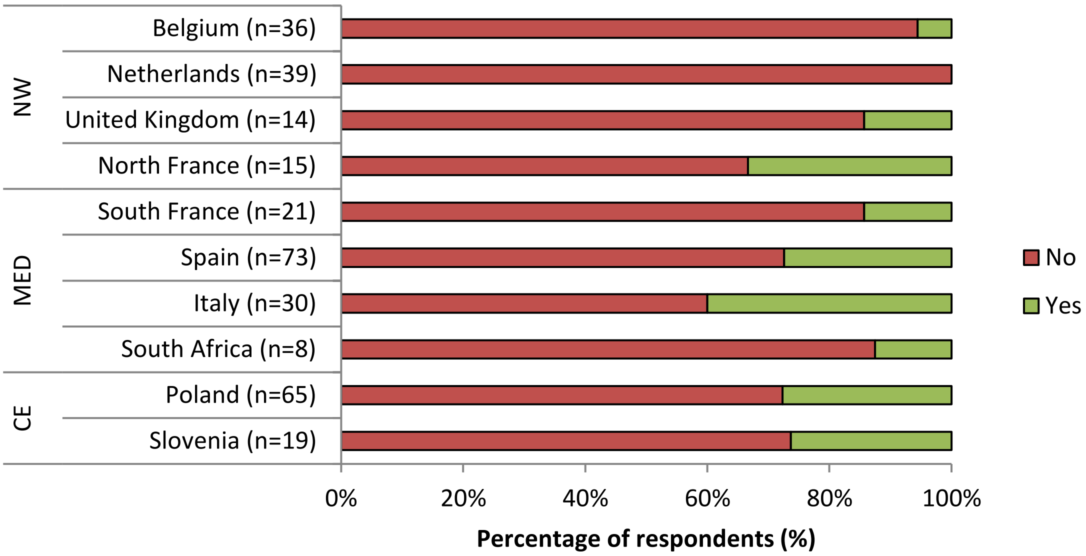

Figure 36 Answers to the question "Is legislation a bottleneck for using sustainable water sources? " CE = Central East, MED = Mediterranean, NW = North West

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 689687

4 Water and nutrient use efficiency

The combined use of fertigation with pressurised irrigation systems, such as drip or advanced sprinklers, can provide numerous practical advantages to the grower. Amongst the most important advantages, are the reduction and in many cases the elimination of mechanical fertiliser application and associated labour savings, reduced total irrigation volumes, automation of both irrigation and nutrient application, and the potential for much more precise control over irrigation and nutrient application throughout a crop.

Currently, and increasingly in the future, horticulture in the European Union (EU) will be conducted in the context of reduced water supply and the implementation of regulations to reduce environmental impacts. In addition to the practical and economic advantages of fertigation, increasing environmental, political and consumer pressure to reduce water use and the loss of nutrients to natural water bodies will make fertigation increasingly attractive to growers[3].

The FERTINNOWA benchmark survey gained insights into the current irrigation and fertigation practices and technologies known and applied by growers. The survey focused on both equipments used by growers as well as the broader techniques and technologies used to manage both irrigation and fertigation, including choice of fertilisers and salinity management.

4.1 Irrigation and fertigation equipment

4.1.1 Irrigation equipment use

When asked about the irrigation equipment used, growers' responses varied greatly and depended mostly on the growing system (covered or uncovered), but also on the growing medium (soil-grown or soilless) (Figure 37). In soil-grown crops, drip tape was the most used equipment (51% and 49% for covered and outdoor crops, respectively). Drippers, also popular in soil-grown cropping systems, were the main equipment used in soilless covered cropping systems (58%). In soilless outdoor crops, sprinklers were the most commonly used equipment (35%), followed by drippers (19%) and overhead aspersion (12%). Other types of equipment seemed to be used more in specific types of cropping systems, for example: microtubing (9 and 8% of soilless covered and outdoor cropping systems respectively), ebb/flood systems (7% of the soilless covered cropping systems), and furrow irrigation (4% of the soil-grown outdoor cropping systems).

In general, it was observed that precision irrigation technologies like drip irrigation were more frequently implemented compared to less precise technologies such as sprinklers and furrow irrigation. Feedback from the end-users during FERTINNOWA's benchmark workshop in October 2016 revealed that for some crops, implementation of drip irrigation is too costly and creates issues around logistics and plant care. This was especially the case for ornamental plant nurseries where plants are grown in small pots and employees have to manipulate the pots and plants frequently.

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[3] Retrieved from the Fertigation Bible.

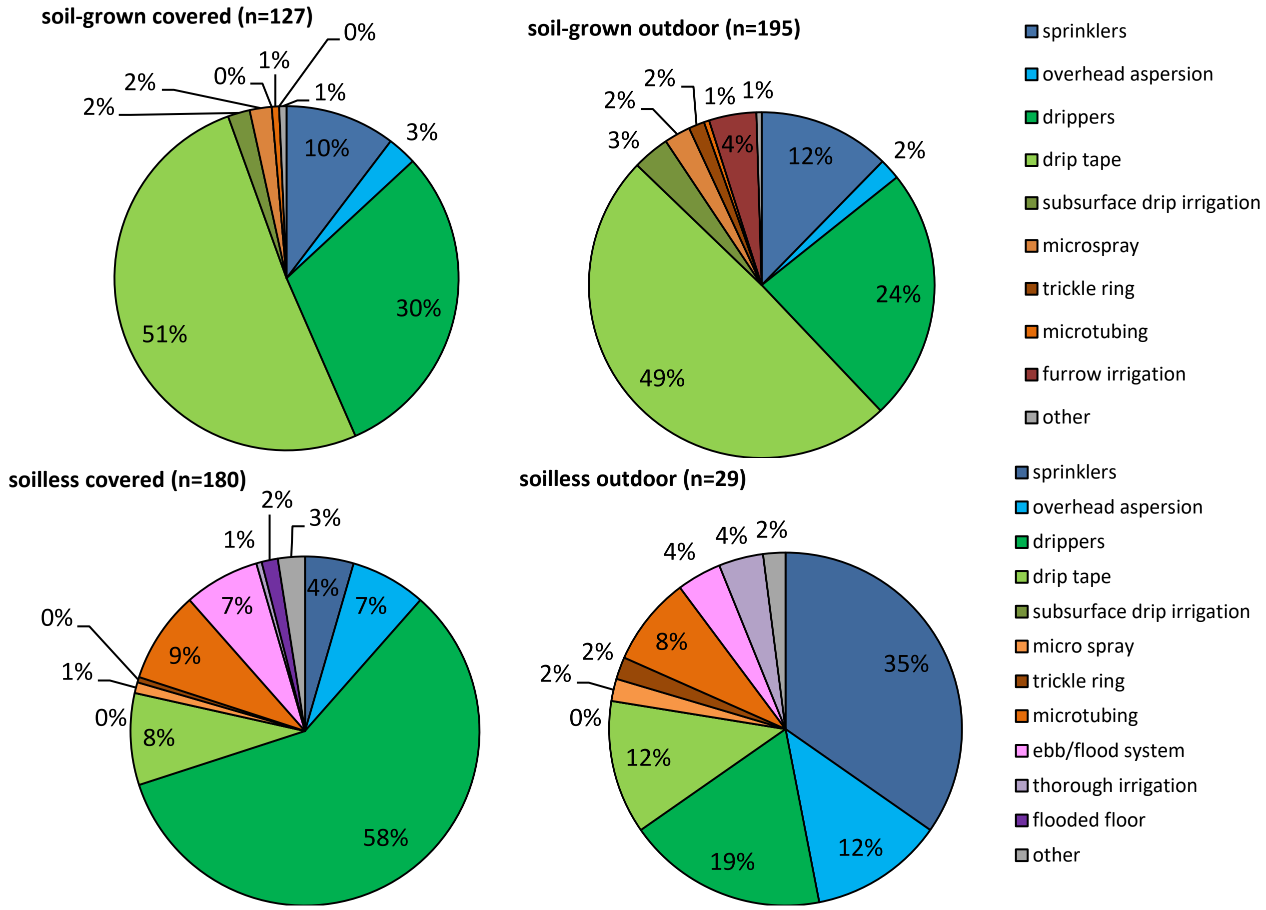

Figure 37 Type of irrigation system used per system type (several types may be used in some cropping systems)

4.1.2 Fertigation equipment use

The fertigation systems used varied across countries and cropping systems. In general, fertigation was implemented through the use of a fertigation unit to mix the water and nutrient/s. Fertigation units with A/B tanks were most frequently used (38%). However, regional differences were observed (Figure 38). In the CE region, single fertiliser tanks were used in 56% of the growing systems surveyed. These tanks were installed to prepare and store the nutrient solution. In the MED region, 36% of the cropping systems were equipped with multiple tanks of concentrated nutrient solution (mainly in Spain), although the A/B tank system was also widely used (31%). In the surveyed NW growing systems, A/B tank systems were the most popular (61%), with the exception of the Netherlands, where 50% of the cropping systems used multiple tanks with a concentrated solution (data not shown). We observed a trend that A/B tank systems were more popular in soilless covered systems while simple fertiliser tanks were more frequently used in soilless outdoor systems. On 68% of the cropping systems, only one fertilisation unit per cropping system (data not shown) was used.

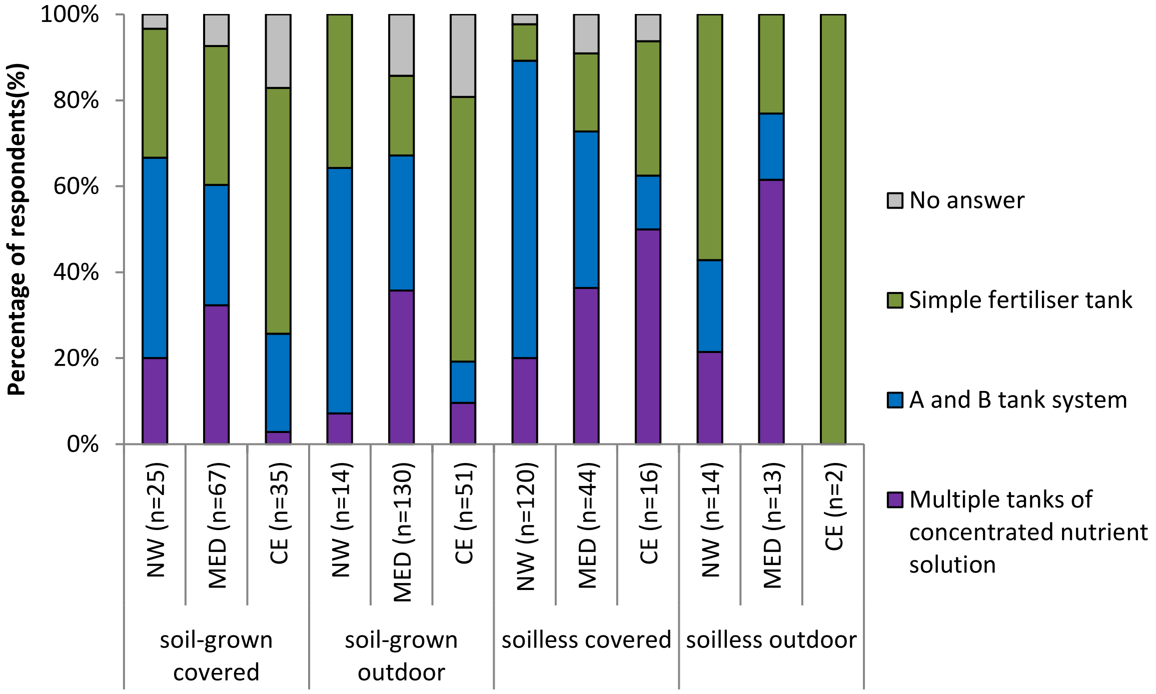

Figure 38 Type of fertigation units used in different cropping systems compared across regions (CE = Central East, MED = Mediterranean, NW = North West)

Respondents were also asked about the type of injection systems present in their cropping systems. The injection systems differed across regions, but 42% of the cropping systems were equipped with pump injection and of this 42%, the cropping systems were mainly soilless (Figure 39). In the soil-grown crops, there was big variability in the type of injection system used and related to whether crops were covered or uncovered. Suction injection systems were reported for 40% of the CE cropping systems while pump injection was predominant in the NW and MED (43 and 46% respectively). Injection through venturi was more popular in the MED region (31%) compared to other regions.

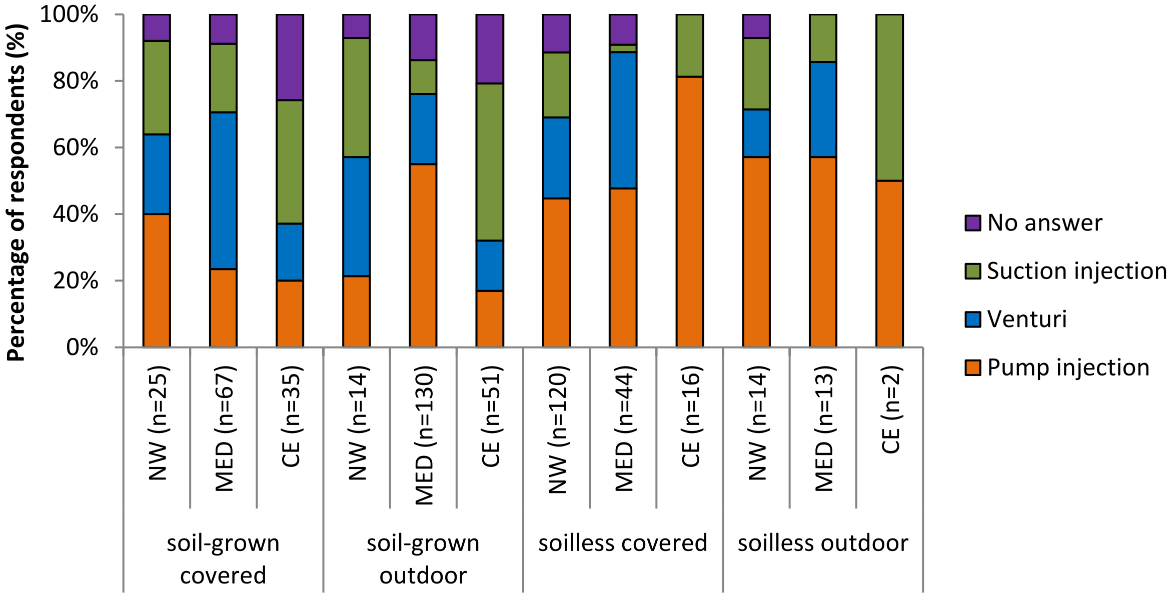

Figure 39 Types of fertigation injection used in different cropping systems compared across regions (CE = Central East, MED = Mediterranean, NW = North West)

4.2 Irrigation and fertigation management

4.2.1 Irrigation management

4.2.1.1 Water consumption

Respondents provided an indication of their crop’s annual water consumption, covering 83% of the cropping systems. In the remaining 17% of cropping systems, respondents were either not aware of the annual water consumption or did not answer the question. In some cases, the growers were aware of the minimal and maximal crop’s water consumption per day but not of the annual water demand. Although the majority of the growers provided an indication of the crop’s annual water consumption, large variations were observed in the water consumption data provided, even within similar crops, growing systems and regions. Therefore, these data could not be considered very reliable. The survey also revealed that water consumption was not always well monitored. Therefore, the report will not discuss the quantitative results neither will it focus on the actual consumption of each cropping system. The report will discuss the control tools applied to optimise water consumption.

4.2.1.2 Tools to support irrigation management decision making

Non-technological approaches

In 23% of the surveyed cropping systems water was applied on a fixed calendar irrigation schedule, either manually or by a predetermined timer-based irrigation schedule. In 57% of the cropping systems, the irrigation schedule was adjusted depending on the crop or soil/substrate appearance. In 61% of the cropping systems, the irrigation was managed based on the crop appearance. The soil/substrate appearance or substrate weight were also considered, but by a lower proportion of respondents (52%). In 20% of the cropping systems, the crop and soil/substrate appearance was the only way to monitor the irrigation management, especially in Spain and Poland. The use of fixed schedules or crop/substrate appearance was higher in the CE region and in soilless outdoor cropping systems (Figure 40). In the majority of cropping systems (69%), respondents reported combining crop and soil/substrate appearance with the use of technological tools.

Technological choices for irrigation management

Irrigation scheduling techniques and tools are quite varied and have different characteristics relative to their applicability and effectiveness. Timing and depth criteria for irrigation scheduling (Huygen et al., 1995) can be established by using several approaches based on soil water measurements, soil water balance estimates and plant stress indicators, in combination with simple rules or very sophisticated models. Figure 40 shows the use of different monitoring tools across regions and cropping systems.

Climate parameters (weather stations, solarimeter, etc.)

The monitoring of weather parameters was the most widely used practice (55). It was mostly used in soilless covered crops (76%) but also on soilless outdoor crops in the MED region (92%) and on soil-grown covered crops in the NW (72%).

Soil/ substrate water status (tensiometers, watermark, capacitance probes, etc.)

In general, soil/substrate sensors were used more than crop water status sensors (50% vs. 16%). In 31% of the soil-grown cropping systems, respondents reported using tensiometers to monitor the soil water content, with respondents in the MED region using watermark sensors and capacitance probes (12 and 10%) used.

Substrate water status (substrate weight, substrate water content, capacitance probes, etc.)

Substrate weight was used to monitor water status in 30% of the surveyed soilless covered cropping systems (or 42% if considering NW cropping systems only), while substrate water content measurements were carried out in 20% of soilless systems. Both substrate weight and substrate water content were used more widely in the NW (24%) compared with the MED (18%) region. No respondents in the CE region with soilless systems mentioned these methods. Capacitance probes were used in 13% of the surveyed soilless systems. Time Domain Reflectometry probes and neutron probes were only used by a few respondents (3%).

Crop water status (leaf-stem water potential, canopy coverage, crop temperature, dendrometers, etc.)

Crop water monitoring was a less common practice applied to only 16% of the cropping systems. Among the tools used to determine crop water status, the leaf/stem water potential was the most commonly used in soil-grown cropping systems, followed by canopy coverage (7% and 6.5% respectively). These users were mainly located in the MED region. Finally, crop temperature (3%) and dendrometers were the least used.

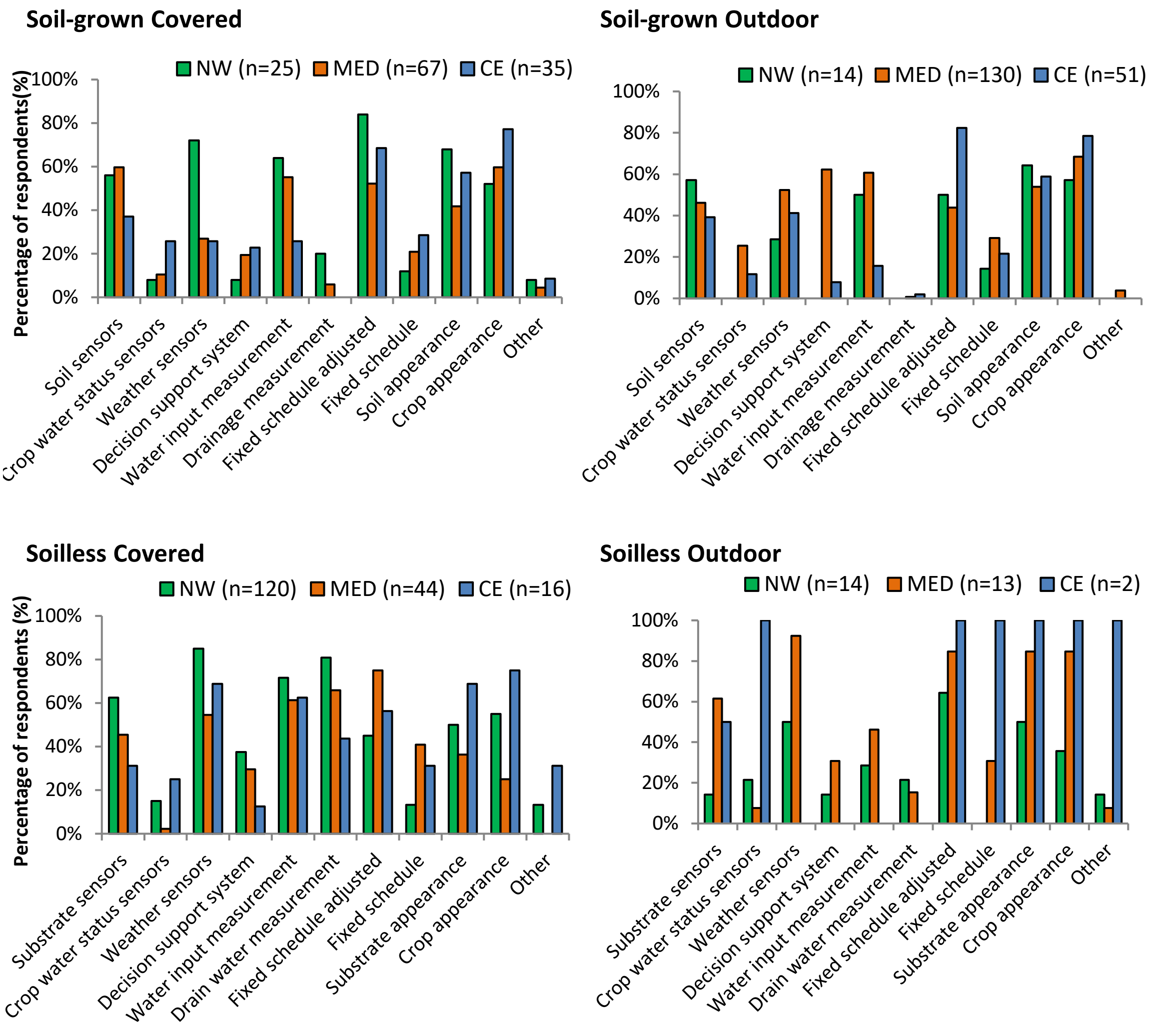

Figure 40 Percentage of soil-grown covered (a), soil-grown outdoor (b), soilless covered (c) and soilless outdoor (d) cropping systems using the different types of management practices to inform irrigation management decision making, across regions (CE = Central East, MED = Mediterranean, NW = North West)

Decision support systems

Decision support systems estimated crop evapotranspiration, water balance calculation methods, printed tables, etc. were used mainly in soil-grown outdoor cropping systems in the MED region (62%). They were also present in soilless covered cropping systems, mainly in the NW (38%).

Monitoring of the water applied

The supply of water was monitored either by measuring the water applied by the emitter (40%) or by monitoring the water delivered to the whole irrigated section (35%). This practice was predominantly used in soilless covered systems (68%) but was also widely used by MED respondents in soil-grown outdoor crops (61%) and in soil-grown covered cropping systems (in MED, 55% and NW, 64% regions respectively).

In soilless covered cropping systems, monitoring the drain water (often expressed as a percentage) is the most widely used method (74%), and it is almost always combined with EC measurement of the drain water (68%).

Irrigation management toolbox

In general, respondents applied multiple tools and practices to support their irrigation management decisions (data not shown). In 33% of the cropping systems, 1 to 3 tools were used. The number of reported tools varied among cropping systems and regions. In the NW region, the soilless covered systems were frequently equipped with diverse types of tools (48% reported more than 6 tools). In the MED and CE regions, the soilless covered cropping systems mostly used between 4 (48%) and 6 (38%) tools. In the NW region, only 50% of the surveyed soilless outdoor crops (mainly ornamentals) were equipped with at least one tool, while 92% of the soilless outdoor growing systems in the MED region used at least 1 tool. In soil-grown crops there was limited use of monitoring tools in the CE region, however in the MED and NW regions, they were generally equipped with 1 to 3 monitoring tools.

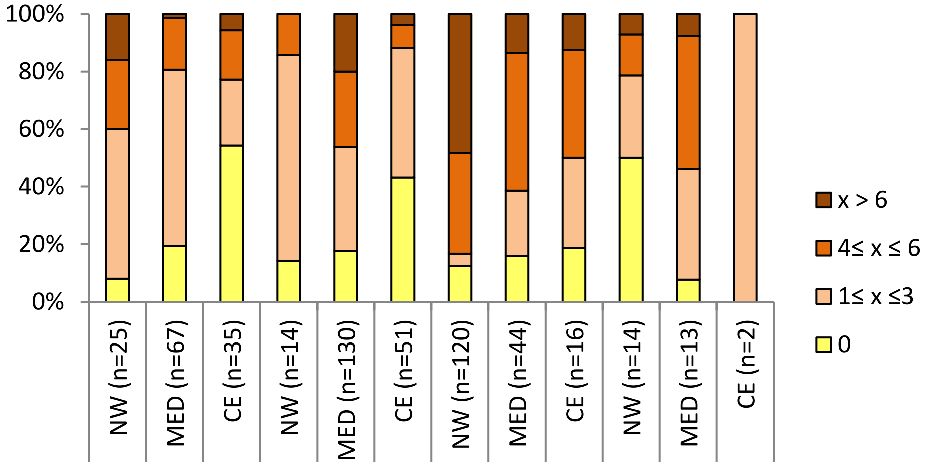

Figure 41 Number of tools used to monitor irrigation divided by cropping system types and regions (CE = Central East, MED = Mediterranean, NW = North West)

Irrigation management control/automation level

Tools supporting irrigation management were categorised as manual, semi-automated or automated. If manual tools were used, the respondents had to carry out the measurement themselves and any adaptations to the irrigation management required manual action. In the case of semi-automated tools, the measurement itself was carried out automatically, so did not require any action from the respondents, although the adjustment of the irrigation was done manually. With automated tools, the measurements and the adjustments were carried out automatically, with no grower intervention.

