D3.4: Reference document on SMART IPM techniques and methodologies

WP3 – Benchmarking methodologies and technologies

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Executive summary

This report presents findings and discussions from a workshop and project partner participation using benchmarking and SWOT analysis for technologies for crop protection in vegetables grown in open fields and in greenhouses. The first section of this report details the methodology and approach for the benchmarking process and SWOT analysis. The second section outlines the results from the four groups of technologies that were benchmarked and from the SWOT analysis. The third section summarizes the outcomes and the fourth and fifth sections finish with challenges, perspectives and key findings and recommendations.

The selection of technologies and the available information about the technologies in each technique group came from the SmartProtect platform where it was entered as a result of Workpackage 2 “Knowledge Collection”. Information was mainly collected from the companies marketing the technologies, mainly from the company web sites. The project partners, guided by JKI, benchmarked four groups of technologies: 1) monitoring, 2) diagnosis and detection, 3) decision support and 4) application. The basic and advanced common criteria helped the partners to assess and benchmark technologies. In addition, the SWOT analysis framework was used to evaluate the advantages and disadvantages of the technologies available in Europe.

The benchmarking process helped to select technologies 1) to monitor pests and pathogens, with platforms such as Campogest, Margaret and iMetos, and technologies based on the use of camera traps for the open field and greenhouses such as Trapview, iScout, CapTrap and Scoutbox. 2) for diagnosis and detection, the group selected immunological tests such as LOEWE®FAST Lateral Flow Kits, AgriStrip (Bioreba) and ImmunoStrip® In addition there were tests for the open field (Agdia), and smart mobile applications for pest and disease monitoring such as Plantix, Cropalyser and Buntata. 3) for decision support two types of technology were selected; 3a) mobile applications where no sensor was used, such as Agrio and Bioline Apps for the open field and greenhouse, and 3b) applications with sensors, which consisted of platforms such as the OPI Support System, AgroNet and Hub@agrimeteo. 4) For application technologies there were 4 groups: 4a) sprayers such as Dropleg Lechler, Dropleg Hardi and Smartomizer; 4b) sprayer drones such as the DJI Drone Agras T16 and the M8A spraying drone; 4c) use of UV with robotic platforms such as Cleanlight UV implements, Thorvald, and Lumion UV-C; 4d) drones & sprays – including distribution systems for beneficials such as the Biospreader for greenhouses, and the open field. In addition, the Alumaster 2.0 for greenhouses only, and the Natutec Drone to work at the small and large scale.

The selected technologies appear promising for testing in the open field and greenhouse production systems. All project partners will test some of the tools in the agricultural season of 2022 according to availability. The benchmarked technologies are available on the market and in Europe and are displayed on the project platform. However, tools such as Spraying Drones are not ready for use in Europe on the broader scale due to strict regulations.

1 Introduction

1.1 Background

In many parts of the world, the main way of managing pest insects and diseases continues to be the application of synthetic chemical pesticides. Nevertheless, Integrated Pest Management (IPM) is a holistic approach to plant health management, based on prevention, monitoring and control. Schematically, the principle of the IPM pyramid is based on a planning strategy for the management of one or more pests; it should start with the range of agronomic practices that might be used to prevent colonization by pests and pathogens such as crop rotation and the use of pest/disease resistant varieties (prevention). The next step is to forecast/monitor any pests or pathogens that do move into the crop, to assist with further decision-making (detection). Moving towards the top of the pyramid is a range of control methods, for example physical or biological control (control) and as a last option the use of synthetic chemical pesticides. IPM is a strategy, which encourages the reduction of pesticide use by employing a variety of non-chemical pest control methods to contain or manage pests below their damage and economic threshold (SmartProtect 2020).

EU-wide countries support IPM through the promotion of organic farming. IPM is one of the tools for low-pesticide-input pest management, and all professional users should implement it (Barzman et al. 2015). IPM includes an integrated focus for the prevention and suppression of organisms harmful to plants with the use of all available information, tools and methods. Besides, IPM goals focus on the use of pesticides and other forms of intervention only when they are justified economically and ecologically, and to reduce any risk to human health and the environment (Deguine et al. 2021). Current use of synthetic pesticides should be reduced, and sustainable biological, physical and other non-chemical methods must be employed to control pests in a satisfactory way.