In general, 49% of the tools reported were applied manually (Figure 42). Automated tools were reported mainly in soilless covered growing systems to monitor weather parameters (31% of the cropping systems) and water and drain water volumes – 54% of the surveyed systems in the NW region used automatic drain water monitoring, while water supply was measured by metered pumps, particularly in covered systems (44%).

Soil/substrate measurement tools (56%) and crop water status measurements (70%) were mainly manual. Tools using calculations like water balance methods, estimated crop evapotranspiration (ETc), decision support systems (DSS) and modelling, were more often manually implemented (33%) compared to automated (12%) or semi-automated methods (7%).

The survey respondents expressed a willingness to shift towards more automated sensors, but the cost was reported as the main bottleneck to doing this. This was reflected in the benchmark's results as the automated tools were mainly used in the NW region in soilless cropping systems, where the investment capacity is higher in the sector.

Some growers were also concerned about the short lifespan of the sensors and the need for a permanent monitoring or calibration to guarantee accurate measurements, as they felt that these tools were not very reliable.

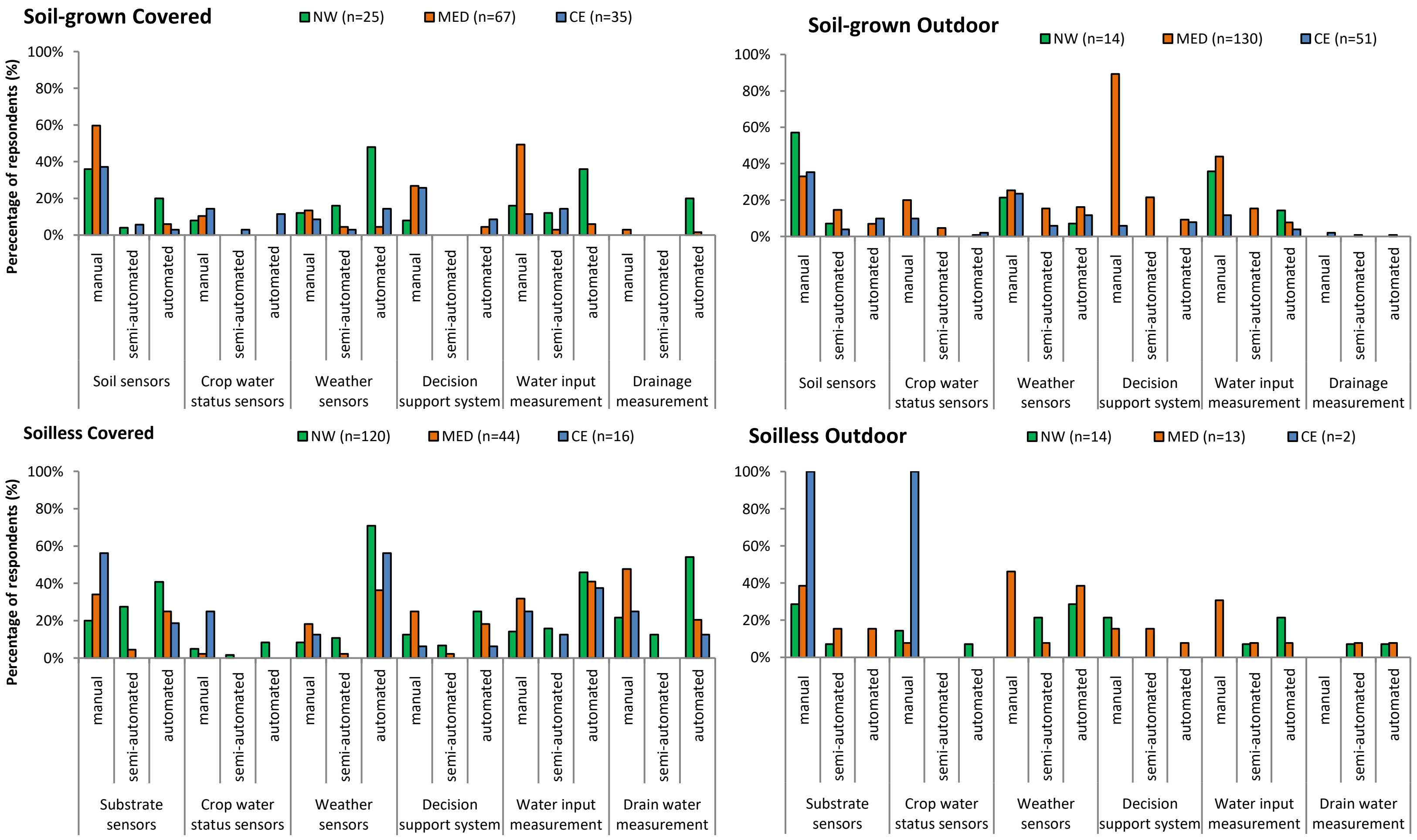

Figure 42 Percentage of soil-grown covered (a), soil-grown outdoor (b), soilless covered (c) and soilless outdoor (d) cropping systems, highlighting different levels of control/automation for each technological approach used to inform irrigation management decisions. Results are divided into regions (CE = Central East, MED = Mediterranean, NW = North West)

4.2.2 Fertigation management

4.2.2.1 Importance of fertigation as fertilisation method

Although fertigation was used by almost all the surveyed systems, only 71% of the cropping systems reported fertigation as the main fertilisation application. Fertigation was by far the most important fertilisation method reported for soilless growing systems (Figure 43).

The survey also revealed more insights into those growing systems not applying fertigation as the main fertilisation application. Manure was reported as a more important fertilisation method for soil-grown outdoor crops in the CE (25%) and MED (31%) regions, and in soil-grown covered growing systems, manure was closely followed by slow release fertilisers (35% of CE systems and 18% of systems in the MED region). In soil-grown outdoor crops, quick release fertilisers were more frequently reported as an important fertilisation source in the MED region (50%) compared to 27% in the CE region. As only a minor number of soilless system respondents reported using methods other than fertigation as their main method of fertiliser application, the results were not reported here.

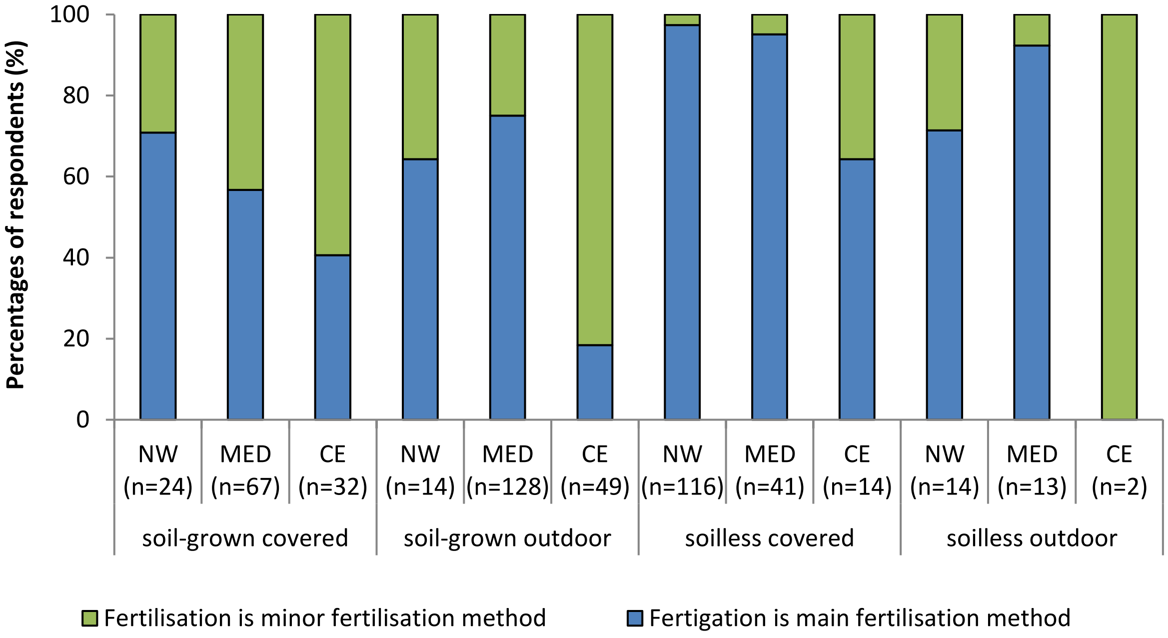

Figure 43 Overview of the percentage of cropping systems applying fertigation as main fertilisation method in each region (CE = Central East, MED = Mediterranean, NW = North West

4.2.2.2 Nutrient quantity management

Although the majority of respondents (83%) registered the amount of nutrients applied to the crops, some regional trends were observed. Only 64% of Polish (from the CE region) and 50% of Almerian respondents (MED region) reported keeping records of the applied nutrients, while all Dutch and Northern French respondents (NW region) tracked and record nutrient application (Figure 44).

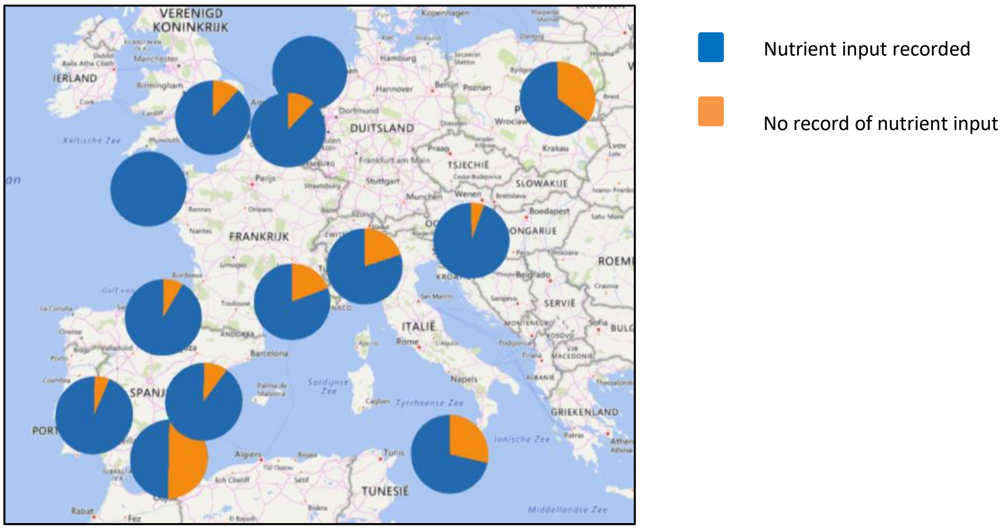

Figure 44 Percentage of respondent recording or not recording nutrient inputs, in the surveyed regions

In general, a higher recording rate was observed for soil-grown outdoor crops (90%) compared to only 58% for outdoor soilless crops. In covered cropping systems only a small difference in the recording rate was observed, 76% for soil-grown crops and 79% for soilless grown crops (data not shown).

4.2.2.3 Type of fertilisers used in fertigation

Soilless growing systems in both the MED and CE regions mainly seemed to use soluble fertilisers or a mixture of soluble and liquid fertilisers, while in NW region, all three types were used. In soil-grown crops, soluble crystals were the most common form of fertiliser used in most instances with the exception of outdoor crops in the MED region where liquid fertiliser was most commonly used.

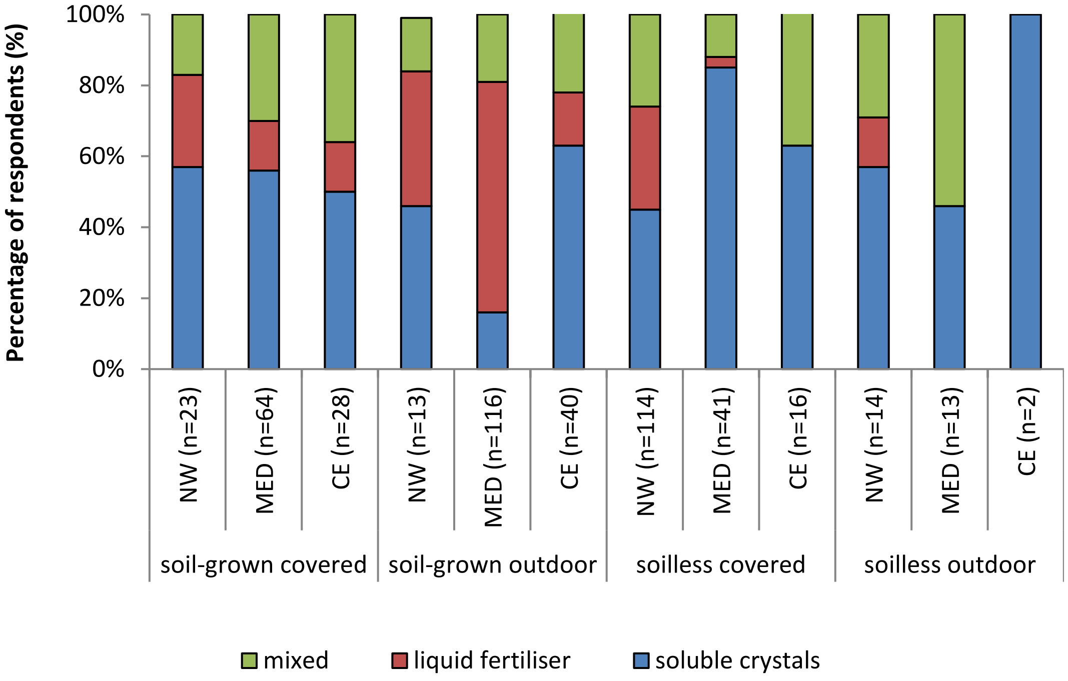

Figure 45 The type of fertilisers applied (soluble/ liquid) on different cropping system and region (CE = Central East, MED = Mediterranean, NW = North West)

4.2.2.4 Applied tools to support fertigation management

Similar to the section on irrigation management, growers were asked about fertilisation management applied at their farms. The majority of respondents (82%) reported adjusting fertiliser supply depending on the crop growth stage. A tendency to adjust nutrient management more frequently in covered crops compared to outdoor crops was observed.

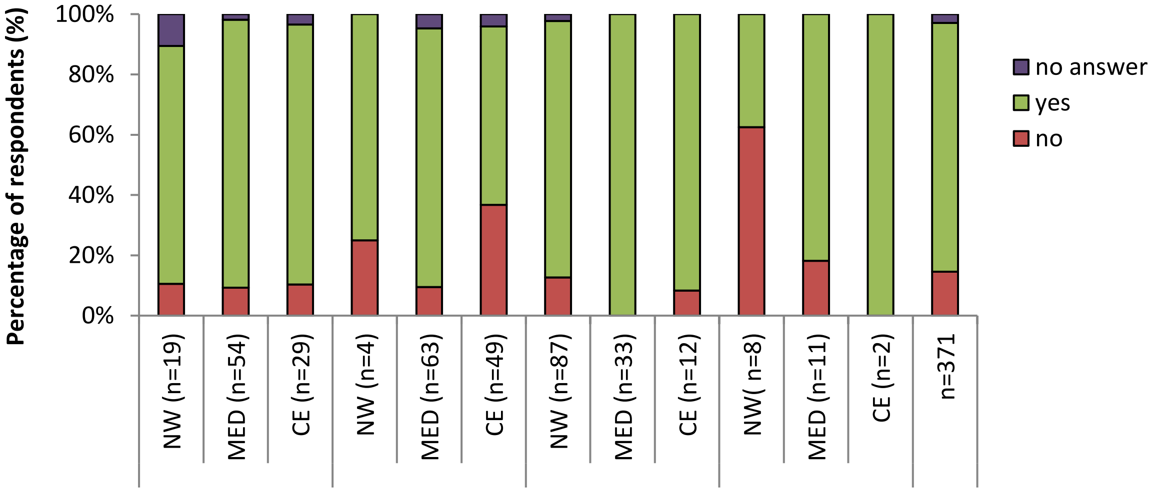

Figure 46 Percentage of respondents adjusting or not adjusting their fertiliser input depending on crop growth stage. Results are divided into cropping system and region (CE = Central East, MED = Mediterranean, NW = North West)

Non-technological approach

In 8% of the cropping systems, crop and soil/substrate observation were the only ways used to monitor nutrient input. Crop observation was used to monitor crop nutrient status in 37% of the cropping systems, it is most used in the CE region (with the exception of soilless covered crops).

Use of fertigation monitoring tools

Figure 47 gives an overview of the tools used to monitor the nutrient status of either the nutrient solution or the crop, soil or substrate nutrient status.

Nutrient solutions (EC, pH)

EC and pH sensors were reported to be the basic ways of monitoring nutrient solutions. In the CE region, EC was measured in only 30% and pH in 28% of cropping systems, while they were monitored in the majority of the NW cropping systems (83% for EC and 79% for pH respectively). In the MED region, 43% used EC sensors and 41% pH sensors. Usually, both EC and pH sensors were used together, except for drain water sensors in soilless covered cropping systems, where pH was measured less frequently than EC (Figure 466).

Soil nutrient status (occasional soil samples, continuously EC and leaf/sap analysis)

For soil-grown cropping systems, the use of soil analysis was frequently reported in all regions (64% on average in covered and 59% on average in outdoor cropping systems). In the NW region, the nutrient status was reported to be continuously monitored by soil sensors measuring EC (35%), while in the MED region respondents use leaf/ sap analysis (58%) for continuous monitoring of the nutrient status of outdoor crops.

Substrate nutrient status (EC, pH)

On outdoor soilless cropping systems, the use of EC and pH sensors in the substrate is very common in CE (100%) and MED (73%) regions, however in the NW region only 14% of the cropping systems were using these practices. In contrast, when looking at covered soilless systems these sensors are mainly used in the NW region (45%).

Drain water (EC, nutrient analysis)

For soilless covered cropping systems, the EC of the drain water was also monitored in 50%, 61% and 78% of the CE, MED and NW cropping systems, respectively. A full analysis of drain water was also very popular in the NW region (73%). Drain water solution monitoring was not used as much in soilless outdoor crops (28%).

Automation level of the monitoring tools

In soil-grown cropping systems, the use of automated sensors for the monitoring of nutrient solutions was higher than for soil monitoring (data not shown). In soilless cropping systems, the nutrient solution was monitored mainly with automated sensors, as was the drain water (e.g 52% in the NW region), however a sizeable proportion of respondents carried out manual measurements of the nutrient solution (34% in the MED region). Automated sensors are not used on soilless outdoor crops in the CE while 69% of the MED cropping systems reported automated nutrient solution sensors (data not shown).

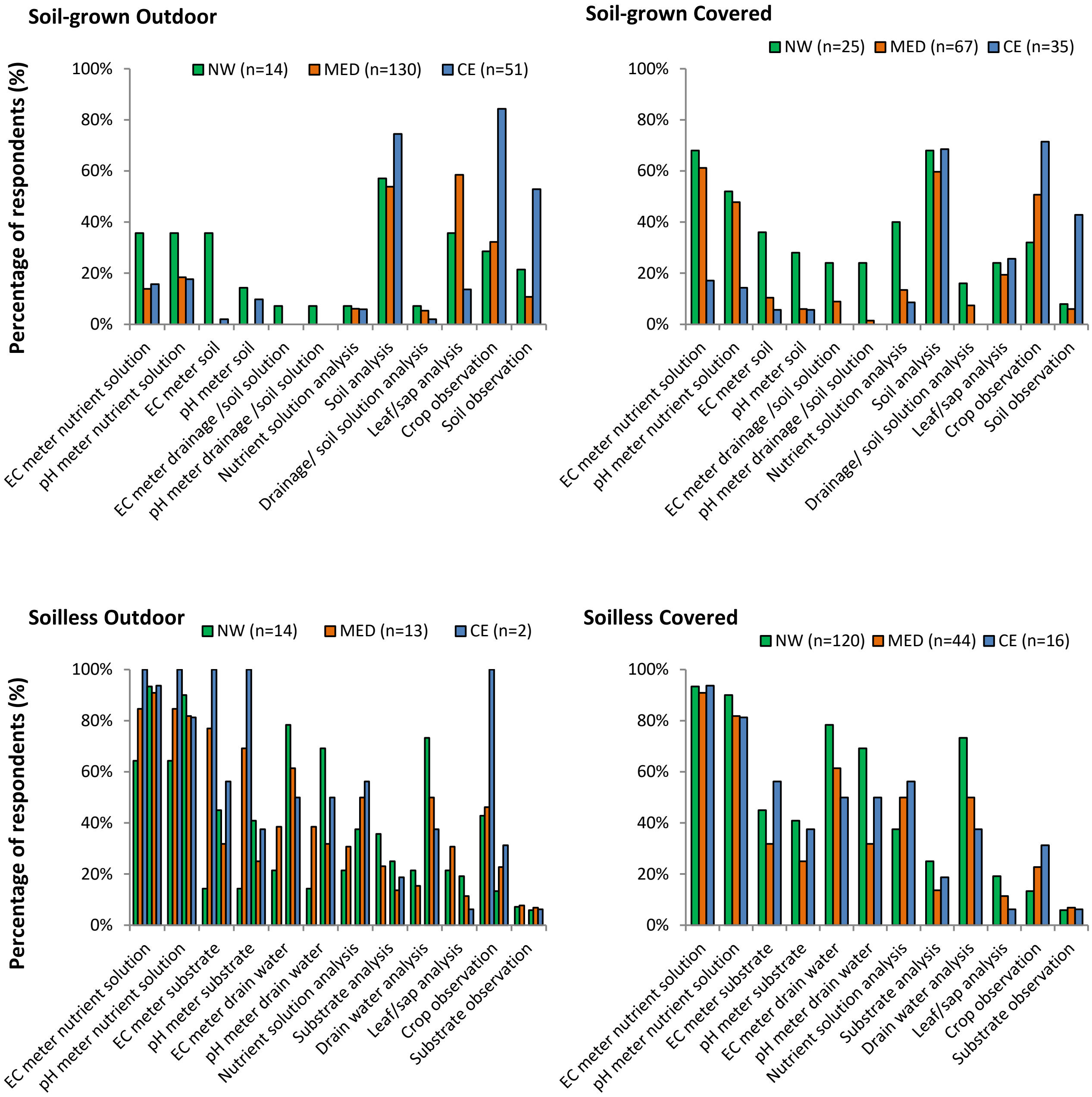

Figure 47 Percentage of soil-grown outdoor (a), soil-grown covered (b), soilless outdoor (c), soilless covered (d) cropping systems using different types of management practice to inform fertilisation management decision making by region (CE = Central East, MED = Mediterranean, NW = North West)

4.2.2.5 Advisors

About 57% of the respondents were assisted by an advisor when fertilisation regimes were calculated. Differences occurred at the country or regional level (Figure 488) rather than at the level of the cropping system type (data not shown). Of the Polish respondents (CE region), 85% said that they calculated their regime themselves, while in the North of France, 88% of the respondents reported that advisors have full responsibility for calculating fertilisation regimes. In the South of France and the Netherlands, 54% and 50% of respondents (S. France and Netherlands respectively) reported that they prepared fertigation regimes in consultation with their advisors.

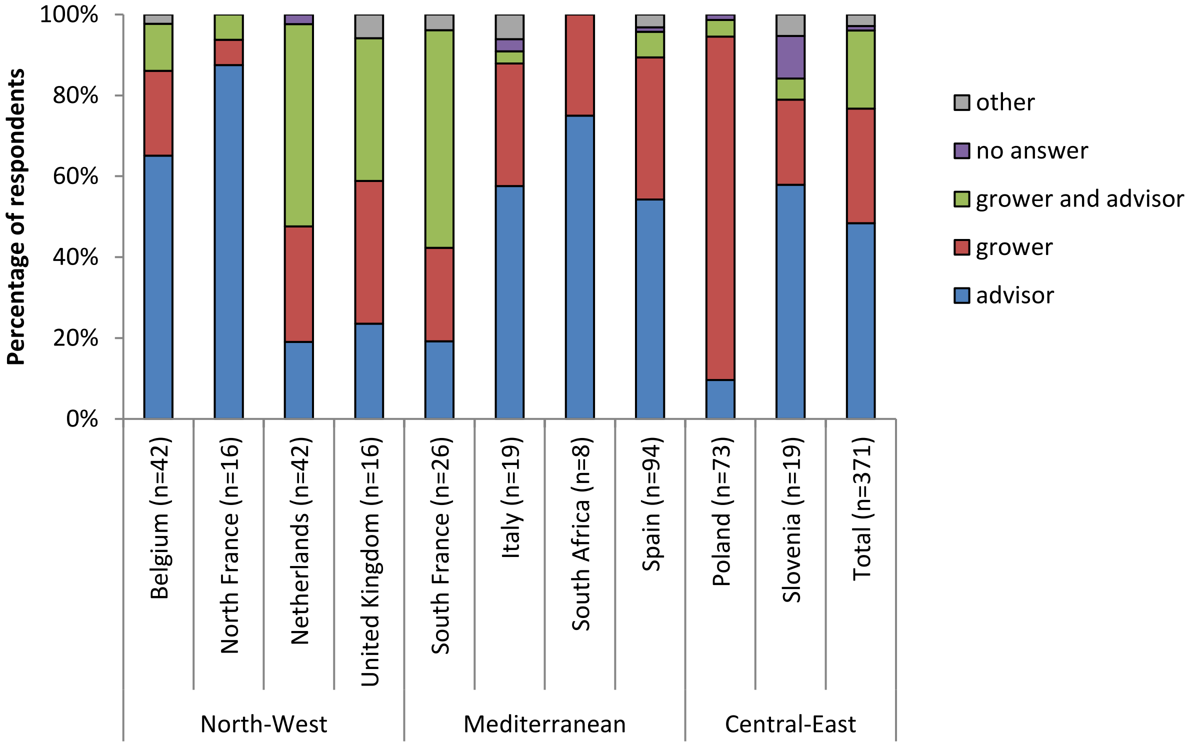

Figure 48 Percentage of respondents in each country receiving help or not when calculating nutrient regimes

4.2.2.6 Implementation of recommendation schemes for fertilisation management

When asked whether official local recommendation schemes for fertiliser management were available, only 27% of the respondents knew of local recommendation schemes and the answers were highly variable between regions (Figure 49). In the MED region, 34% of the respondents knew of recommendation schemes, compared to 15% and 26% of the respondents in the CE and NW regions respectively.

Respondents mentioned a variety of different schemes that they used. For example, there are (previously) governmental schemes such as RB209 (nutrient management guide) in the UK, or schemes and advice from research centres such as Wageningen University in the Netherlands, INTIA and IVIA in Spain, CTIFL in France, PCH in Belgium, CAFS in Slovenia, etc. Crop-specific recommendations were also available from commercial companies.

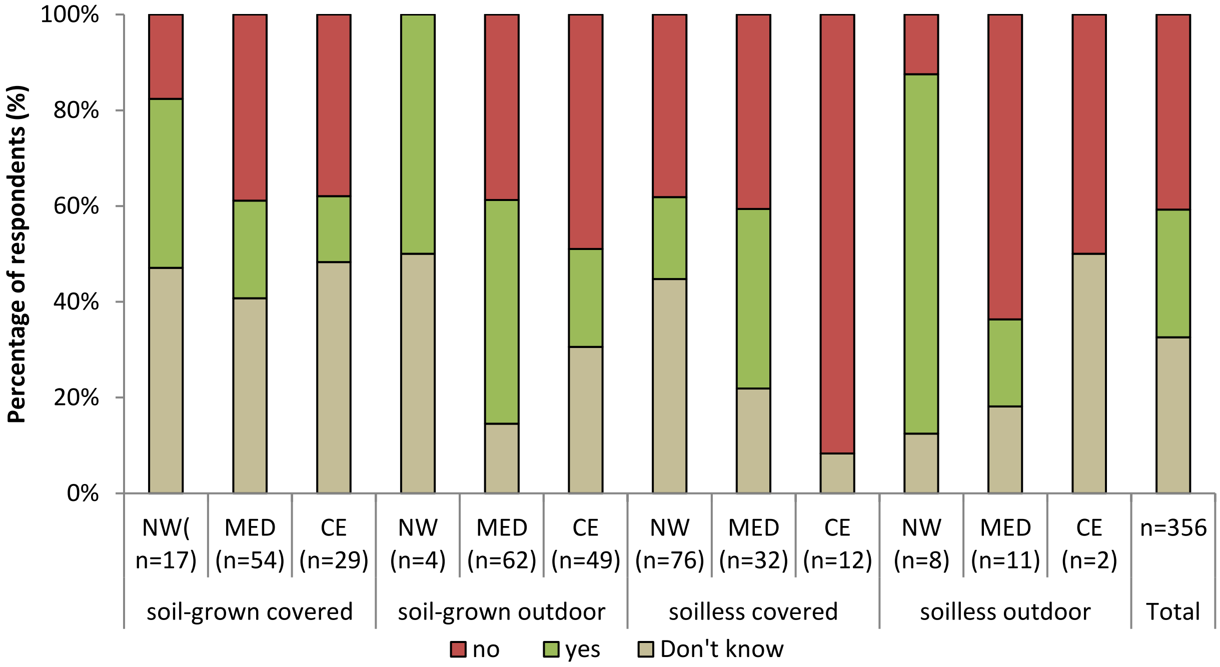

Figure 49 Percentange of responses in each region (CE = Central East, MED = Mediterranean, NW = North West) to the question 'are official local recommendation schemes available (for fertilizer management)?'

Of the respondents above who did know of local recommendation schemes, 67% used them (Figure 50).

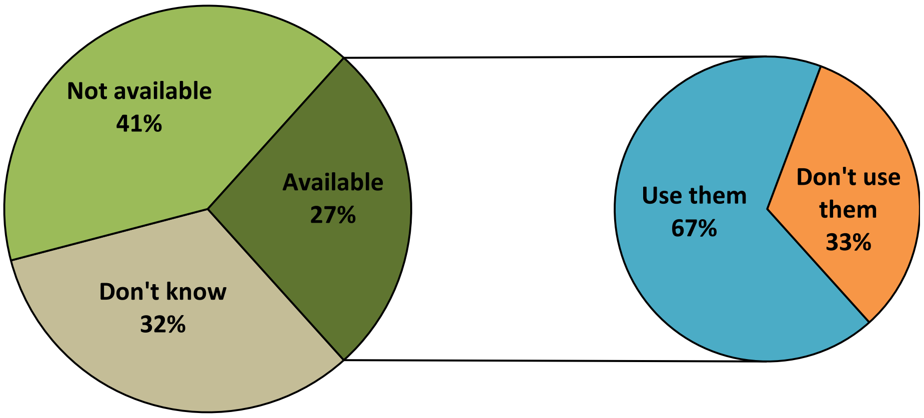

Figure 50 Percentage of responses to the question 'are official local recommendation schemes available (for fertiliser management)?' Of those who know of available schemes, the percentage of respondents who do and do not use them

Growers not using local recommendation schemes were asked what the barriers were (Figure 51). The main reasons were that they do not trust the scheme and that the schemes are not crop/system specific enough. However, we should bear in mind that only a small number of growers responded to this question so there may be other reasons which have not been captured here.

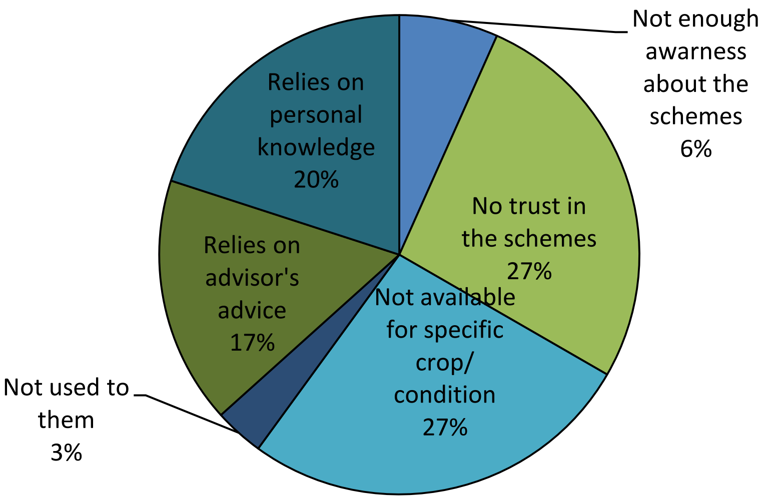

Figure 51 Percentage of different reasons why respondents do not use local recommendation schemes (for fertiliser management)

Respondents were also asked what would encourage them to use a local recommendation scheme. By far the most common answer was receiving help from an advisor (51%). Two other popular factors were feedback from other users on the recommendation scheme, and financial support to implement them, especially so in the NW regions. In the MED region, the need for appropriate documents from authorities was also reported as an important factor (Figure 51).

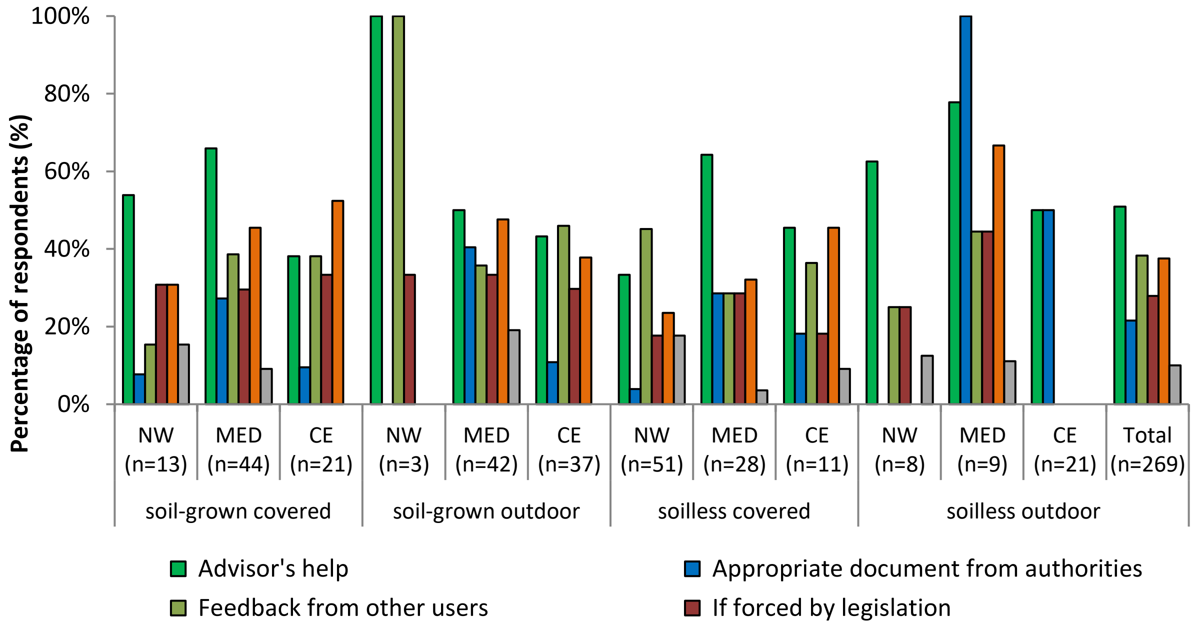

Figure 52 The bars are separated into different methods that encourage fertiliser recommendations use. Results are divided into cropping system and region (CE = Central East, MED = Mediterranean, NW = North West)

1. Implementation of nitrogen schemes

Linked to the recommendation schemes, growers were also asked which nitrogen management scheme (N scheme) they used to manage their crop (Figure 53). The majority of growers (44%) did not use an N scheme, or they were not aware of any (32%) as it was not their responsibility (data not shown). Of the growers who did not use an N scheme, 44% were from the UK and 32% from Poland.

The two most commonly used N schemes were Nmin, a tool which takes soil mineral N present in the in root zone at the start of the crop, into consideration and also the N mineralised during the growing season (11% of respondents in the CE, 3% in the MED and 9% in the NW regions); and Nbalance (8% of respondents in the CE, 4% in the MED and 13% in the NW regions), which takes into consideration both N inputs and outputs during the growing season (2). In the NW, a small number of respondents use the KNS (4%) or RB209 (6%) schemes.

As can be seen in Figure 53, 42% of the respondents felt that more detailed or more frequent sampling of their plants and soils/substrates would improve the effectiveness of the N scheme being used. However, it should be noted that only a low percentage of respondents (16%) answered this question. Despite it not being fully representative, it gives us an idea of how growers have improved the effectiveness of the N scheme they were using.

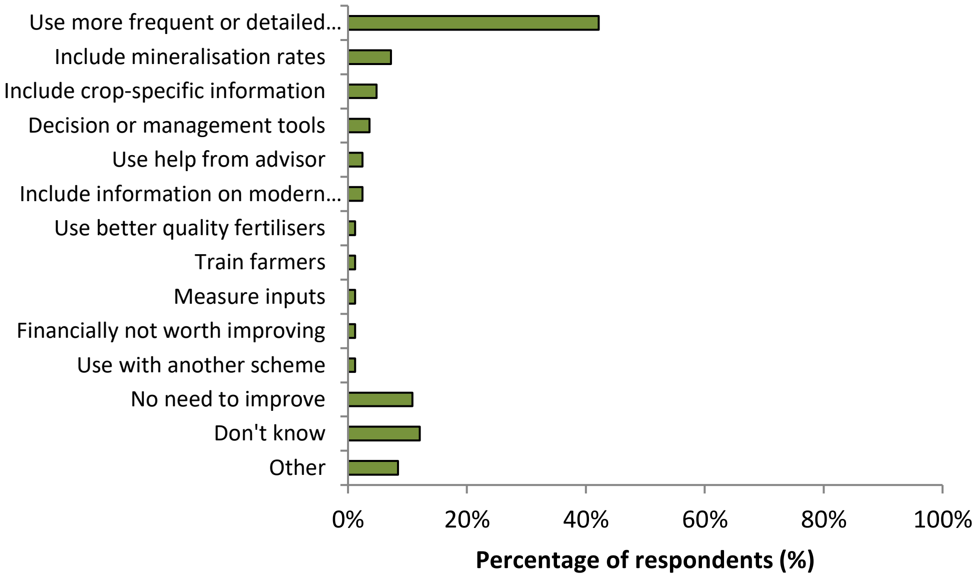

Figure 53 Ideas expressed by respondents to improve N fertiliser schemes (n=83)

Figure 544 below shows which factors growers considered when determining their N fertiliser plan, across different regions.

Respondents most commonly considered soil mineral N when planning and 39% of these growers were based in the MED region. However, this result could just be down to a higher number of respondents coming from the MED region. Although the split is fairly even, the factor considered least was N mineralisation, with 22% of responses saying that it was not considered in fertiliser plans.

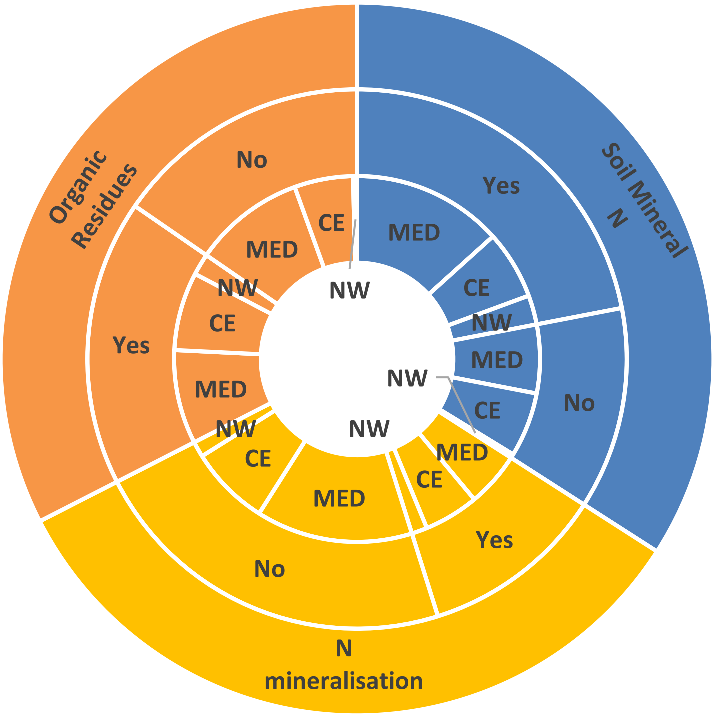

Figure 54 Outer ring shows the factors respondents consider when determining their N fertiliser plan. The middle ring shows the proportion of respondents who consider the factors in the outer ring. The inner ring shows the proportion of respondents from the Mediterranean, Central-East and North-West regions who consider the factors

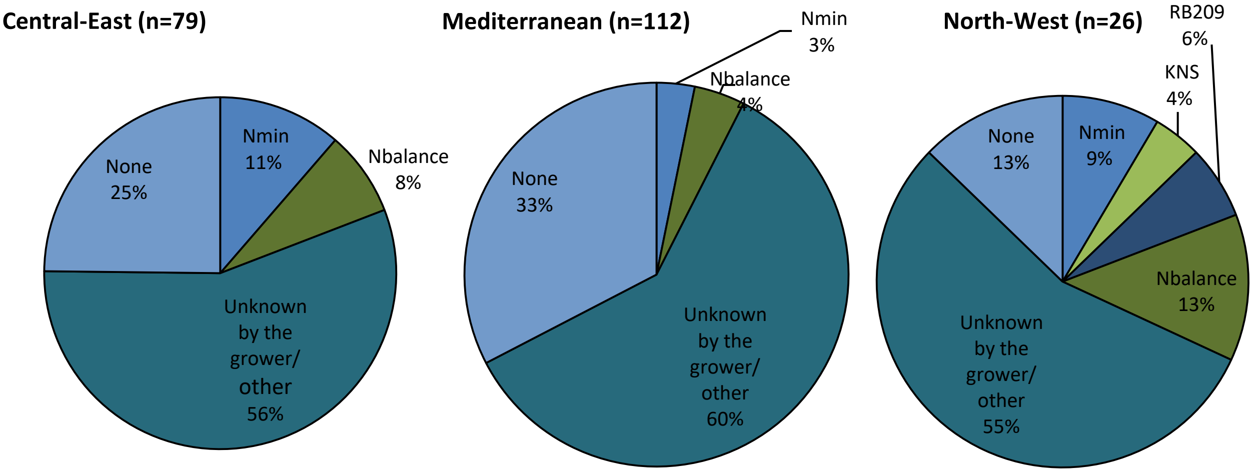

Figure 55 Percentage of respondents using different nitrogen management schemes in each region

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2. P analysis

Soil phosphate (P) analysis was used more often than not by growers in the NW and CE regions to determine P application rates (Figure 566). For the soilless grown crops, the number of answers was limited so we cannot draw any conclusions. The most numerous responses were from the MED region, and for both soil-grown and soilless growers, the percentage who did use soil P analysis compared to those who did not was not vastly different (49% yes and 51% no for soil-grown and 54% yes, 46% no for soilless growers, respectively).

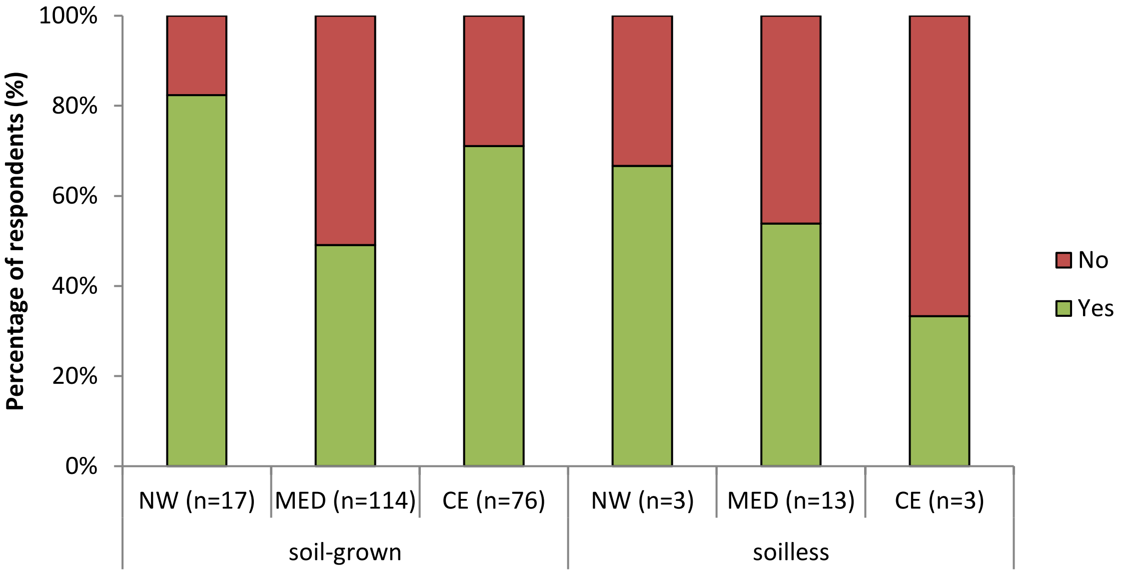

Figure 56 Percentage of respondents who did and did not carry out P analysis when determining P application rates. The bars are separated into different cropping systems within each region (CE = Central East, MED = Mediterranean, NW = North West)

4.2.3 Management of salinity in fertigated cropping systems

4.2.3.1 Consideration of salinity management

When growers were asked if they considered salinity within their fertigation management, 57% respondents answered positively (data not shown). Consideration of salinity as part of fertigation management seemed to depend on both the region as well as the cropping system. In general, respondents with soilless covered crops were much more likely to consider salinity compared to the other growing systems. A clear regional trend was found for soil-grown covered crops: in the NW region, 83% of respondents considered salinity compared to the 21% of the CE and 51% of the MED respondents. Regional differences were much less pronounced for the other cropping systems (Figure 57).

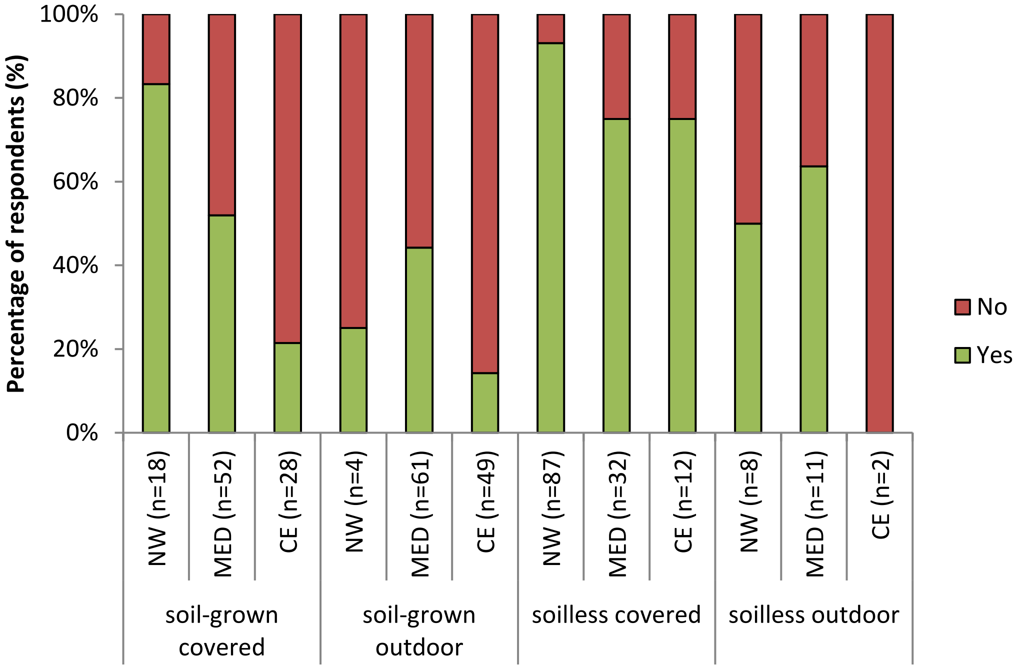

Figure 57 Percentage of respondents considering salinity in their fertigation management. Results are divided into cropping system and region (CE = Central East, MED = Mediterranean, NW = North West)

4.2.3.2 Practices to measure salinity

With regard to measuring soil or substrate EC, responses varied widely, with respondents tending to be at either end of the extreme; 37% never measuring EC and 25% measuring it every day (Figure 58).

If we drill further into the data, we can see that overall, respondents with soil-based cropping systems measured EC less frequently than in other cropping systems (Figure 58). In soil-grown crops in the NW region, 70% of respondents measured it several times per cropping season and 47% of MED respondents measured it at least once a year. The CE region had by far the most respondents who never measured EC (85% with soil-grown cropping systems). In soilless cropping systems, 53% of the NW respondents measured the EC of the substrate daily, whereas only 37% in the MED and 31% in the CE.

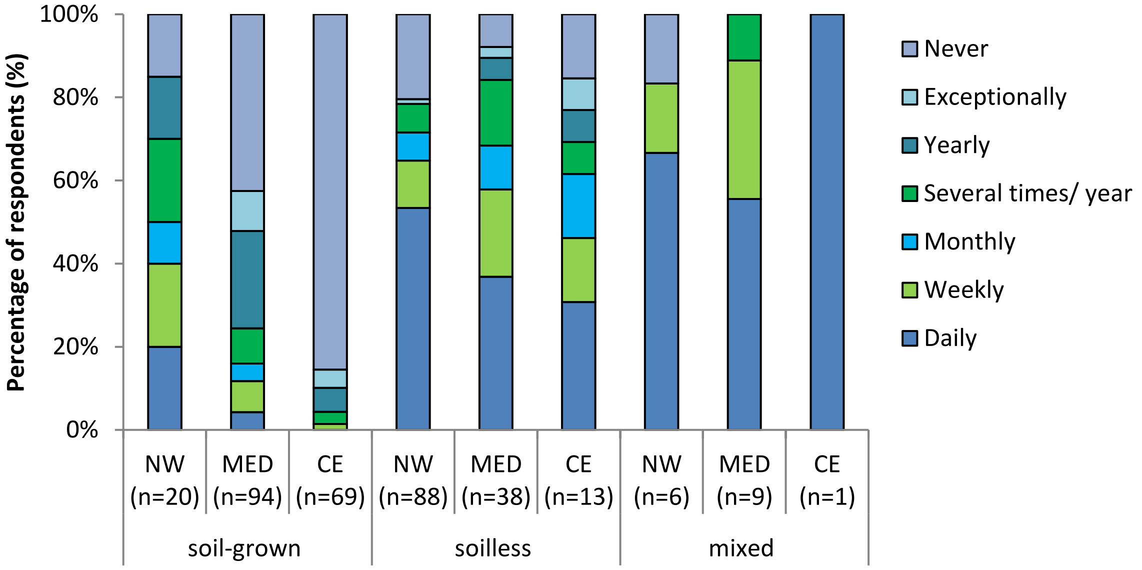

Figure 58 Frequency of EC measurement of soil or substrate in each region (CE = Central East, MED = Mediterranean, NW = North West)

4.2.3.3 Methods used to manage salinity

Additional water

Adding additional water to the system was the most common method of managing salinity (36% of respondents). This method was used in all types of cropping systems.