To promote a sustainable agricultural system, EU Directive 2009/128/EC recommends reducing pesticide use, fostering the adoption of prevention measures, non-chemical control methods, and chemical substances with minimal environmental impacts (European Parliament, 2009). The need to reduce the use of pesticides and particularly fungicides was highlighted in the strategy of the European Green Deal 'from farm to fork', which focuses on the reduction of chemical pesticide use by 50% by 2030 (European Commission, 2020). This reduction should foster the protection of biodiversity and promote organic farming and sustainable clean food systems. The reduction of pesticide use should be in accordance with IPM goals. There is a lack of knowledge about Smart technologies that might be used in IPM and the EU-project SmartProtect, is a thematic network with a focus on cross-regional knowledge sharing of Smart IPM technologies that could provide solutions for farmers and advisors.

The SmartProtect project aims to stimulate knowledge flow in the regional Agricultural Knowledge and Innovation Systems (AKISs) across EU partner countries. Its focus relies on the innovative potential of advanced methodologies for IPM, and integrated precision farming technologies and data analytics for vegetable production.

SmartProtect focuses on the introduction of innovative, smart technologies and technologies in the IPM-focused areas of 1) monitoring and detection of beneficials, pests and pathogens;

2) diagnosis of pests and pathogens, 3) decision support and 4) technologies for applying beneficials and pesticides. The selection of technologies and the available information about the technologies in each technique group came from the SmartProtect platform where it was entered as a result of WP 2 “Knowledge Collection”. Information was mainly collected from the companies marketing the technologies, and from the company web sites. The WP3 and project partners benchmarked the technologies in the frame of their technical, socio-economic and regulatory context based on data collected.

This report is an outcome from a virtual workshop conducted on 16th December 2021 where project partners shared and discussed technological solutions, which are currently part of the SmartProtect open platform. Sub-groups of project partners evaluated tools and technologies for one and half months before the workshop. The benchmarking process and an in-depth SWOT analysis evaluated the advantages and disadvantages of the various IPM technologies.

1.2 Objectives

The objective of this part of the SmartProtect Project is to carry out benchmarking and in-depth SWOT analysis of the innovative technologies and methodologies that support IPM management and that are available in Europe.

1.3 Goals

The goals of benchmarking are:

1. To evaluate the attributes, features, availability and use of monitoring, diagnosis and detection, decision support and application technologies through basic and advanced common criteria.
2. To compare characteristics between technologies using benchmark scores.
3. To select technologies and methods according to basic and advanced common criteria described in the benchmarking template.
4. To identify advantages and disadvantages of the technologies and methods at regional and EU level using a SWOT analysis.
5. To form the basis of the selection of technologies for demonstration trials within the project.

2 Methods

2.1 Approach

A previous online workshop was conducted on 9 November 2021 where all project partners learned about benchmarking and SWOT-analysis. This was organized by JKI. The benchmarking method evaluated information on the technologies/methods taken from the interactive project platform. All sub-groups were assisted by the JKI team when any help was needed. Subsequently, on 16 December 2021, a final workshop was carried out where the sub-groups presented their results from the evaluation of the technologies.

The benchmarking method assesses products/technologies through basic and advanced common criteria. Benchmarking is an organizational improvement mechanism.

*To **benchmark**, is to improve a known product with which users are familiar or accustomed to that other newer products can be compared to.* (Moriarty and Smallman 2009).

Benchmarking is a process that not only seeks to identify reference points, but has the objective to align them in some favourable manner. *"Benchmarking is about comparing a company with other companies, compare technologies with other technologies, etc." (Andersen and Pettersen 1996)*. Benchmarking is learning how to improve activities, processes and management – benchmarking is learning too.