Increased EC

Increasing the global EC of the system was the second most common method used for managing salinity in soilless crops with 32% of respondents using it. Increasing the global EC in a system seemed counterintuitive to combat salinity, however, increasing the EC by adding a different salt (e.g. potassium or calcium) displaces the sodium from the soil or substrate, reducing the overall salinity of the system.

Discharge of drain water

In soilless systems, salinity problems were also solved by discharging drain water (29%). This method was also used by 13% of respondents with mixed systems.

Leaching irrigation

In soil-grown cropping systems, using leaching irrigation between cropping seasons was applied by 25% of the respondents.

Flushing the soil

The practice of flushing the soil or substrate was applied by 15% of the respondents, in different types of systems.

Other

Other methods used are the correction of water/fertiliser ratios (11%) or the addition of low saline fertilisers or correctors (8%).

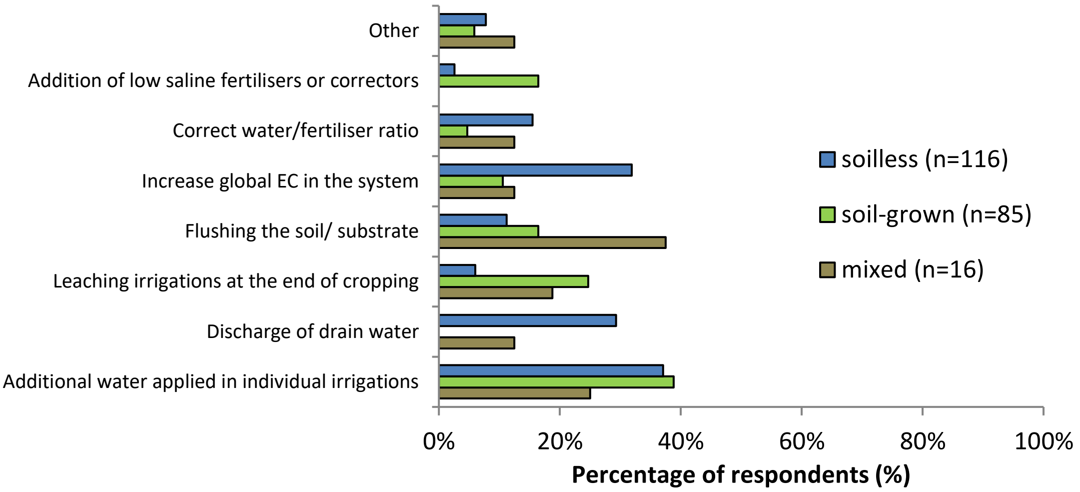

Figure 59 Percentage of respondents using different methods to manage salinity, split into soil-grown, soilless and mixed farms

For all cropping systems in all regions, personal grower experience was used most to determine how much additional water should be applied when dealing with salinity, with 77% of the respondents using this method at the very least (Figure 60). Of the respondents, 31% also mentioned being guided by an advisor when deciding how much water to apply. Technical literature was used slightly more in soil-grown cropping systems (8%) than in other types of cropping systems, while decision support systems were used more in soilless cropping systems (27%). No major differences among the surveyed regions were observed (data not shown).

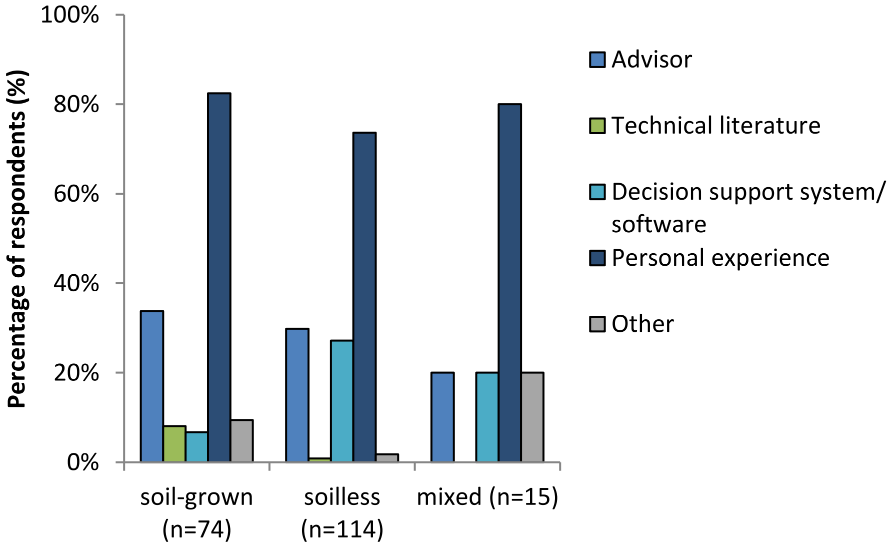

Figure 60 Methods of determining how much additional water to apply in each cropping system

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4.3 Needs expressed by growers/expectations

Different options were proposed in the questionnaire which may help growers to manage salinity better. Of the different support options available (advisors, appropriate documents from authorities, financial support/subsidies, other growers' feedback, technical workshops or other support systems), 50% of respondents felt that financial support would enable them to manage salinity issues better (Figure 611). This was closely followed by 49% of the respondents saying adequate devices to manage salinity would be useful (especially mentioned by soil-grown respondents). In addition, 45% of the respondents wanted the better availability of analyses and 41% of the respondents wanted the help of an advisor. Within these results, respondents with soil-grown systems appeared to have more need for support, with a higher percentage asking for these options than soilless respondents. Despite peer-to-peer learning often being promoted as a good way of learning in agriculture and horticulture, here the answers suggest that this is not particularly popular, with just 16% of the respondents indicating that they would find it useful in managing salinity.

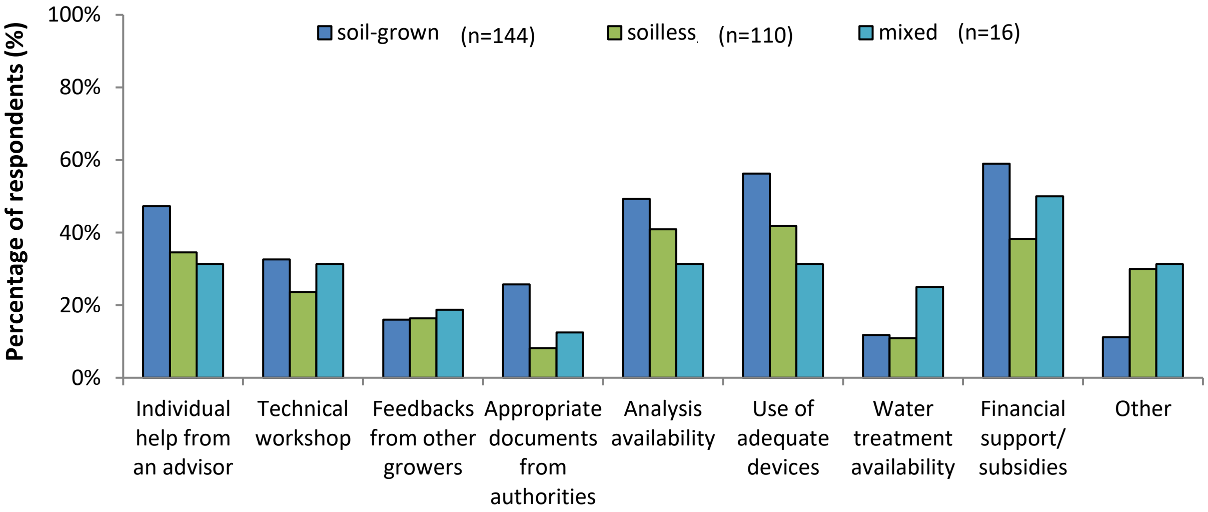

Figure 61 Percentage of respondents wanting different options to help them manage salinity

4.3.1 Use and role of external advise

Generally speaking, respondents in our sample were advised mainly by commercial advisors or private consultants (59%). Government extension services (23%) and the cooperative advisors (21%) were also widely reported. Fewer respondents (16%) reported being advised by other growers. Other sources of advice (independent technical centre, irrigation communities, research centres etc.) were sought by about 16% of the growers. It was observed that CE respondents took more advice from government extension services than other regions (Figure 622). The sources of advice in the MED region were more diverse. This is the region where cooperative advisors were the most consulted. In soilless crops, there was a predominance of commercial advisors in all regions.

In almost all countries, 60 to 80% of respondents used one source of advice. It appears that 9% of respondents did not use any source of advice (this was mainly in Poland, where 16% of respondents did not seek advice), while 6% of them used three or more different sources of advice. In some regions (e.g. North of France) it was more common to use two sources of advice.

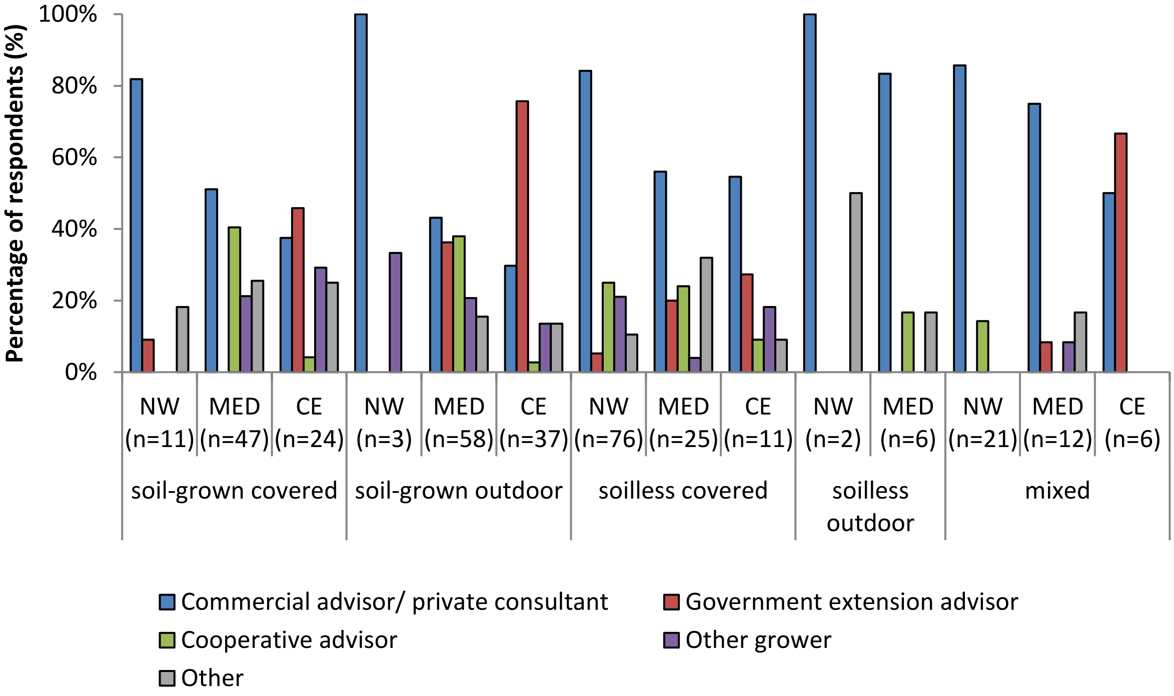

Figure 62 Percentage of respondents using the different sources of advice. Results are divided into cropping system and region (CE = Central East, MED = Mediterranean, NW = North West)

Irrigation and fertilisation seemed to be monitored the same way, with a similar split across advice sources. For the advice on effluent management, the pattern is different mainly due to the fact that this question was answered only by growers who manage their effluents, while almost all growers answered the previous questions (Figure 633). The private consultants/commercial advisors and the other sources of advice (technical centre, researchers) were used more when considering effluents management (55% and 20% respectively), while government extension services were used less.

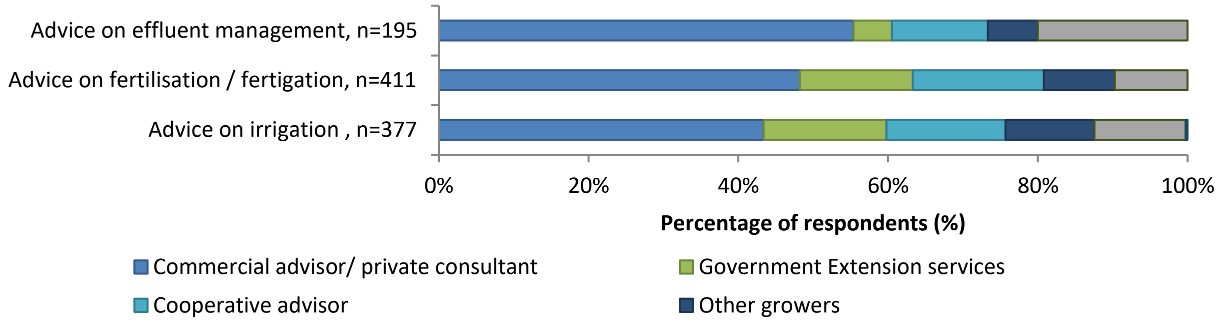

Figure 63 Proportion of different advice sources used per sector (irrigation/ fertilisation/ effluent management). Respondents could select several answers

4.3.1.1 Public support related to irrigation/fertigation management

Overall the respondents applying for or receiving subsidies related to their irrigation/fertigation management were few (22%), with the exception of the Slovene respondents (CE region) where 75% of them applied for or received subsidies. Of the 22% who answered positively, that they received subsidies, said that they are funded from European (41%), regional (36%) or national (23%) pots of money. However, those figures were highly dependent on the country and cropping systems. A minority of the respondents will apply to subsidies related to water management in the next 3 years (22%). Among them, 35% of them had not yet applied for or received subsidies.

If we want to assess whether subsidies are a possible driver for change, it is worth noting that 38% of respondents (n=324) would consider changing their system if they were supported by subsidies to do so (Figure 644).

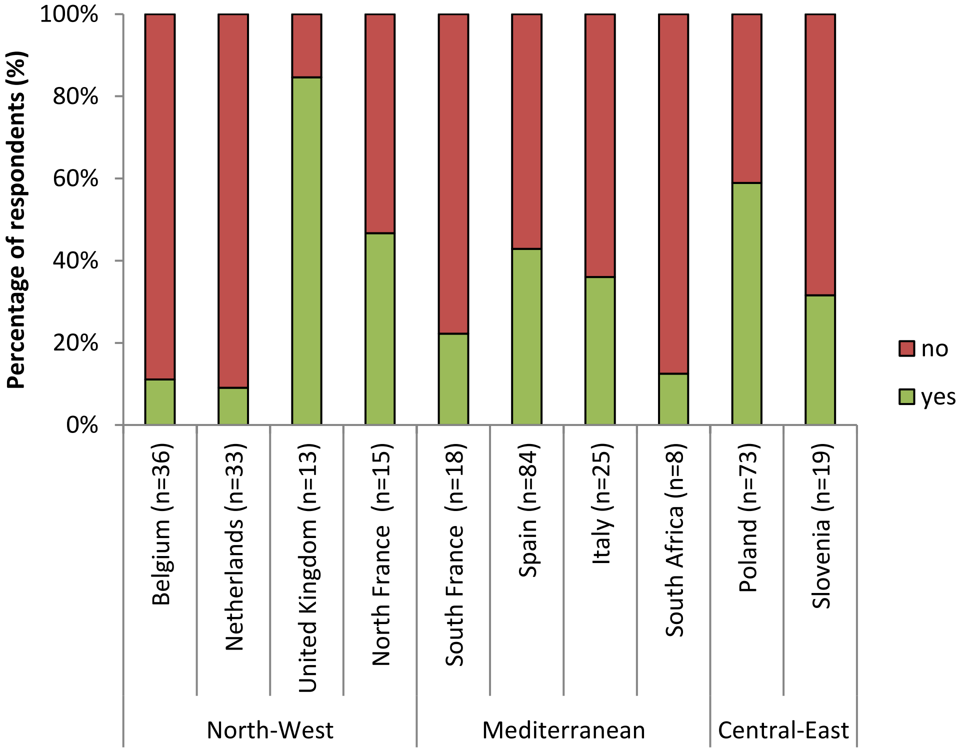

Figure 64 Percentage of respondents who said that they would consider modifying their practices if it meant receiving subsidies to do so

4.4 Solutions and bottlenecks to a sustainable water and nutrient use

4.4.1 Advantages and disadvantages of fertigation systems

Growers were interviewed about their views of their own irrigation and fertigation system. The main advantages and disadvantages reflect the arguments for and against adopting more efficient technologies or technologies more appropriate for their systems. It is important to take these advantages and disadvantages into account to understand how we can help the adoption of more efficient technologies.

4.4.1.1 Economic considerations

The main disadvantage for 15% of the respondents is the high cost of their fertigation system. This was the prevalent response in the CE (22%) and MED (18%) regions (Figure 66). Not all the respondents specified if the high cost related to implementation, maintenance or running costs. However, some of them believed that the implementation cost for changing the whole irrigation system was high i.e. when they switch from aspersion to drip irrigation. Others commented that the maintenance cost of their system is high, especially in terms of replacing equipment with a short life-span (sensors, drippers, tape lines, valves, etc.) as they often need replacing frequently (once each year or more). The low reliability of the equipment was mentioned by a few respondents, highlighting the issue of programmed obsolescence. Others focused on the cost of inputs for running the system (water, fertilisers, energy supply).

On the other hand, 13% of the respondents from our sample mentioned that their systems were relatively low cost (Figure 645). Respondents that fell into this category were generally from the CE and MED regions (16% in both regions) who use simple systems with low automation.

4.4.1.2 Ease of use and automation

The second disadvantage mentioned was the lack of automation of the irrigation systems (mentioned by 10% of respondents), mainly in the MED region (16%) (Figure 65). Respondents reported spending too much time opening/closing the valves manually, triggering irrigation events, dosing fertilisers by hand, and taking manual measurements, etc. They also complained about the lack of control they have over their systems. When fertigation was triggered, respondents could not monitor (in real-time) how effectively water and nutrients were supplied to the crop, due to low availability of solution sensors (EC, pH) or affordable crop/soil sensors. The lack of monitoring tools for possible leaks was also mentioned. Respondents from all regions considered their system "time/labour consuming". This was either because they had a manual system which was time and labour consuming, or because they had to check that the automated system was functioning well and manage potential failures. Low flexibility in their irrigation system and the difficulties of optimising irrigation for a diverse range of crops or crop developmental stages (e.g. in diversified production or ornamental crops) were highlighted as issues as well.

In contrast, respondents who have automated cropping systems highlighted the automation as the main advantage (8% of respondents overall; 13% of the MED region respondents): a lot of them focused on whole system management (Figure 655). Flexibility in the system was seen as an advantage in NW (18%) and MED (12%) regions. An automated system was considered advantageous if it is easy to manage, flexible and adaptable to the cropping system. Automated control of the system with sensors, probes, etc. was also important to the respondents, with 18% of MED respondents mentioning it as an advantage. The reliability of the system (easy or low maintenance and cleaning) was also widely appreciated, especially in the NW region where 12% of the respondents highlighted it.

4.4.1.3 Water and nutrient use efficiency

Irrigation systems lacking efficiency were highlighted as another disadvantage by some respondents, mostly regarding technical aspects. Clogging of drippers or irrigation lines was mentioned as an issue by 6% of respondents, and some (5%) reported having problems with irrigation uniformity, which decreases the water use efficiency (Figure 666). Other disadvantages mentioned were difficulties associated with leaks leading to the wasting of water, and problems with pressure management, which can cause damage to equipment and require a lot of labour.

Respondents were satisfied with the water (13%) and nutrient (11%) use efficiency of their system, as well as with the optimisation of fertigation (precision delivery of fertigation to meet crop demand, 8%) (Figure 655). A fair portion of the respondents appreciated that they succeeded in reaching a good crop yield and quality due to their fertigation system (11%).

4.4.1.4 Water use

In relation to water use, when respondents faced no problems, water availability (5%) and quality (4%) were considered an advantage (Figure 65). On the other hand, when poor, water quality and availability was considered a disadvantage by 5% and 3% (respectively) of respondents (Figure 66). Regarding environmental impact, 4% of respondents considered drain water recirculation as an advantage, while 5% reported the absence of recirculation as a disadvantage.

4.4.1.5 Other disadvantages mentioned

The difficulties that arise in management due to a small storage capacity, the dependency on suppliers for the maintenance of the irrigation system, and disease management were all raised as minor issues. The lack of buffer capacity (due to the limited amount of water available for the crop in the substrate compared to soil-grown crops) was mentioned as an issue for soilless systems because an irrigation failure can have a big impact on crop development and yield. Lastly, the cleaning of the systems was reported as a problem by some respondents because they cannot effectively control the cleanliness of the system, which can hugely affect the following crop.

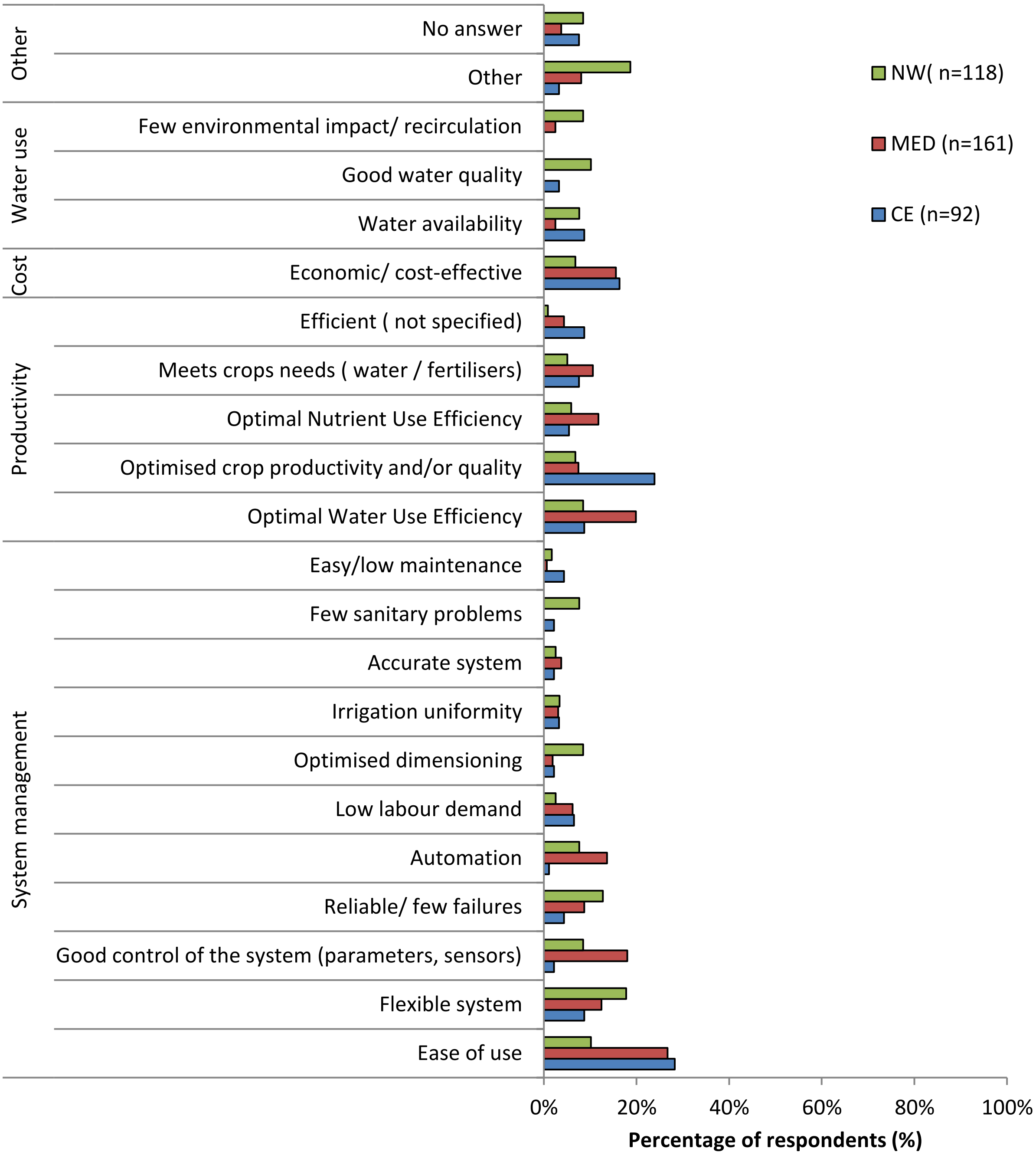

Figure 65 Advantages of the fertigation systems, as expressed by the respondents. Results are divided into cropping system and region (CE = Central East, MED = Mediterranean, NW = North West)

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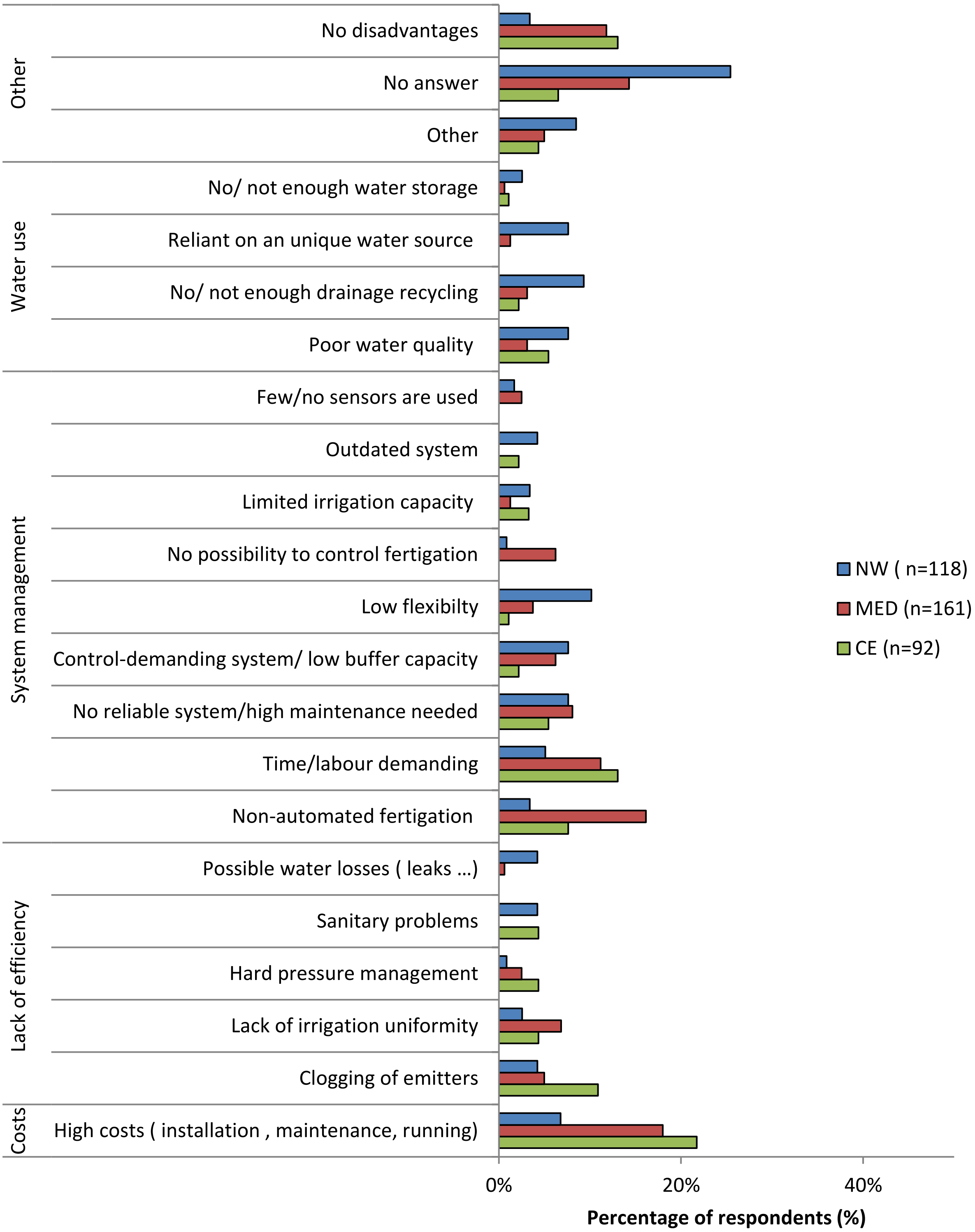

Figure 66 Disadvantages of the fertigation systems, as expressed by the respondents. Results are divided into cropping system and region (CE = Central East, MED = Mediterranean, NW = North West)

4.4.2 Improvements wished by growers

Respondents expressed a wish to improve their irrigation/fertigation systems. In Table , the diversity of solutions mentioned by growers is represented.

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Table 3: Improvements wanted by respondents particular to their irrigation/fertigation system, and level of importance to each region. The number of "+" represents the importance of the factor to each region. CE = Central East, MED = Mediterranean, NW = North West

	Category	Explanation , examples	NW	MED	CE
Automation and control Precise monitoring	Implement or increase the use of automation of the irrigation/ fertigation	Implement or increase the automation of irrigation/ fertigation, e.g implement solenoid valves, automatic quantitative application, automatic EC/ pH/ nutrient correction, automated ebb/flood system	+++	++++	++++
	Implement automated sensors	Automatic pH/ EC sensors, connected soil moisture sensors, connected balances or water content sensors	++	+++	+
	Implement manual sensors	Tensiometers, capacitance probes, watermarks, easy-to-use tools…		++	
	Remote control of the water status of the crop	Crop sensors		++	
	Implement a DSS or a software	Change or adapt N scheme, DSS based on vapour pressure deficit and radiation, WISE system…	+	++	+
	Improve recording and monitoring of irrigation	Record the amount of water input, measure/ quantify the drainage		++	+
	Improve fertilisation control / improve monitoring of the nutrient content	Use more analysis, measure ion concentration in the soil solution, more frequent drain water analysis, leaf analysis	+	++	
	Improve fertigation application	Use multi-tank fertilisation unit, use of liquid fertilisers, change N scheme	++	++	
	Continuous nutrient monitoring/ ion – selective measurement	Sensors in the nutrient solution (e.g potassium, calcium), Iron measurement	+++		
	Improve climate control	Use climate sensors, improve weather forecasting		+	
Improve water quality/quantity	Collect and use rainwater	Start or increase the collection of rainwater to irrigate the crop	+++	++	+
	Use of desalinated brackish water	Seawater or urban wastewater		+	
	Use water of a better quality	If available	+		
	Diversify water sources	Additional wells			+
	Increase storage capacity or improve storage conditions	Build a storage, dig a pond, build underground storage, fix leakages, renew cover, increase the storage capacity	+++	++	++

	Device against algae growth	The ultrasonic device, a system to prevent algae growth into the water silo floating balls in the storage	++		
	Improve pH control	Addition of acid	+		
	Aeration of the water	Add extra oxygen			
	Improve salinity control	Removal of sodium	+++	+++	
	Demineralisation	Reduce carbon bicarbonates (clogging), deironing , reverse osmosis, implement a technology removing nutrient from discharge water	++	+	++
	Control root exudates	To avoid phytotoxicity	+		
Recirculation / Drain water management	Implement/ improve recirculation	Collect the drainwater and recirculate it	+	+++	+
	Install/ change a disinfection system	Implement UV, biofiltration, ozonation, chlorination ; find alternative to current system	+++	++	+
	Reuse of the drain water for other uses	Use of drainage from trayfields on soil-grown crops (e.g orchards)	++	+	
	Reduce the part of the discharged water	Try to reduce the discharge water to zero	+		
Improve the system	Increase irrigation/fertigation capacity	Increase the flow, increase the fertigation area, extend the use of fertigation to other	+	+	++
	Improve flexibility of the system	A higher level of sectorisation, management of several crops	+	++	+
	Improve fertilisation unit	Improve organic fertilisers injection, enable the release of two fertilisers together, automatic A/B tank		++	
	Improve pressure management	Self-pressure compensating drippers, equip pump with flow regulator, autoregulated dripper		++	+
	Improve filtration system	Install a different type of filtration system, use SAF-filters, implement sand filter, self-cleaning filters, install bandfilter	++	+	++
	Install drip or micro-irrigation	Install precision irrigation instead of sprinklers, change towards more efficient drippers, underground irrigation	+	+	+
	Increase the precision of the system	Use more precise equipment			+
	Install systems preventing clogging	Prevent clogging of T-tape, drippers	+		
	Mulching	To avoid evaporation		+	
	Switch to substrate growing	To save water and fertilisers	+		

The topic that appeared by far the most in responses was the willingness to automate the irrigation and fertigation system. Linked to this, many respondents were willing to use more sensors (and more analysis) to more closely monitor and control the soil or crop water and nutrient status, increasing precision. Respondents were willing to use more sensors to monitor soil moisture but also nutrient status. The improvement of fertigation management was also sought through the implementation of decision support systems, and the adaptation of N schemes, etc. Precision equipment for fertigation application is also wanted by respondents.

Respondents are willing to improve the monitoring of water inputs by collecting and using rainwater, as well as investigating the possible use of other water sources. Storage management is also of great interest because a lot of respondents reported plans to install water storage or increase storage capacity. Reuse of drain water was also considered interesting and some respondents reported looking for the right disinfection system for their drain water. Other respondents planned to find different uses for their effluents, or even to reduce them to nothing.

Technical improvements of the systems were wanted by a lot of respondents such as renewal of equipment (pumps, filtration system, drippers, fertilisation unit…) for more efficient, precise and reliable systems. They also have specific requirements such as solutions to prevent clogging in tubes or drippers.

It should be noted however that a considerable number of respondents would not change anything to their irrigation/ fertigation system.

4.4.3 Bottlenecks impeding improvements

The only part of the group of respondents declared that they would be able to implement the above improvements in the next few years. The reasons for not implementing improvements are mainly due to economic bottlenecks. Respondents mentioned that the capital investment alone in innovative technologies would be too high, and they did not always have a clear idea of the level of benefit they would get, citing a need for in-depth cost-benefit analyses before investment.

It should be noted that many respondents also considered their farms too small to be worth the investment because the innovative technologies were tailored to bigger farms. Others mentioned that they would wait for the cost to decrease.

Moreover, several respondents indicated that their income from their crop is low due to the economic crisis, and therefore they did not consider now or the next few years to be an appropriate time to invest in a new system.

It should also be noted that the irrigation system does not seem to be one of the main priorities for respondents regarding investments, with them often reporting that implementation of irrigation/fertigation technologies was a low priority compared to other topics (e.g. crop protection, climate control, energy savings, labour, etc).

Apart from the cost, a broad range of other reasons was mentioned by respondents as a bottleneck to investing in innovative technologies:

-Respondents fear the complexity of monitoring tools. For example, some of them believe that if they upgraded to precision tools, they would have to permanently keep an eye on them to avoid any instances of irrigation deficit in the crop. They are sometimes not convinced by the reliability of automated equipment.

-The availability of the innovative technologies in the industry. Several respondents reported not being aware if the innovation was available on the market and/or available in their area (e.g for ion-specific sensors). Some of them also reported that they would not implement systems because it was not common in the area and due to a lack of experience with them. This is often linked to a lack of advice, which was reported by a few respondents. Several respondents also mentioned that equipment available on the market could not be tailored to their system. One respondent even reported that in his opinion, no viable technologies were available on the market for his problem.

-Technical bottlenecks linked to the implementation of a specific technology were mentioned (e.g brine management using reverse osmosis). The difficulty of technical implementation was mentioned as a major concern, especially if the crop is always in place (e.g. perennial crops). The need to technically adapt the system to implement an innovative technology can dampen the enthusiasm of the respondent. Respondents were also worried about the sanitary risks involved in some of these technologies (e.g. recirculation of drain water).

-Logistics: the respondent may cultivate small fields, set at some distance from each other, limiting the use of sensors or automated irrigation systems. The implementation of water storage is often blocked by a space limitation, and irrigation system improvement can be hindered by challenging landscape characteristics. Some respondents justified their decision not to make improvements to their limited access to water sources.

-Regulatory issues played a role in some cases: respondents may out on miss building permission (e.g for water storage), it can be difficult to get an authorisation. Legal restrictions may occur regarding the implementation of technology. For example, in the case of reverse osmosis, it might be forbidden to discharge the concentrated salt streams into the underground.

-Personal factors such as respondents being close to retirement and not interested in making new investments can be bottlenecks. Others reported a lack of time or a lack of knowledge to implement new technologies. A few respondents also mentioned that they were not able to make a decision because they were not the owner of the farm (or the land), or because the irrigation was managed by other people.

Finally, a high number of respondents reported that they found their current systems efficient enough to continue with. However, several respondents mentioned that they are already in the process of implementing innovative technologies or planning to.

4.4.4 Pathways to improve the adoption of sustainable practices

4.4.4.1 Factors affecting new practice adoption

Growers were asked to select from a list the first five factors that would drive them to adopt more efficient fertigation management practices (Table). There were some differences between regions and cropping systems. The reduction of production costs and improvement of crop quality were mentioned as the main factor in all systems. The reduction of labour costs was mentioned by most of the respondents, except those in soilless outdoor systems. Yield increase was mentioned in outdoor soil-grown crops especially in the NW region, and licensing/legal constraints were mentioned mostly by soilless outdoor growers. Improving financial return was considered as important but secondary to the other factors mentioned above, as well as protecting and improving production (except in soilless outdoor cropping systems where it seems to be a major driver).

Table 4. Drivers for adopting more efficient fertigation and irrigation management practices

System	Region	First driver for change	Second driver for change	Third driver for change	Fourth driver for change	Fifth driver for change
soil-grown covered	CE (n=29)	Reducing labour costs (e.g. operation of manual valves)	Improving crop quality	Reducing production costs (water, energy, electricity)	Improving financial returns	Improve security of production
	MED (n=53)	Reducing production costs (water, energy, electricity)	Improving crop quality	Increasing marketable yields	Reducing crop and soil damage	Improving financial returns
	NW (n=19)	Increasing marketable yields	Improving crop quality	Licencing/ legislative changes and need to demonstrate efficiency use	Improve security of production	Improving financial returns
soil-grown outdoor	CE (n=49)	Reducing labour costs (e.g. operation of manual valves)	Reducing production costs (water, energy, electricity)	Improving financial returns	Improve security of production	Improving crop quality
	MED (n=63)	Improving crop quality	Reducing crop and soil damage	Reducing production costs (water, energy, electricity)	Reducing labour costs (e.g. operation of manual valves)	Improving financial returns
	NW (n=4)	Reducing labour costs (e.g. operation of manual valves)	Licencing/ legislative changes and need to demonstrate efficiency use	Reducing production costs (water, energy, electricity)	Improve security of production	Increasing marketable yields
soilless covered	CE (n=12)	Security of water supply	Reducing production costs (water, energy, electricity)	Improve security of production	Improving crop quality	Reducing labour costs (e.g. operation of manual valves)
	MED (n=31)	Reducing crop and soil damage	Improving crop quality	Reducing production costs (water, energy, electricity)	Improving financial returns	Increasing marketable yields
	NW (n=87)	Improving crop quality	Reducing production costs (water, energy, electricity)	Increasing marketable yields	Improve security of production	Improving financial returns
soilless outdoor	CE (n=2)	Reducing labour costs (e.g. operation of manual valves)	Improve security of production	Improving crop quality	Licencing/ legislative changes and need to demonstrate efficiency use	Improving financial returns
	MED (n=11)	Reducing labour costs (e.g. operation of manual valves)	Improve security of production	Licencing/ legislative changes and need to demonstrate efficiency use	Reducing production costs (water, energy, electricity)	Reducing crop and soil damage
	NW (n=8)	Licencing/ legislative changes and need to demonstrate efficiency use	Increasing marketable yields	Improving crop quality	Improve security of production	Addressing current or future water availability

4.4.4.2 Tools expected to accompany the adoption of new practices

Growers were asked about what they would find useful to improve their fertigation management. The list of tools was not exhaustive but the answers gave indications about growers' expectations. The first choice tools were similar across cropping systems and regions; growers find it useful to exchange and learn from each other and want feedback on the experience of others (Table). They look to visit sites where best management practices or sustainable technologies are demonstrated. The second choice tool was to have direct access to specialists or researchers for advice on fertigation management and to get financial support to change practices.

Technical tools like remote sensors to manage irrigation and fertilisation were also popular among respondents, but were, although important, a secondary option. Updated nutrient management guidelines would also be useful, as well as documents comparing different systems or explaining best practice and associated benefit. Decision support systems or workshops were slightly less popular among the respondents.

Table 5: Ranking of tools considered as useful to help growers in modifying their practices

System	Region	First choice	Second choice	Third choice	Fourth choice	Fifth choice
soil-grown covered	CE(n=29)	Visiting sites which demonstrate fertigation best practices	Updated nutriment recommendation guides	Learning from the experiences of other irrigators/ fertigators	Direct face-to-face access to fertigation specialists and leading researchers	Nutrient management decision support system for portable devices (tablet, smartphone)
	MED (n=53)	Visiting sites which demonstrate fertigation best practices	An appropriate document explaining the best practices and advantages (efficiency/financial returns)	Affordable real-time nutrient diagnostic tools	Financial support/ subsidies to apply BMP or to implement technology	Affordable remotely accessed automatic sensor-activated system for fertigation and irrigation management
	NW (n=19)	Learning from the experiences of other irrigators/ fertigators	Direct face-to-face access to fertigation specialists and leading researchers	Nutrient management decision support printable tables	Affordable real time nutrient diagnostic tools	Affordable remotely accessed automatic sensor-activated system for fertigation and irrigation management
soil-grown outdoor	CE (n=48)	Learning from the experiences of other irrigators/ fertigators	Updated nutriment recommendation guides	Document about technologies-comparisons of systems	Visiting sites which demonstrate fertigation best practices	Direct face-to-face access to fertigation specialists and leading researchers
	MED (n=63)	Direct face-to-face access to fertigation specialists and leading researchers	Financial support/ subsidies to apply BMP or to implement technology	Affordable remotely accessed automatic sensor-activated system for fertigation and irrigation management	Learning from the experiences of other irrigators/ fertigators	Updated nutriment recommendation guides
	NW (n=2)	Affordable remotely accessed automatic sensor-activated system for fertigation and irrigation management	Financial support/ subsidies to apply BMP or to implement technology	Direct face-to-face access to fertigation specialists and leading researchers	Updated nutriment recommendation guides	Visiting sites which demonstrate fertigation best practices
soilless covered	CE (n=12)	Visiting sites which demonstrate fertigation best practices	Direct face-to-face access to fertigation specialists and leading researchers	Affordable remotely accessed automatic sensor-activated system for fertigation and irrigation management	Document about technologies-comparisons of systems	Updated nutriment recommendation guides
	MED (n=32)	Visiting sites which demonstrate fertigation best practices	Learning from the experiences of other irrigators/ fertigators	Updated nutriment recommendation guides	Direct face-to-face access to fertigation specialists and leading researchers	Affordable remotely accessed automatic sensor-activated system for fertigation and irrigation management
	NW (n=74)	Learning from the experiences of other irrigators/ fertigators	Visiting sites which demonstrate fertigation best practices	Workshops involving suppliers of fertigation equipment and nutrient management services	Direct face-to-face access to fertigation specialists and leading researchers	Nutrient management decision support system for portable devices (tablet, smartphone)

soilless outdoor	CE (n=2)	Updated nutriment recommendation guides	Visiting sites which demonstrate fertigation best practices	An appropriate document explaining the best practices and advantages (efficiency/financial returns)	Workshops on how to improve your own water availability	Financial support/ subsidies to apply BMP or to implement technology
	MED (n=11)	Financial support/ subsidies to apply BMP or to implement technology	Document about technologies-comparisons of systems	Affordable real-time nutrient diagnostic tools	Visiting sites which demonstrate fertigation best practices	Workshops to better understand water source issues in your region and how abstraction management might be improved to make more irrigation water available
	NW (n=8)	Learning from the experiences of other irrigators/ fertigators	Visiting sites which demonstrate fertigation best practices	Affordable remotely accessed automatic sensor-activated system for fertigation and irrigation management	Nutrient management decision support printable tables	Affordable real-time nutrient diagnostic tools

5 Effluent management and minimisation of environmental impact

Implementing fertigation is already an important step towards the more efficient use of water and nutrients. Fertigation can also significantly reduce the environmental impact of these crops. However, we still find serious nutrient enrichment of both ground and surface water in areas with intensive fertigation practices all over Europe. For both soilless and soil-bound fertigated crops, excessive nutrient leaching or discharge is reported, both for high- and low-tech growing systems. Despite widespread recirculation of nutrient solutions from greenhouses, significant enrichment of surface water is still frequently observed near greenhouses with soilless cultures. In a Flemish study, the discharged water of 13 greenhouses growing soilless crops of fruit vegetables (cucumber, tomato and sweet pepper) and ornamentals were monitored. This study revealed that only 25% of the monitored greenhouses succeeded in closing the water cycle during two years (Berckmoes et al, 2013). Five to 15% of water is still discharged into sewers or surface waters (Beerling et al., 2013, Van Os E., 2017, Balendonck et al, 2014). In many cases nutrient solution is discharged due to 1) accumulation of sodium, 2) fear of unknown growth inhibiting factors (root exudates, residues of plant growth control agents), 3) mismatch of nutrients and 4) fear of spreading diseases (at the end of the season and during the season) (Beerling et al, 2013, Berckmoes et al, 2013). There can also be discharged from 1) wash water of filters, 2) cleaning of the irrigation system, and 3) system failures.

The impact of the effluents depends on 1) the nutrient concentration of the effluent, 2) the frequency of discharge, 3) the volume of the discharged water and 4) the destination of the discharged water. As an example, wash water from a fast sand filter contains on average 360 mg NO3 per litre in the case of a soilless tomato crop, while the nutrient solution contains around 1.800 mg/l (Berckmoes et al, 2013). Evaluation of the impact of the discharged water can only be made when the above four factors are taken into account.

Both soil-grown and soilless growing systems applying fertigation can produce nutrient wastewater streams during the production process. Although drain water in soilless crops and drainage water in soil bound crops are the most well-known wastewater streams, the cleaning water of the irrigation system and filter systems can also contain considerable concentrations of nutrients and residues of plant protection products (PPP).

This chapter describes the current status of effluent management as reported by the surveyed growers. FERTINNOWA's benchmark survey questioned growers of fertigated crops about their current practices and the bottlenecks faced to minimise the environmental impact of their practices. The survey did not imply any type of quantification (in terms of volume) or qualification (in terms of nutrient content) of the discharged water streams. This chapter reflects the views of the respondents. This does not mean that the answers provided comply with the actual situation or legislation.

5.1 *Current status of sources of discharged water*

5.1.1 Drain water

5.1.1.1 Quantification of drain water discharge

The growers were asked to quantify the percentage of drain water that is collected, and also the percentage recirculated. Drain water refers to the excess of irrigation water that drains from the substrates. Therefore, for the questions referring to drain water, we used a subset of the data which only contained the respondents with soilless crops. It should be noted that 20% of the growers of soilless crops did not answer as to whether they collect drain water and 30% did not answer the question about drain water recycling (data not shown).

Overall, of the 166 respondents, 51% collected all drain water. In general, the NW region had the highest number of respondents (72%) who collected at least 80% of the drain water (Figure 67). The highest ratio of respondents who do not collect drain water was found in the CE region (33%), followed by the MED (27%) and the NW (20%), although most of the soilless cropping systems were located there (Figure 677). In the NW, those growers were located mainly in the UK. The main cropping systems associated were strawberry, soft fruits, or potted ornamentals.

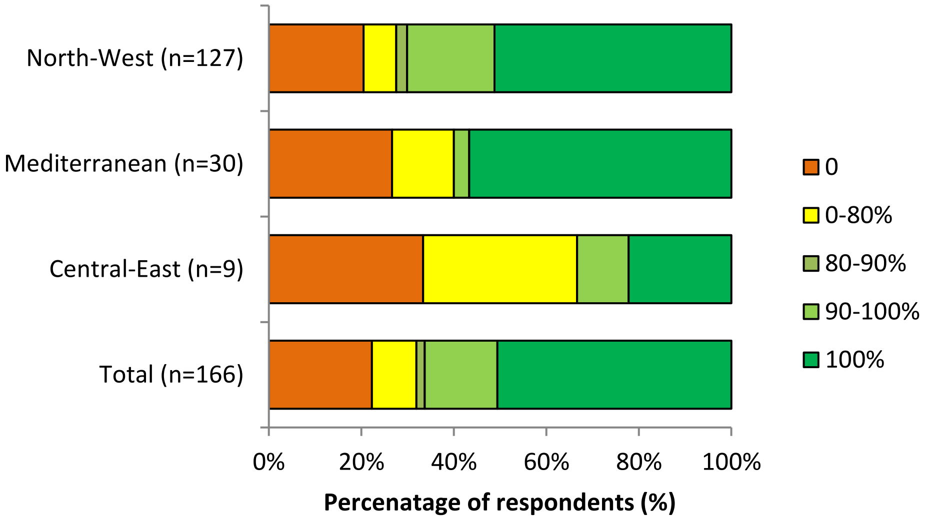

Figure 67 Levels of drain water collection by the respondents in each region.

Out of the 144 respondents answering the question on recirculation, 42% recirculated all the drain water while 26% did not recirculate any drain water (Figure 688). The remaining 32% recirculate part of the drain water varying between 1 to 99%. In the MED and CE regions, 50% and 44% of the respondents respectively are not recirculating the drain water, while in the NW region the opposite was observed; more than 60% of the growers recycle more than 90% of their drain water. However, 26% of growers do not recycle the drain water at all. Those

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growers were located mainly in the NW (growing strawberry and soft fruits) and in the MED growing tomatoes.

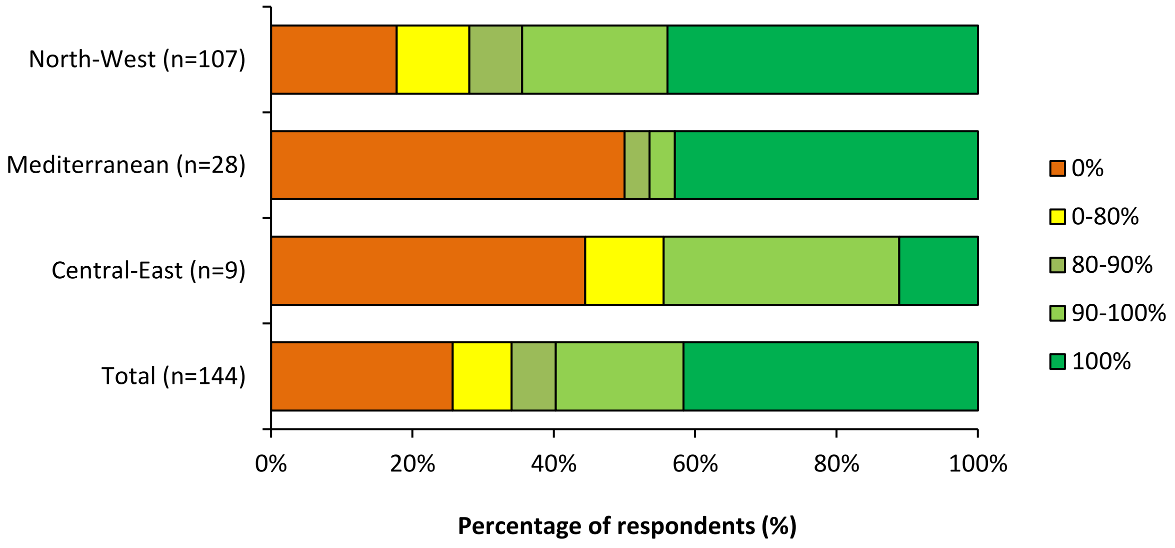

Figure 68 Levels of recirculation by the respondents in each region.

5.1.1.2 The frequency of drain water discharge

In total 61% of the respondents with soilless cropping systems answered this question. As only a minority of the growers with uncovered crops answered, in this section, we are referring only to the respondents with soilless covered crops. It is worth noting that only 8% of these respondents did not discharge any drain water during the whole growing season (Figure 699). While 44% of the respondents answered that they need to discharge drain water occasionally (a few times per year); 27% of the respondents discharge the drain water on a daily base (Figure 699).

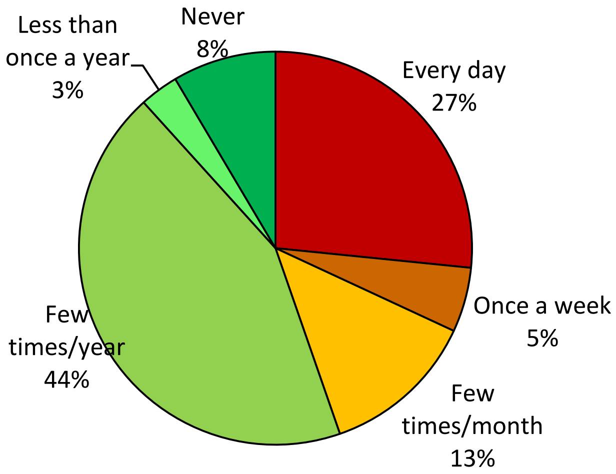

Figure 69 Frequency of drain water discharge by the respondents with covered soilless crops (n=94)

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The majority (67%) of the respondents discharging daily is found in the MED region. In contrast, in the NW region, only 15% of the respondents were discharging daily, whereas the majority (54%) of the respondents discharged only a “few times per year”. Only 8% of the NW respondents did not discharge any drain water. In the CE region only five growers, growing soilless crops in greenhouses, answered this question and two of them (40%) discharge on a daily to weekly basis.

5.1.1.3 Destination and treatment of drain water before discharge

In our sample, 67% of the respondents answered the question “is the drain water treated before discharge?” A large majority of them (95%) did not apply any treatment to the drain water before discharging it. It has to be mentioned that two growers from the NW region (Belgium and the Netherlands) treat the drain water to remove both nitrogen and phosphorus from it before it is either discharged or reused. In the Netherlands, four other growers also removed plant protection product residues (data not shown).

Results and discussions with horticulture experts revealed that growers feel there is a lack of solutions to remove nutrients before discharging the drain water.

The destination of the discharge water varied. Of the respondents, 74% indicated having one or more destinations for their discharged water (data not shown). In 25% of the discharge events, the drain water is directly discharged into the environment (ditch, surface water). This mainly happened in Belgium, France and the Netherlands (Figure 7070). In about 24% of the discharge events (Netherlands, France, etc.), the drain water was released to the sewage systems, however, from the responses, it is not clear if the sewage system is passing through a water treatment plant (Figure 70). Other main practices were spreading the discharged water on cultivated land (16%) or in bare fields (14%). These growers are situated mainly in Belgium, Poland, France, Netherlands, and Spain (data not shown). In 9% of the events, the discharged water is re-used on other crops (Figure 70). In 6% of the discharge events, the discharged water was discharged to on-farm tailing ponds or constructed wetlands (Figure 70). They were implemented by respondents located in Belgium and France.

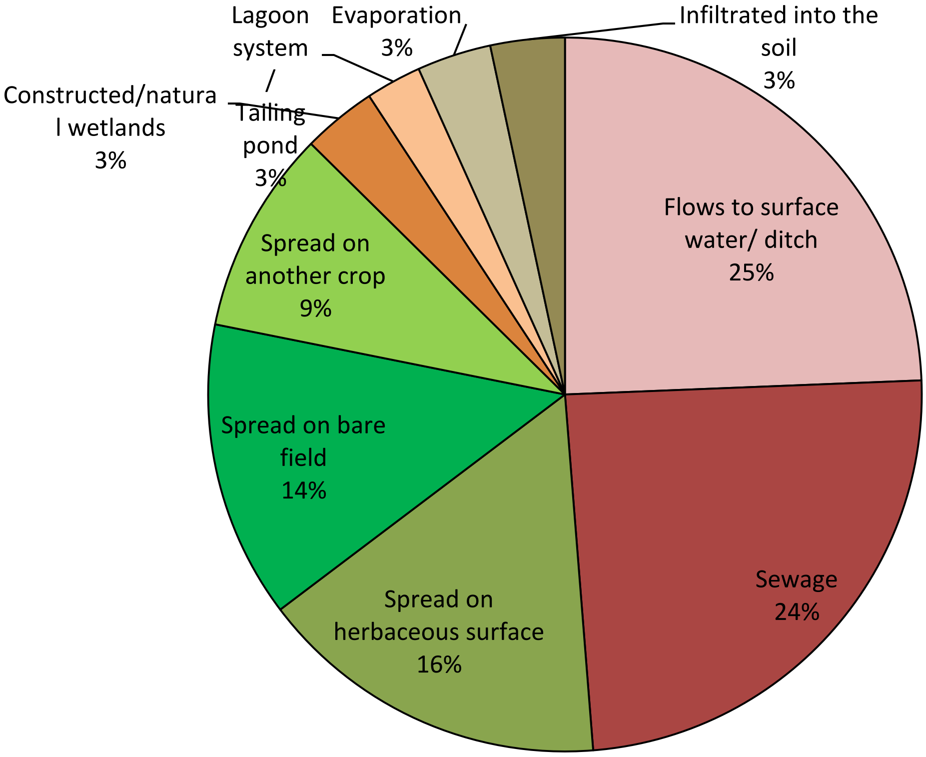

Figure 70 Destinations of the discharged drain water used by the respondents (n=113).

5.1.2 Drainage water

Drainage water refers to the water flowing through the soil below the cropping system. The water is collected through a drainage collection system. In our survey, the presence of such a system was not explored on soilless systems and therefore the data focuses on soil-grown crops. Only 16% of the respondents of soil-grown crops had an underground drainage system. In the NW region, about half of the growers indicated that they have a drainage system, while in the MED region less than 3% of the growers had one (Figure 71). Only 15% of the respondents that had a drainage system said that they measured the nitrogen content of the drainage water (four growers in the NW and one in CE, data not shown).

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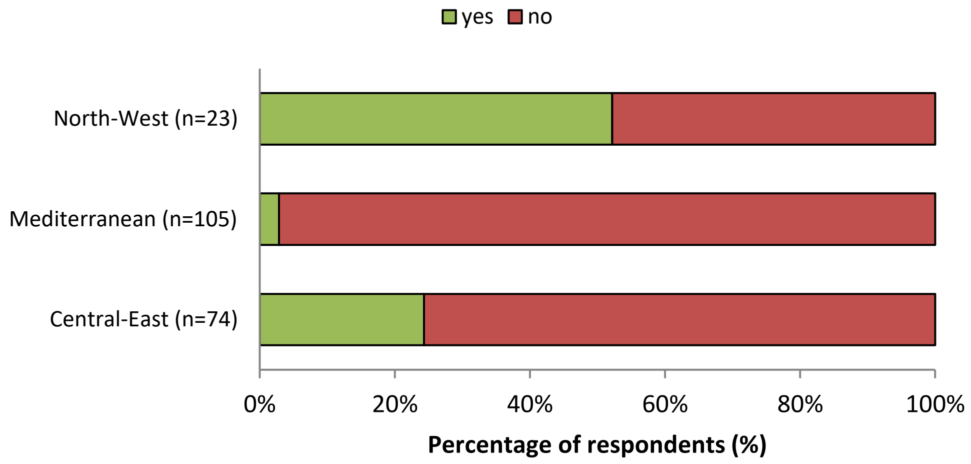

Figure 71 Percentage of the respondents using underground drainage systems on soil-grown crops (n=202)

5.1.3 Effluents from maintenance

The benchmark survey focused on the methods and frequency of maintenance, not on the volume of the water applied for the maintenance. Therefore, we will not discuss the total volume of maintenance water used by the growers.

5.1.4 Cleaning methods

Cleaning water refers to water that is produced while cleaning parts of the fertigation system, which includes the filter systems, underground pipes[4], irrigation lines[5] and the tanks.

Of the growers questioned, 84% described how they maintain their filtering system. Backflushing[6] is the most common method applied to clean filters and is used mainly in the CE (65%) and NW (70%) regions (Figure 722). Another common method is to increase pressure[7] (29% of the respondents in the MED) or rinse the filters (33% of the respondents in MED). However, when somebody is looking the results and the differences among the regions, they should bear in mind that the growers may use different types of filters for which the most appropriate method should be chosen. Differences were found between cropping systems. Backflushing (61%) and manual cleaning (12%) were the preferred methods on soilless crops, while on soil-grown crops backflushing (41%), increasing pressure (30%) and rinsing (22%) are preferred (data not shown).

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[4] Refers to fixed part of the irrigation system

[5] Refers to the flexible parts of the irrigation systems; these can be changed easily

[6] Backflushing: remove dirt particles by inverting the water flow through the device.

[7] Pressure increase: increase the flow pressure into the pipes or systems in order to remove dirt particles from the device.

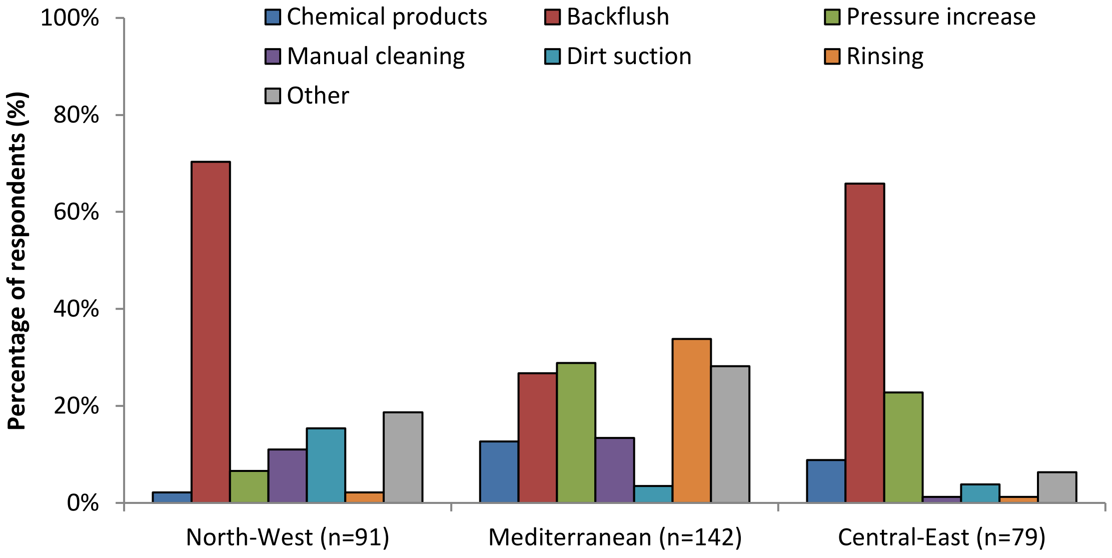

Figure 72 Methods used by the respondents to clean filters in each region

The growers were asked about their cleaning practices regarding their pipes (the fixed parts of the irrigation system) and irrigation lines (flexible parts of the irrigation system). Out of the interviewed growers, 32% indicated to clean the pipes while 70% indicated to clean the irrigation lines. Respondents mainly reported cleaning irrigation pipes (42%) and lines (53%) with chemical products (for example with nitric or phosphoric acid, sodium hypochlorite or hydrogen peroxide). In the NW region, 61% of the respondents used chemicals to clean their irrigation pipes and 78% their lines, respectively (Figure 73). In the MED (having mainly soil-grown cropping systems), chemical products are used to a lower extent and mainly for the irrigation lines (51%), while irrigation pipes are usually rinsed (50%). A not insignificant number of respondents (37%) in the CE region (with soil-grown crops) reported replacing irrigation lines instead of cleaning them, while the most popular way to clean irrigation pipes is to increase pressure (58%).

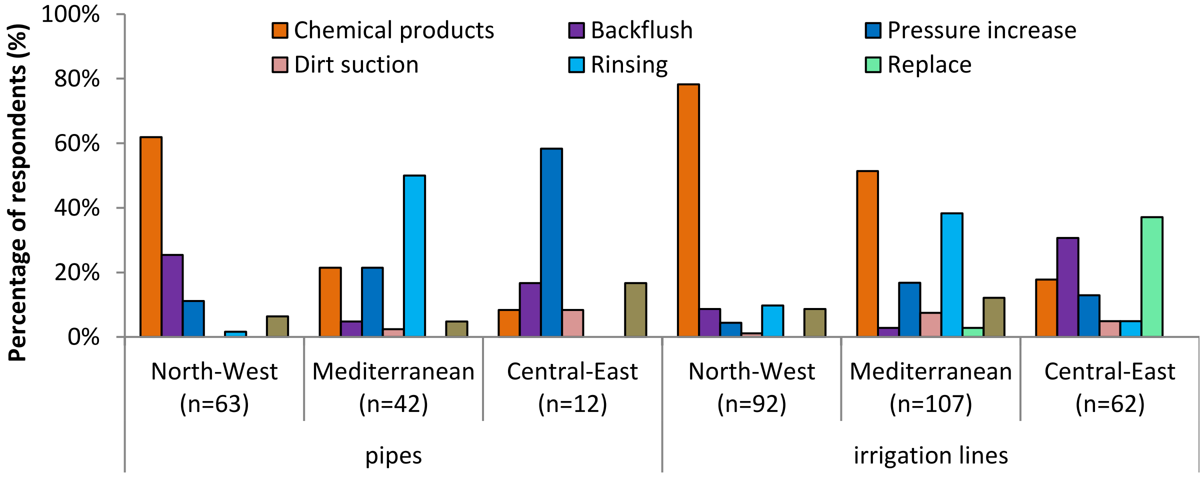

Figure 73 Methods used by the respondents to clean irrigation pipes and lines (fixed and flexible part of the irrigation system) in each region

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Of the growers questioned, 51% described how they clean water storage tanks. In the CE and MED regions (growing mainly soil-grown crops), 47% and 39% of respondents respectively mostly reported rinsing their tanks (Figure 744), while respondents in the NW (with mainly soilless crops) were using chemical products to clean them (39%). Dirt suction was used more by respondents in the NW (26%). Manual cleaning of the water storage is also a common practice in MED and the NW (respectively 23 and 18%).

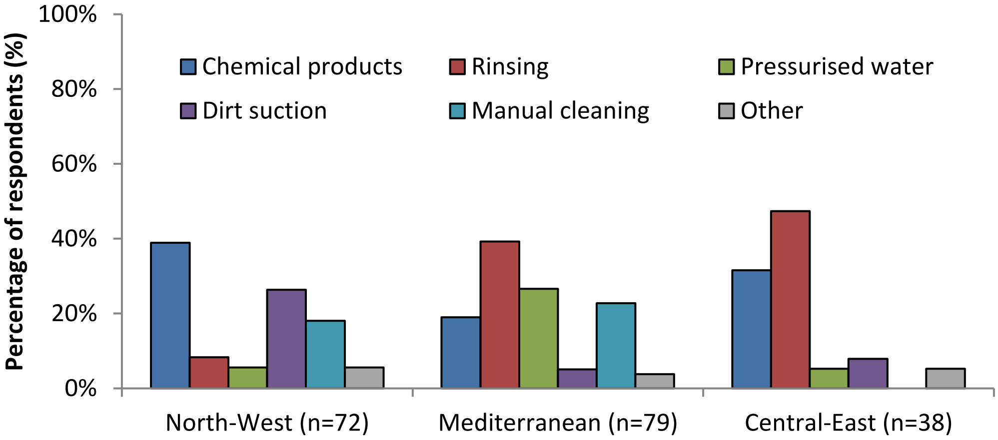

Figure 74 Methods used by the respondents to clean tanks in each region

5.1.4.1 Frequency of maintenance

The frequency of maintenance can also have an impact on the total quantity of cleaning water. No major differences were observed between regions or cropping systems. In general, 70% of the respondents indicated that they clean the filters more frequently than a few times per month (Figure 75) and 21% of the respondents cleaned them every day. Irrigation lines were cleaned a few times per year (28%) or only yearly (34%). On the other hand, the underground pipes were rarely cleaned; 34% of the respondents cleaned these pipes yearly and 38% said they never cleaned them. Tanks are generally cleaned once a year or less.

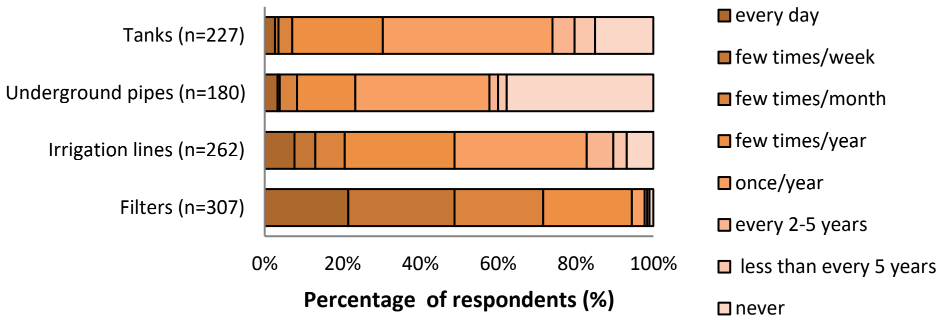

Figure 75 Frequencies of cleaning the parts of the irrigation system

5.1.4.2 Destination of the cleaning water

As the cleaning water might contain considerable concentrations of nitrogen and/or phosphorus, it is important to know its destination (Figure 76) gives an overview). It seems that, as was the case for the discharged drain water, the destination of the cleaning water is related to the region. In the MED region, the cleaning water is mainly spread on cultivated land (66%). The whole system is rinsed on site and the rinsing water (possibly added with nitric acid) flows at the extreme of the cultivated plots. Only at a minority of the farms does the cleaning water still flow directly to surface water (14%). In the CE region, the cleaning water generally either evaporates (56%) or is discharged to surface water for the soil-grown crops (26%). In the NW region where mostly soilless cropping systems were surveyed, the cleaning water is either recirculated (33%), discharged into the surface water (26%), evaporated (23%) or spread on another crop or cultivated land (23%). Few growers mentioned they put this water into the sewage system (2%) or that they treat it before discharge (2%).

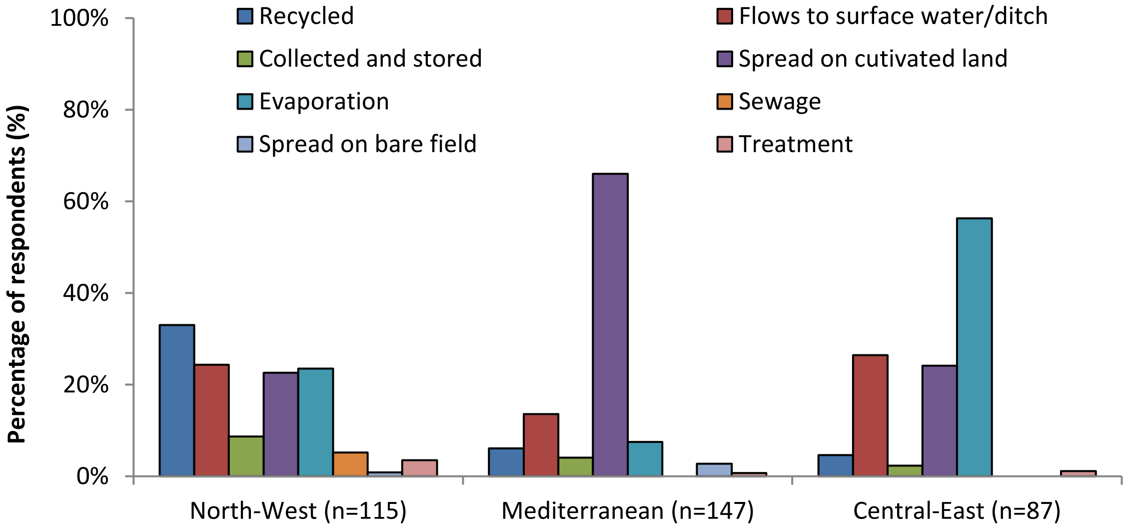

Figure 76 Destination of the cleaning water per region and growing system

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5.1.5 "Flush/rinsing" water

In some crops or regions, the irrigation system is flushed with clean water just before or after applying nutrients. This practice is not considered maintenance but relates to fertigation management.

Figure 77 shows that there were significant differences regarding this practice when comparing both the regions and the growing media:

- Soil-grown crops: In the MED region we observed that rinsing the irrigation lines was common practice for these crops. Of the respondents from this region, 67% rinsed the irrigation lines. In the CE and NW regions, this practice was less frequently used, excluding soil-grown outdoor crops in the NW. The four NW respondents with soil-grown outdoor crops all answered that they rinse the irrigation system before and/or after applying nutrients.
- Soilless crops: In the CE region, the irrigation lines were not rinsed before and/or after applying nutrients, similarly in the NW region only 10% of growers rinsed the lines. In the MED region, 30% (covered crops) to 50% (outdoor crops) rinsed the fertigation lines.

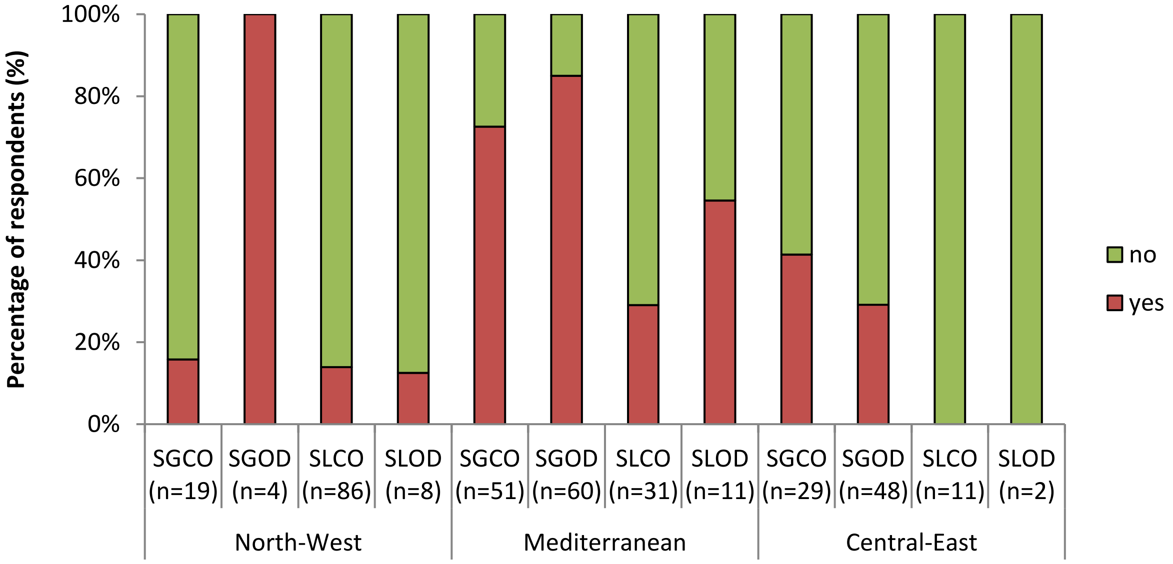

Figure 77 Respondents indicating to rinse the irrigations system before and/or after applying nutrient. SGOD: soil-grown outdoor, SGCO: soil-grown covered, SLOD: soilless outdoor, SLCO: soilless covered

In some cases, respondents mentioned that they rinsed the irrigation system only after applying fertilisers containing specific nutrients, such as nitrogen, calcium, potassium or phosphorus. Other growers rinse the system especially after disinfection, or in the morning to avoid side effects like chemical reactions that might have occurred between different nutrients that remained in the irrigation system.

5.1.6 Socioeconomic factors linked to discharged water recycling

As only a few data were gathered regarding the bottlenecks linked to the effluents coming from maintenance (cleaning and rinsing water) and drainage systems, this section of the survey will focus on the reported bottlenecks linked to drain water treatment and recycling.

5.1.6.1 Conditions to recycle the drain water

The different levels of drain water recycling can be explained by several factors. We asked the respondents about the criteria they use to start recycling drain water. Only 58% of the growers with soilless cropping systems interviewed answered the question, and they were mainly growers from the NW region. Of these respondents, 29% declared that they recycle all water except the cleaning water (Figure 788). Additionally, 27% of these respondents mentioned that they start recycling drain water some weeks after crop establishment, and of these, 10% started recycling only when drain water volume was sufficient (Figure 788). In general, 3% of the respondents mentioned that recycling drainage was done only for specific uses (e.g. for irrigating particular kinds of crops, in particular in the CE).

In the NW region (Figure 788)11% of the respondents mentioned that a reason for recycling drain water is low electrical conductivity (EC). The category “other” includes respondents from the NW region that begin recycling drain water only when it has high nitrogen content or low sodium content. In this category, respondents also mentioned that they avoid using the drain water when they suspect nutrient imbalances, growth inhibition issues in their crop, or diseases spread. They are also mindful of the risk of contamination by chemical products used to clean the irrigation system.

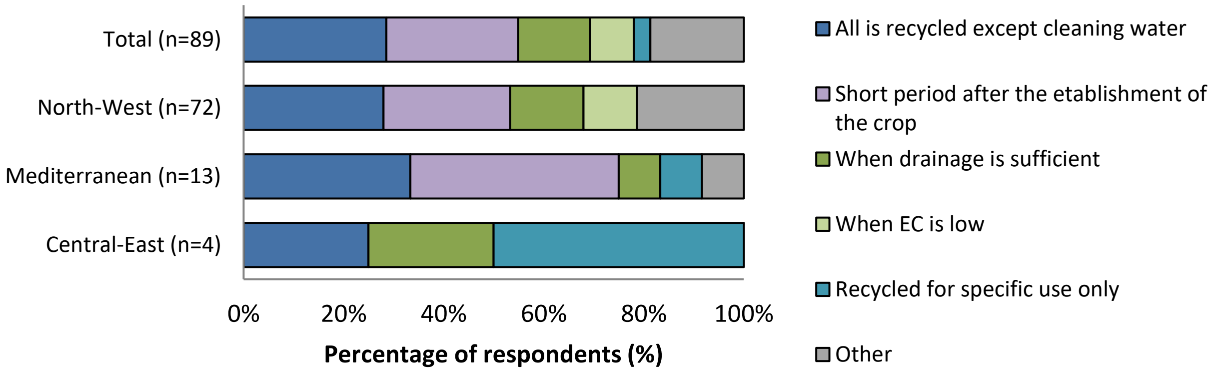

Figure 78 Criteria followed by growers to trigger drain water recycling

5.1.6.2 Reasons for recycling the drain water

It is important to identify factors influencing a grower’s decision to recirculate the drain water in order to understand how the adoption of recirculation could be enhanced. About 81% of the responses were given by growers located in the NW region, as this was the region questioned that had the majority of the soilless cropping systems.

The factors that influence growers' decisions were similar both in the NW and MED region.

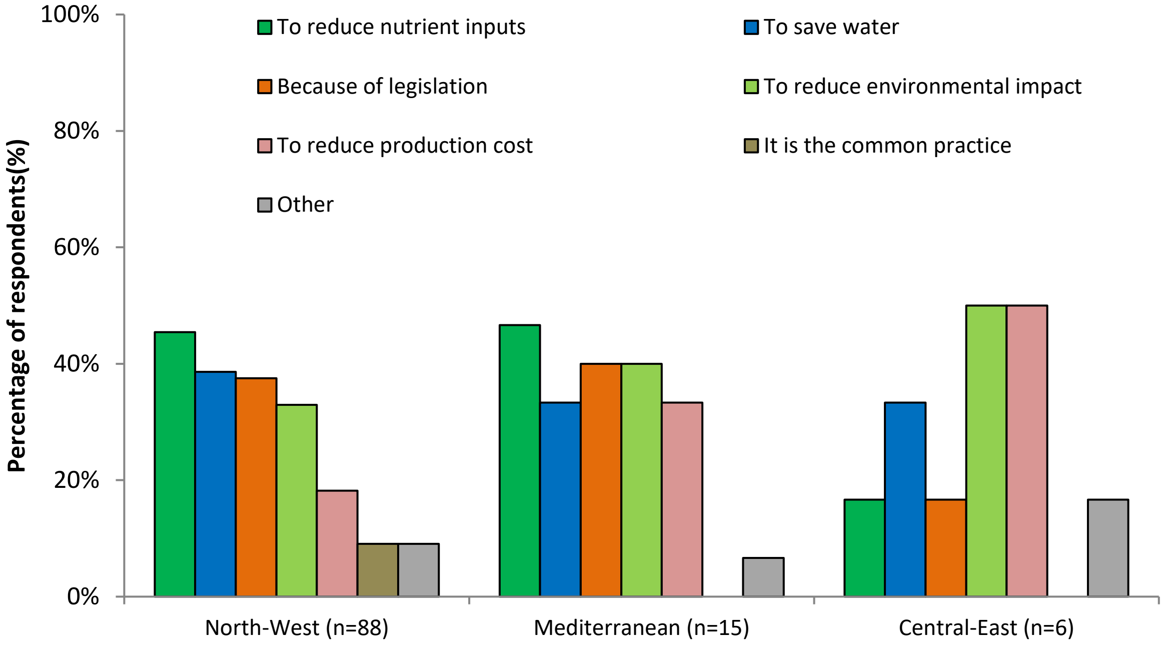

Figure 79 Reasons that the respondents implement drain water recirculation

About, 45% and 47% of the respondents from the NW and MED region respectively indicated that the reduction of nutrient input is their main reason for implementing recirculation (Figure 799). Other reasons of similar importance were saving water, reducing environmental impact and because of legislation. Moreover, 33% of the MED respondents stated that recirculation helps to reduce production costs. In the CE region, although there were few responses, they were very diverse. Reducing environmental impact and production costs were equally important (50%) to growers there. In contrast with the MED and NW regions, for the CE region, legislation (17%) is not a leading reason for implementing drain water recirculation (Figure 799).

5.1.6.3 Issues faced by growers who recycle the drain water

Of the respondents with soilless growing systems, 43% mentioned bottlenecks related to drain water recycling. Of the soilless growers, 81% recycled the drain water (mainly in the NW region, where 85% of NW growers recycled drain water), and 19% of the respondents do not recycle drain water, but still answered the questions.

The main issue faced was ion accumulation (48%) (especially sodium), which causes an increase in EC in the irrigation system, and could cause an imbalance in the nutrient solution It was reported to be a problem mainly for strawberry and tomato as well as other fruit and vegetables (cucumbers, pepper, eggplant, etc.).

The spread of diseases was reported by 25% of the respondents. This is especially prevalent among growers of potted ornamentals and cut flowers but also mentioned by a few tomato, cucumber and lettuce growers. Growers with the same type of crops also complained about root exudates, however, only a small proportion of them was affected by this (12%). Growth inhibition (the reason was not specified) is faced by a few growers in the NW region (13%) on cucumber, lettuce and also tulip, sweet pepper and eggplant.

Other minor issues were also mentioned, especially in the NW region, such as: the presence of residues from chemical products (plant protection products or cleaning products), the presence of residues from substrates or other sediments that can cause clogging in the irrigation system, the difficulty in controlling changing levels of specific ions (Si, Fe, HCO_3) or the pH, and the difficulties linked to the management of drain water volumes (volumes are sometimes higher than can be recirculated).

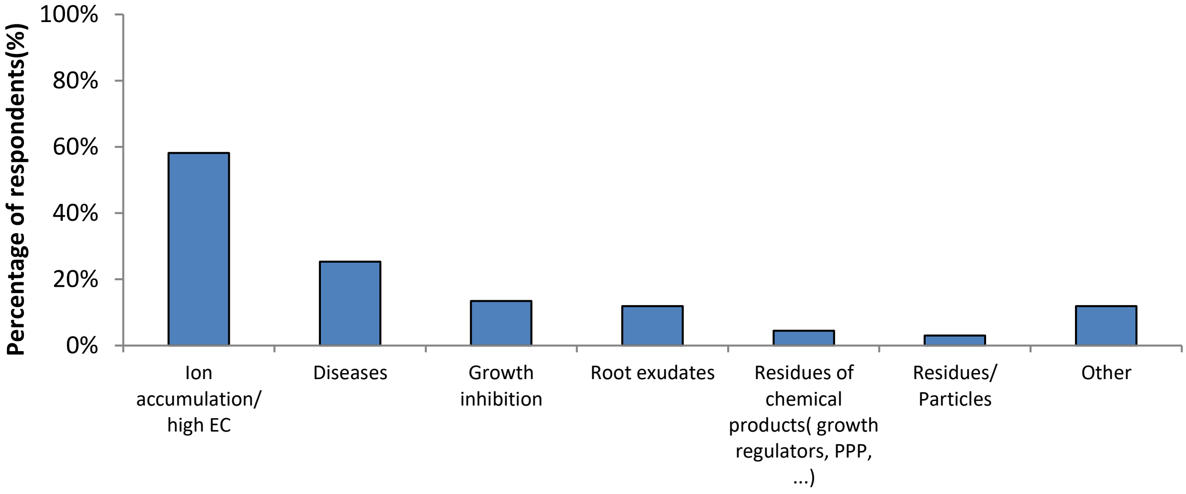

Figure 80 Issues faced by growers who recycle drain water (n=67)

5.1.6.4 Concerns regarding drain water recycling

Only 50% of the respondents explained the reasons for not recirculating the drain water. In the CE region, the main reason was the higher production cost (70%) when recirculating the water followed by the big investment cost (31%) (Figure 80). Interestingly, disease risk was the main reason in the MED, mentioned by 43% of the respondents while approximately 37% indicated financial reasons playing a part as well. In the NW region, 48% of the respondents mentioned different reasons such as incompatibility with the substrate they are using, the quantities of the drain water being both too high (from tray fields) or too low, their systems are not adapted, because it is not mandatory or because the legislation is unclear.

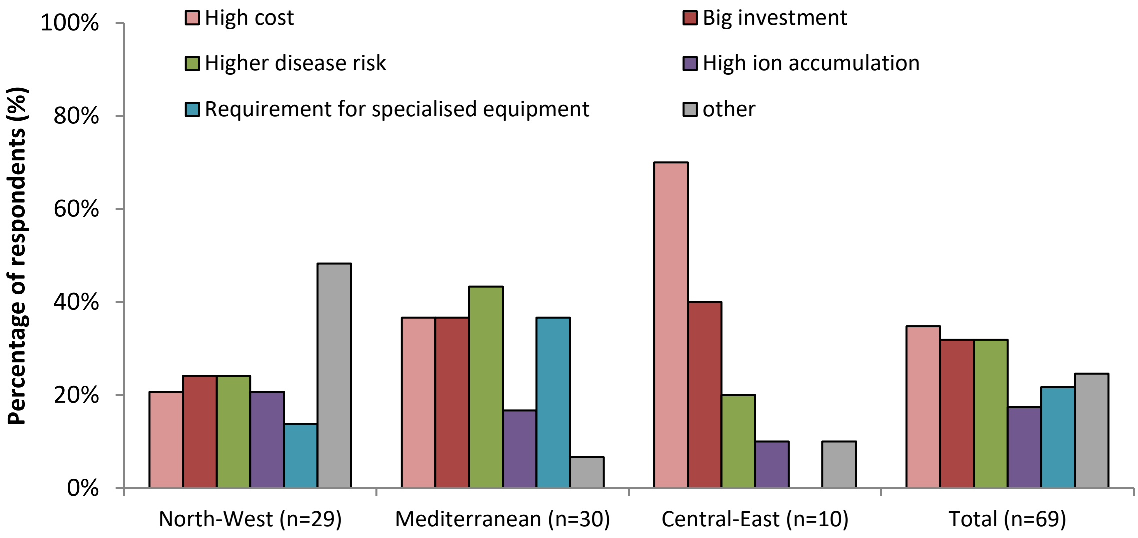

Figure 81 Reasons mentioned by respondents for not recirculating the drain water

The growers willing to implement new practices to limit effluent discharge were asked to identify the difficulties they face related to implementation. The main barrier mentioned in all regions was the high cost and it was mentioned by 83%, 91% and 65% of the respondents in the CE, MED and NW, respectively. Respondents in the CE region (25%) were particularly concerned by the risk of compromising the crop yield. While in the NW, unclear legislation was listed as the second most important difficulty (16%) affecting the implementation of practices that limit effluent discharge. Amongst the other problems mentioned (22%) in the NW were, lack of time, lack of knowledge, and lack of solutions available for small quantities of drain water.

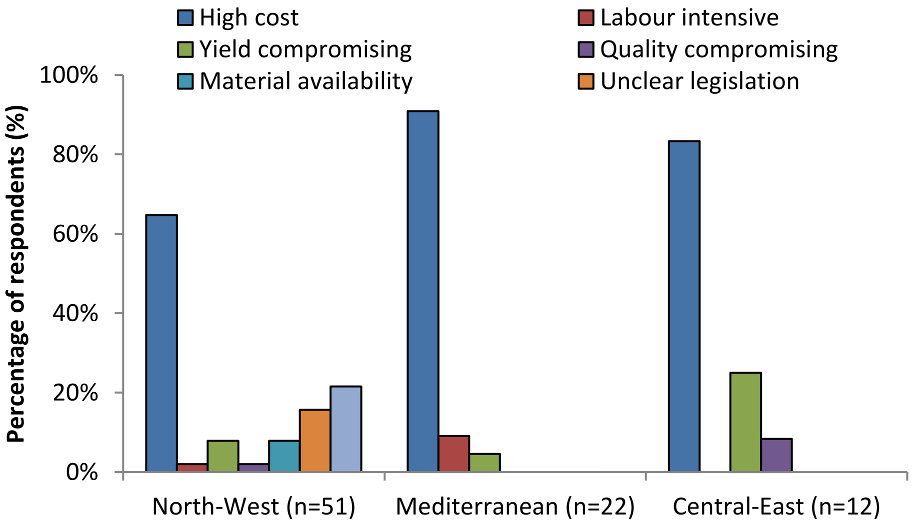

Figure 82 Factors mentioned by respondents as main barriers or difficulties to implement practices aiming at limiting effluent discharge

5.2 Monitoring of global emissions of the farm

5.2.1 Monitoring by the grower

Of the respondents, 20% monitor the emissions through the drain or drainage water of their farm. However, the proportion of growers monitoring is highly variable within regions; 45% NW, 11% MED and 4% in the CE region (Figure 83). In general, the emissions of soil-grown crops had only limited monitoring (6%) while in soilless crops monitoring was carried out by 40% of the respondents.

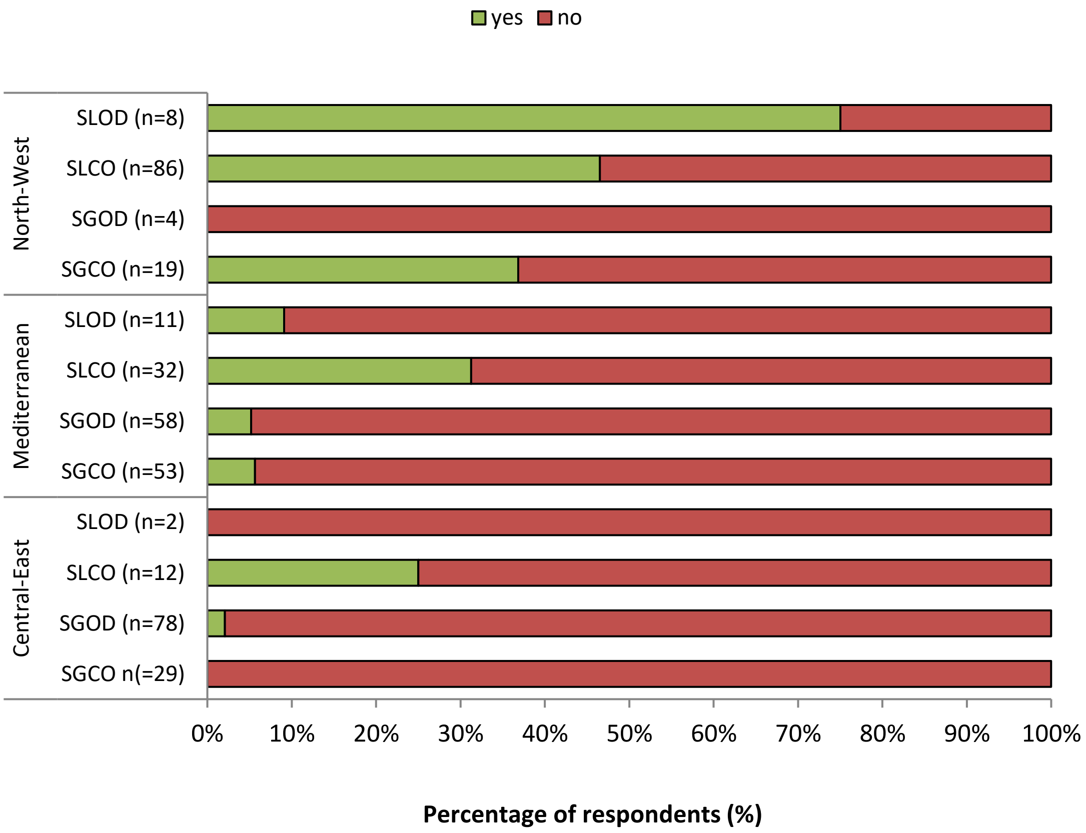

Figure 83 Control of the farms' emissions (n=362). SGOD: soil-grown outdoor, SGCO: soil-grown covered, SLOD: soilless outdoor, SLCO: soilless covered

The growers monitored their emissions mainly by analysing the drain water from the collection reservoir (77% of the respondents). Some growers (10%) carry out analysis of the surface water downstream of their site (Figure 84).

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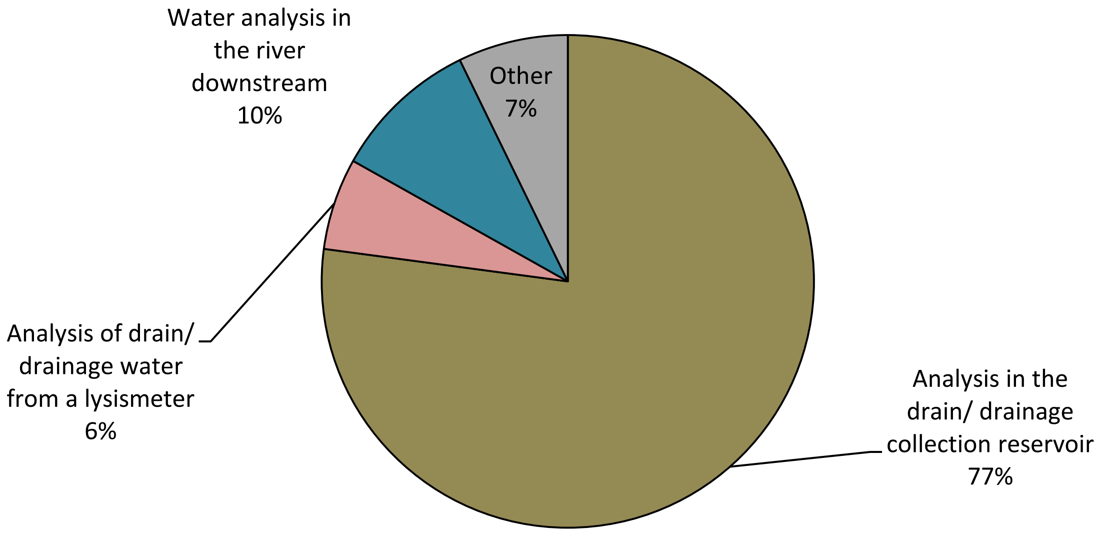

Figure 84 Methods used by growers to assess the emissions of their farms (n=77)

5.2.2 Restrictions and legal constraints

To better understand what drives growers’ decisions related to effluent management, it is important to know if they face any legal restrictions. It is worth noting that 13% of the respondents (mainly Spanish, Dutch and French) were not aware if they were located in a zone with environmental constraints. Of the respondents, 48% were not located in a zone affected by environmental constraints, and 39% were located in a zone with environmental constraints; 82% of them being in a Nitrate Vulnerable Zone (NVZ). A small proportion of the respondents (18%) reported that their farms were located in protected areas such as a Natura 2000 zone, a landscaped park, a protected zone for birds or native plants, or a coastal area. Around 52% of respondents face constraints; however, 10% of growers are not located in a zone with environmental constraints.

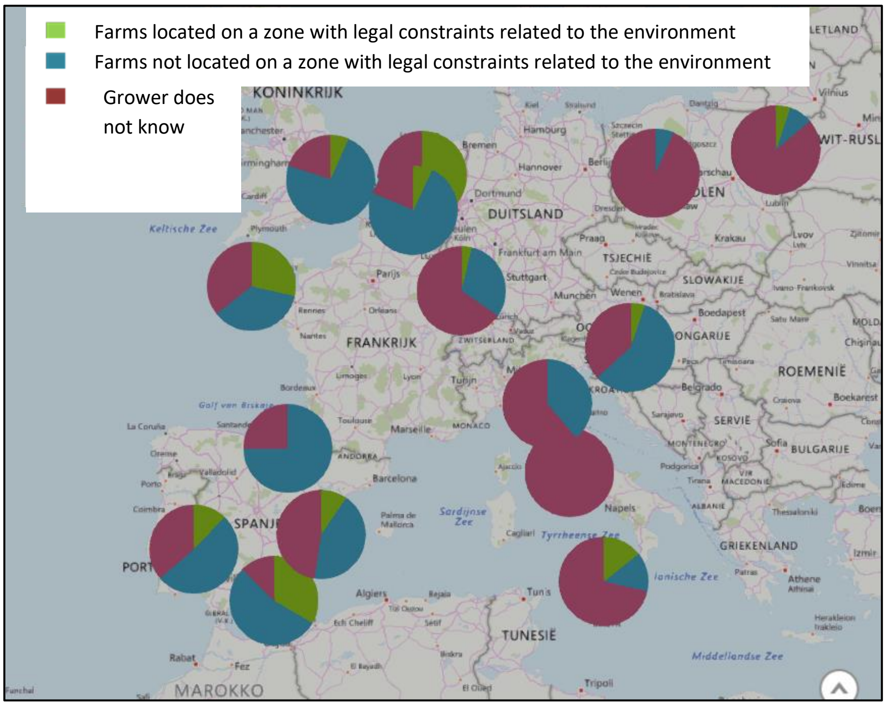

Figure 85 Farms located in a zone with legal constraints related to the environment

We tried to investigate further to identify whether there are local legal restrictions on drain water management, however, the results were inconclusive as we collected contrasting opinions from growers located in the same region, related to their legal responsibilities for drain water management. Moreover, some growers mentioned that they do not know if there are any restrictions that they have to follow.

Growers that were aware of legal restrictions for drain water management were asked to state how they planned to adapt in order to comply with legislation. This question was the last of the questionnaire and a lot of growers misinterpreted it giving answers related to overall fertigation/irrigation management. However, we gathered some insight mainly from soilless growers on their future plans. Growers with a recirculation system in place were planning to improve it by increasing the recirculated volume, improving the disinfection system. A few growers were planning to implement drain water collection and/or recirculation. Growers that discharge drain water are planning to change the destination of the discharge, reduce nutrient content before discharging or install constructed wetlands.

5.2.3 External control

Some respondents (37%) reported facing restrictions or controls related to their emissions, enforced by external authorities. The ratios of controlled/not controlled differed between regions and even within countries. We observed that the controls were enforced more in the NW region (72%), while only 22% and 12% in the MED and CE regions respectively (Figure 86). The controls were carried out by regional or governmental agencies as well as certification agencies such as Global Gap.

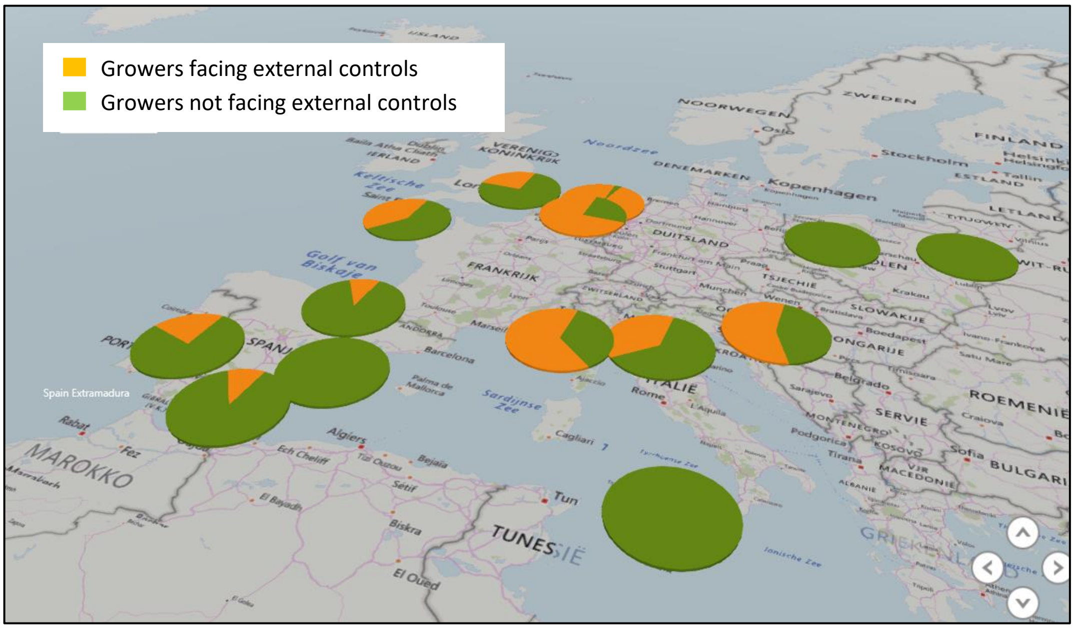

Figure 86 Ratios of growers facing external controls regarding their emissions in each region (n=284)

5.3 Actions planned

In the next years, 23% of the respondents are planning to implement new practices to limit effluent discharge into the environment. This rate was higher in the NW region (41%) than in the MED (18%) or CE regions (8%).

However, as can be seen in Figure 86, there are big differences within regions and even within the same country e.g. in the north of Italy, respondents have completely different opinions to those in central Italy. The highest proportion of growers planning to implement new practices was found in Belgium (52%), followed by the Netherlands (42%) (Figure 86). In the CE region, limiting effluent discharge is not a priority as less than 10% of the growers answered positively from both Slovenia and Poland. In the MED region, Italian growers (35%) are more willing to implement new techniques, while in the other countries the proportion is approximately 15%.

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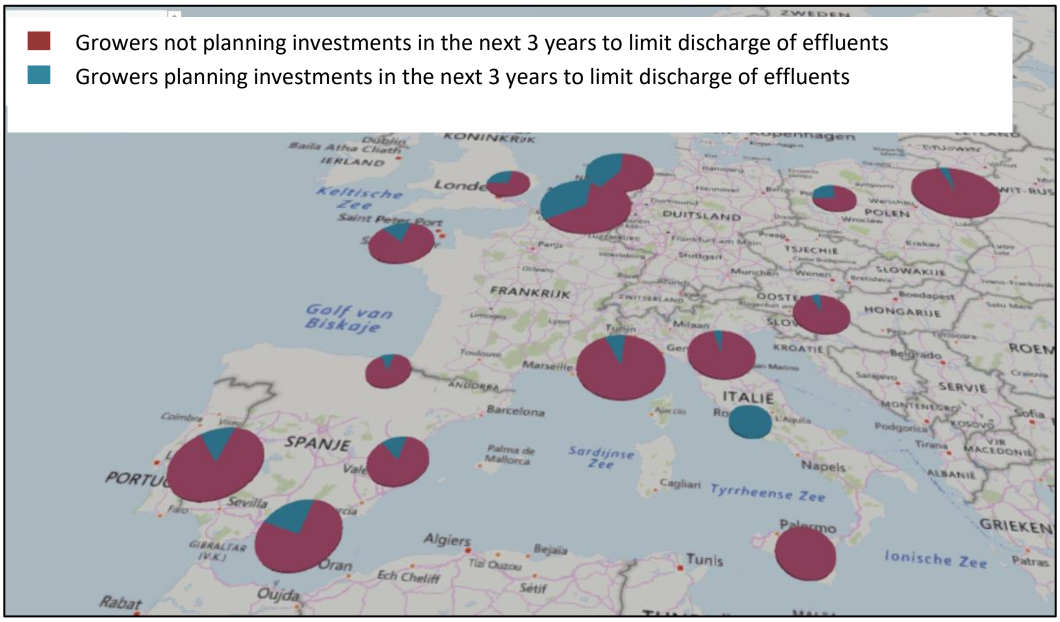

Figure 87 Respondents planning to implement new practices to limit effluent discharge in the next 3 years (n=235)

Overall, respondents were mainly considering implementing drain water recirculation (100% in the CE region, and 67% of the NW respondents). In the MED, 38% of the respondents were ready to implement nutrient best practices, as well as collecting drain water to avoid nutrient leaching, while only 17% were thinking about implementing drain water recirculation. In the MED and the NW, a few growers (8 and 7%) were planning to spread their effluents on crops or grasslands. In the NW, 10% of the respondents were thinking about implementing end-of-pipe solutions to remove the nutrients from the effluents before discharge (Figure 88).

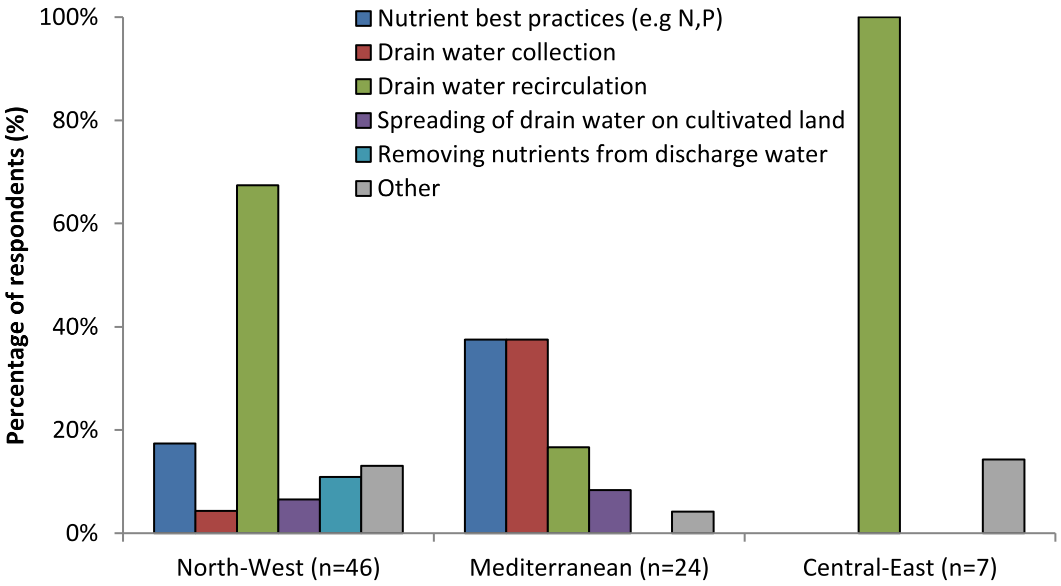

Figure 88 Practices to be implemented by respondents by regions to limit the effluent discharge

6 Conclusion

The FERTINNOWA Benchmark survey aimed to gather information on perceptions and behaviours regarding irrigation management on fertigated crops across Europe. The survey collected information under the following main sections:

1. Grower perception about water source management
2. Agricultural practice related to irrigation and nutrient management
3. Agricultural practice and perception towards minimising environmental impact due to discharge/emission of nutrient wastewater.

Participating farms were found through opportunistic and critical case sampling. With critical case sampling generalisation cannot be made to population, but they can help in making logical generalisations. However, these logical generalisations should be made carefully. This chapter reflects the most important conclusions for each section based on the views of the respondents. This does not mean that the answers provided comply with the actual situation or legislation.

6.1 On farm management of water sources

6.1.1 Types of fresh water sources

Based on the interviewees responses, groundwater was identified as the most applied water source for irrigation practices. 60% of the respondents applied groundwater as a water source for irrigation. It was less used by Spanish and Slovenian respondents. Although rainwater was the primary water source for irrigation in most of the NW region, still these respondents reported that their farms as well had to possibility to use groundwater. Irrigator's communities provided the primary source of irrigation water to the majority of the farms in Spain. A minority of the surveyed farms reported to use surface water, mains tap water and other types such as desalinated water or disinfected urban wastewater.

Most of the respondents (62%) relied on a single water source, while about 32% of the farms interviewed used 2 water sources. Respondents in the NW region used more diversified water sources compared to their MED and CE colleagues. A possible explanation could be the fact that rainwater was used more frequently as a water source at these farms.

6.1.2 Water quantity

When talking about water quantity issues one must always take into account the interaction between water availability and the crops water demand. While the latter might be more stable throughout the years, the water availability might vary significantly between the years. Although water quantity problems would be expected a serious issue in the MED regions, water quantity problems were more frequently reported by the NW respondents.

On the surveyed farms applying rainwater or groundwater or both, shortage problems were reported to occur from March to September. Farms receiving water from irrigator's communities reported mainly water shortage issues in spring.

Storing water was considered to be important for water management because water can be collected when it is abundant (e.g. in winter (rainwater) or between water turns (irrigator's community water)) and enables the respondent to relieve the pressure on less resilient water sources during drier periods of the year.

Depending on their requirements, financial means and available space, respondents chose different types of storage. Covered storage was considered safer (regarding the risk of sanitary issues). If respondents stored their nutrient solution, it was usually used within a short timeframe and covered, because this nutrient-rich water would be a perfect place for bacteria and fungus to develop. Bigger outdoor storage facilities were usually difficult to cover. Only a few respondents used them to store rainwater or groundwater. Half of them were used to store rainwater collected from roofs and impermeable surfaces like container and tray fields. Some respondents also stored the water from the irrigation community in lined or unlined storage, to optimise the use of their "water turn "and have a backup if needed. This was also done for groundwater to have enough stored water in case a problem occurred with the pump or when high crop water demand occurred. Some respondents mixed different sources before they used them and stored them together.

However, respondents who stored water also faced different bottlenecks. Lack of space for rainwater storage was reported to be an important bottleneck. A lot of respondents did not consider this topic a priority if their water supply was not at risk of shortages (networks with high flow capacities: surface water, some water communities).

Water storage should be carefully maintained, because leaking, material degradation and flooding could cause loss of water. The other main problem for respondents was the presence of unwanted material in the water (e.g. algae or microalgae). Stored water was also sensitive to external particles such as sediments, leaves, bird or fish droppings etc.

Respondents from different regions and even within countries had different perception regarding the future of their water supply. Overall, respondents believed that water availability will remain the same. However, in Spain and Poland, the majority of the respondents believed that water availability will be reduced in future.

6.1.3 Sustainable management of water quality

6.1.3.1 Mineral composition

Irrigated agriculture is reliant on a suitable water supply of usable mineral quality. Water quality criteria for irrigation can vary greatly. The suitability of water for irrigation is determined not only by the total amount of salt but also by the type. Some of the respondents that experienced issues with mineral water composition chose to switch to a less problematic water source (e.g. rainwater instead of groundwater with a high EC in the case of coastal regions in the NW region). Respondents also commonly mixed different water sources to mitigate the problem, or adjusted the nutrient inputs to the system. Few respondents chose to treat their supply water, partly because it is generally a large quantity and the treatment would be very expensive. This was not the case for growers who directly used desalinated water. Specific ion problems, like iron, can be mitigated through the use of buffer storage to precipitate the iron out of the nutrient solution, but generally, low-tech solutions were preferred to high-tech solutions which were considered to be more expensive. Solutions would probably be adopted if less expensive and easily available.

Respondents of the MED region were concerned that the water quality will decrease in future. The colleagues in the CE and NW region did not share this concern.

6.1.3.2 Sanitary status

Irrigation water can act as an inoculum source or spreading mechanism for a range of biological problems including plant pathogens, algae and biofilm-forming organisms. Plants can be repeatedly inoculated with pathogens, whether via the original water source or by pathogens entering the irrigation system at various points. Of the respondents, 39% reported facing sanitary problems, even if rarely. Based on the survey data, it was not possible to distinguish whether the problems were associated solely with the water source type or the storage as well. In almost all water sources, except tap water, bacterial problems were mentioned. Respondents reported problems with *E.coli, Agrobacterium rhizogenes*, other *coli* forms, and *Pseudomonas* (species not specified). Fungal problems including *Phytopthora spp., Pythium spp. , Fusarium spp*. were more pronounced in recirculated drain water. Other problems included *Salmonella* and biofilm formation. Respondents experiencing sanitary problems usually treated the water but sometimes the solutions were considered not 100% effective. Respondents were well aware of the different treatment options, however, they often considered the investment cost to be a major obstacle towards adopting them. Disinfecting water using UV light was the most common disinfection method, used in 10 of the cropping systems, mainly in the NW region.

The presence of algae was identified as the main sanitary problem related to water storage. Problems related to algae were reported by growers in almost all the surveyed countries. Few technical solutions were considered satisfactory, highlighting the lack of effective solutions on the market.

6.1.4 Sustainable water resource use

All over Europe, water of fair quality for irrigation is getting scarcer and growers need to question their water resource management. The FERTINNOWA survey showed that the majority of the respondents considered their water supply to be ‘sustainable’ or ‘very sustainable’.

In general, most of the interviewees were not able to provide precise water consumption data. In regions where water supply was managed by growers, precise and reliable water consumption data were not always recorded. However, in regions where water was managed by irrigators’ communities, water consumption data were stored because the growers had to pay the irrigators’ community.

Some regions within countries showed a clear interest in adopting more sustainable water sources, such as Extremadura, Sicily, the western part of Poland, and also countries, particularly the UK. Local concerns surrounding water availability could explain this interest and may be a driver for change. The shift towards a more sustainable water supply involves several bottlenecks. Respondents generally considered rainwater collection and installing drain water recirculation as an important step towards more sustainable water supply. In the case of rain water, storage capacity was reported an issue because respondents might not have the space to build storage (e.g. in densely populated areas like in the Netherlands). Moreover, respondents were not particularly aware of other resources (especially in the MED region where water resources are managed collectively) and felt that rainwater collection would not be compatible with the rain pattern and that their greenhouses were not suitable for rainwater collection. Investment needed to build water storage was considered high and respondents did not list it as a priority when they had easy access to another resource of decent quality. Moreover, some respondents were concerned about using rainwater, as they thought it would be difficult to manage the pH. In the CE region, this topic was at the forefront of respondents' minds, because the use of groundwater is increasingly taxed. In the NW region, use of rainwater was already considered normal by respondents who seemed interested in increasing storage capacity to have a more resilient water supply.

Some respondents considering drain water recirculation had fears regarding sanitary issues. Nevertheless, they were still considering the method. For respondents without automated systems, it was more difficult to change to recirculating drain water because they feared it may adversely affect the nutrient solution. The equipment for treating drain water was considered very expensive and constitutes a real bottleneck for respondents.

For other respondents, the way to improve the sustainability of their water use was to diversify their water sources, for example, to avoid the depletion of a borehole. They would collect rainwater, dig a new borehole, potentially add another water source, and mix those water sources to have a more consistent water composition. This approach was mainly taken in regions with water quality problems, e.g. in Spain.

6.2 Water and nutrient use efficiency

Water and nutrient use efficiency was very dependent on cropping system and the medium used (i.e. soil or substrate). The MED and NW regions were more closely aligned in their irrigation and fertigation practices than the CE region. In soilless crops, especially covered soilless crops, changes in water and nutrients can have an impact very quickly, and this was reflected by the higher levels of monitoring and automation associated with this cropping system. Respondents with this type of cropping system also sought out more specialist advice for their system in general, however for particular issues, (such as salinity), it is the respondents with soil-grown systems who appeared to require more help. When it comes to new or innovative technology, respondents were happy to learn from each other and gain feedback on particular tools, however when it comes to specific decisions about their own systems, they wanted advice more from advisors or specialists.

6.2.1 Irrigation management and equipment

Precision irrigation technology such as drip irrigation was already widely used, however it doesn't often suit systems with plants grown in pots which are frequently handled (e.g. in the ornamental sector). Respondents appeared to be more aware (or concerned with) the day-to-day needs of a crop rather than overall annual water consumption. Most respondents relied on their own experience for when to irrigate, based on crop or substrate appearance, combined with technological tools. However, a large proportion used experience alone (CE region and soilless outdoor crops). Tools to monitor weather were used by a majority of respondents, as were soil and substrate sensors rather than crop water sensors. MED and NW regions used more tools to support irrigation management decisions (with the MED region using the most) compared to the CE region (especially for soilless covered systems in the NW).

Investment capability is higher in NW soilless crop systems, with a corresponding higher automation of tools (especially for monitoring weather and drainage water). The majority of tools used by respondents were manually applied; there was a willingness to automate, but cost was a major barrier.

6.2.2 Fertigation management and equipment

The majority of respondents adjusted nutrient application to crop growth stage, especially in covered crops. Generally, respondents did use tools to monitor fertigation, but again, monitoring was used much more in the MED and NW regions compared to the CE region. A majority of respondents used pump injection systems, mainly in soilless systems in the NW and MED regions. The CE region differed again, using mainly suction injection systems. A/B tanks were the most widely used. There were differences in whether soil/substrate or leaf nutrient status was monitored (NW vs MED regions), and there were differences between cropping systems (e.g. drainage was monitored more in soilless systems). Generally there was poor visibility of recommendation schemes (awareness was low) but if respondents were aware of them they then tended to make use of them. Most respondents did not use an N scheme, but soil P analysis was used in the NW and CE regions.

Consideration of salinity as part of fertigation management seemed to depend on both the region as well as the cropping system. In general, respondents with soilless covered crops were much more likely to consider salinity compared to the other growing systems. A clear regional trend was found for soil-grown covered crops: the NW region was more concerned with salinity compared to MED and CE respondents. Respondents with soil-based cropping systems measured EC less frequently than in other cropping systems. Adding water was the main method to address salinity, based on respondents' own experience or that of an advisor. Interestingly soil-grown systems seemed to require more support with this issue than soilless systems.

When seeking advice, again there were differences between regions; the NW and MED regions used commercial/private advisors, whereas the CE region used governmental extension services. Most respondents used at least one source of advice, and advisors used more heavily when it comes to effluents management.

6.2.3 Growers willingness and pathways to improve irrigation and fertigation management

With the exception of Slovenia, few respondents applied for or received subsidies. Any received subsidies were usually funded at the European level, however this varies between cropping system and country. Respondents were mainly concerned with cost, whether initial investment costs, or running costs due to replacement of equipment (short life span or low reliability). However, concerns about cost depended on the complexity of the cropping system and level of automation (both are generally higher in the NW region). Lack of automation was cited as a disadvantage due to time and labour costs, and lack of monitoring and control capability was felt to reduce the respondents' ability to optimise their own system. A high level of automation seemed to require a different way of thinking; a 'whole system' approach.

Respondents were generally satisfied with the efficiency of their systems, but highlighted specific issues that can cause problems, such as clogged filters or pipe/dripper leaks. Poor water quality and availability can be a major hurdle for some growers and in soilless systems, a lack of buffer capacity mean irrigation failures which can massively impact crop quality and yield.

There was a willingness to automate and increase the use of sensors and precision equipment. Increasing water storage capacity was a popular method, probably because it was considered a relatively easy win in a cropping system. However, there were a considerable number who wouldn't make any changes to their systems.

Capital investment and the perceived level of benefit received from investing were major bottlenecks to improvements being made. There was also a perception that innovative technology is tailored to larger farms or nurseries, so smaller outfits didn't see the benefit. Some bottlenecks were more easily addressed than others, for example, awareness of and trust in new technologies could be more easily addressed than personal issues (a grower coming up to retirement age so not willing to invest) or wider issues such as economic slumps or regulatory barriers. This suggests that it may be better to focus on the 'easier wins' first.

If making fertigation more efficient resulted in reduced production and labour costs and improved crop quality ad yield, the majority of respondents would adopt the new technology. To increase adoption, most would want feedback on new tools/technologies from other growers and access to specialist advice, as well as increased financial support.

6.3 Effluent management and minimisation of environmental impact

This part of the benchmark survey attempts to explore the current practices for effluent management, and understand growers' challenges and the factors influencing their decisions. Although this study is only exploratory and generalisations should be avoided as the response rate on this section was relatively low, we believe that the findings that emerged are valuable. To our knowledge, there is no official information in Europe about the topics mentioned above. The benchmark study is the first to identify multiple different discharged water streams for fertigated crops at a European level. In general, the environmental impact of the discharged water depends on the frequency, amount, and concentration of the pollutants and the destination of the discharged water. Of the soilless growers who responded to the survey, 26% were not equipped to recycle drain water. It is remarkable to note that from the respondents that collected drain water, only 41% recirculated 100% of the collected drain water. This suggests that in general, 59% of respondents with soilless crops are still discharging drain water. There appears to be a clear regional distinction. In the NW region 65% of the respondents recirculated at least 90% of the collected drain water while this only was 45% in the MED and 42% in the CE region. It is worth noting that there is a discrepancy between the results indicated for recirculation and discharge of the drain water. Indeed, 42% of the respondents indicated to recirculate all their drain water while only 8 % indicated that they never discharge water. The reasons why, despite discharging, growers feel that they recirculate all the drain water, would need further investigation.

In the case of soil-grown growers, 44% were equipped with a drainage system, which means that they could theoretically collect and recycle drainage water (from underneath the soil). However, the practice is very limited and growers were not questioned about it in our survey. When looking at the frequency of the discharge events, it was found that 27% of the respondents are still discharging drain water daily and on most events, the discharged water is not treated before it is discharged. In 49% of the discharge events, the discharged water was directed towards surface water or sewage systems. For the latter it was not clear if the sewage water was treated afterwards. Although the survey did not provide information on the concentration and volume of the discharged water, it is to be expected that high amounts of nutrient rich water are still being discharged into the underground water layers and surface waters. Studies in the NW region showed that on average 5-10% of the nutrient solution is discharged yearly. However, big fluctuations between farms were found (Berckmoes et al. 2013; Beerling et al; 2013). A Dutch study in 2013 estimated the annual soilless greenhouse emission to be 1.300 ton N, 200 ton P and 1.134 kg PPPs (Beerling et al, 2013). Similar studies were carried out in Almeria for example, a horticultural region of around 43.000 ha of mainly plastic greenhouses (Hortidaily, 2015). In this region, soil samples with medium values of 279 and 360 kg mineral N/ha were found for greenhouses, respectively, at the depth of 40 and 60 cm. It is expected that these amounts would have been higher if lower depths had been sampled. Mineral N in the profile after cropping is considered to be at risk of leaching given the common local irrigation practice of applying high volume irrigation (Thompson et al., 2002).

Apart from quantifying and qualifying these methods, it is very important to identify growers' drivers and challenges or constraints concerning drain water/drainage recirculation, in order to allow both scientists and policymakers to develop strategies that can support these growers. Reducing nutrient inputs, saving water, complying with legislation and reducing environmental impact were the main drivers for recycling drain water. However, regional differences do occur. Both scientists and policymakers should bear this in mind as these triggers are key elements in the process of technology transfer towards growers.

A notable feature in the responses is the wide range of technical challenges reported by the growers, relating to recirculation of drain water, which can affect the crop quality, and needs to be resolved. Ion accumulation and high electronic conductivity are by far considered to be the main challenges related to drain water recirculation. Furthermore, problems related to spread of diseases, growth inhibition and root exudates were reported.

Similarly to an American study by Cultice et al. (2016), growers that are currently not recycling are more concerned about the risk of disease spread and the high cost or the capital required for investment, rather than the environmental impact of their production. Therefore, a “nudge” to stimulate voluntary water recycling is not present, and the possibility of spreading disease presents a significant barrier to invest in water recirculation. In the Almeria region in Spain, a decrease in the area of soilless crops, from around 20% of the growing area (1999-2000) to 9,8% (2012-2013), was reported as the beneficial effects were considered low by growers (Garcia Garcia, 2016). Some of the reasons include the high costs compared to soil-grown crops, issues with recycling inorganic substrates, the commercial development of suitable rootstocks for soil-grown crops with resistance to nematodes, the low buffering capacity of substrates in case electricity supply is interrupted, and the deeper technical knowledge required to manage soilless systems.

Widespread adoption of recycling irrigation water could be supported through government incentives or growers’ ability to pass cost increases on to customers. Moreover, in the NW region, incompatibility with the substrate they are using, the quantities of the drain water being both too high (from tray fields) or too low, were all named as major challenges by more than one grower, which indicated the need for tailored technological solutions.

The benchmark survey showed that external controls, either by regional or governmental agencies as well as certification agencies can be the main trigger for growers to further reduce the environmental impact of their farms.

Apart from the drain water discharge, the management of maintenance water can be a potential source of contamination as the chemicals (e.g. nitric acid, phosphoric acid, sulphuric acid, etc.) applied to clean the irrigation systems, may contain nutrients (nitrogen, phosphorus, etc.) (Netafim, 2012). However, the extent of pollution caused by the maintenance water in horticulture is not known. The data collected by the current survey cannot quantify the size of this problem but indicates that the problem is greater in the CE and MED regions as the water is not being recycled.

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