In Workpackage 2: Knowledge Collection, the partners selected the Smart IPM technologies for later evaluation. A total of 105 technologies and methods were assessed. Four groups of technologies, namely monitoring (1), diagnosis (2), detection and decision support (3), and application (4), were evaluated with basic and common advanced criteria (Table 1). Each group consisted of from one to four sub-groups to compare subsets of techniques for benchmarking (Table 1). In WP3, the partners JKI built the benchmarking template and supported the partners during the benchmarking process.

Table 1 – Groups and sub-groups of technologies evaluated within the benchmarking process

Groups			
Monitoring (1)	**Diagnosis and detection (2)**	**Decision support (3)**	**Application (4)**
Sub-groups			
1) Crop 2) Insect	1) Elisa, RNA, DNA methods 2) Disorder detection mobile apps	1) With sensors 2) Without sensors	1) Sprayers 2) Spraying drones 3) UV-systems 4) Beneficial distributors
Common basic criteria			
(1) Available in EU; (2) Production system; (3) Crops; (4) Farming scale; (5) Application range; (6) Countries used; (7) Special technical requirements; (8) Special agricultural landscape; (9) Special training; (10) Buying costs; (11) Renting costs			
Common advanced criteria			
(1) Working speed; (2) Acreage covered; (3) Support; (4) Mode of operation; (5) Accuracy			

The benchmarking template had two groups of parameters to gather and evaluate the information about each technique. These groups consisted of a) common basic criteria, and b) common advanced criteria. The second group of criteria was modified, if needed, for each sub-group according to technology characteristics, and after consultation with experts. The criteria and scoring used by each technology sub-group are described in the section on results.

2.2 Benchmarking process with technology information

The common basic criteria parameters were similar for all groups and sub-groups (Table 1). Partners carried out the work on benchmarking and SWOT analyses in the predefined working groups consisting of different partners from the consortium. All partners participated in the benchmarking and their inputs and perspectives from different areas of Europe were considered. Finally, all partners described concisely the benchmarking and SWOT results. Consequently, expert knowledge from project partner institutions was used when it was needed.

2.2.1 Common basic criteria

The **common basic criteria** consisted of eleven parameters that evaluated the assets of the technologies in providing a score for the benchmarking (in the Benchmark Score column) and provided descriptive information of each technique in a separate column (Table 2). A virtual workshop was run in November 2021 to demonstrate how to use the benchmarking template. During the workshop, the project partners learned which information should be included and how to evaluate and compare the technologies. The basic criteria assessed the availability and use of the technologies in farming production systems, the technical requirements and, if available, also information on costs.

Table 2 – Description of each common basic criterion used for benchmarking techniques

Available in EU	Benchmark Score (1 = weak; 10 = strong)	Production system	Benchmark Score (1 = weak; 10 = strong)	Crops	Benchmark Score (1 = weak; 10 = strong)	Farming Scale	Benchmark Score (1 = weak; 10 = strong)	Application range	Benchmark Score (1 = weak; 10 = strong)	No. of pests and pathogens	Benchmark Score (1 = weak; 10 = strong)	Special technical requirements	Benchmark Score (1 = weak; 10 = strong)	Special Agricultural landscape	Benchmark Score (1 = weak; 10 = strong)	Special training	Benchmark Score (1 = weak; 10 = strong)	Buying costs	Benchmark Score (1 = weak; 10 = strong)	Renting costs	Benchmark Score (1 = weak; 10 = strong)
No available in Europe	5	1 system	5	1 crop	1	1 scale	5	1 target	1	1 Pest or path	1	yes	5	yes	5	yes	5	not for sale	3	not for rent	3
Available in Europe	10	2 systems	10	2 crops	2	2 scales	10	2 targets	2	2 Pests or path	2	no	10	no	10	no	10	the average of buying costs per unit of the techniques in the	6	the average of renting costs per unit of the techniques in the same category	6
N/A				3 crops	3			3 targets	3	3 Pests or path	3	no informatio	0					less than the average of buying costs per unit of the techniques in the same category	9	less than the average of renting costs per unit of the techniques in the same category	9
				4 crops	4			4 targets	4	4 Pests or path	4										
				5 crops	5			5 targets	5	5 Pests or path	5										
				6 crops	6			6 targets	6	6 Pests or path	6										
				7 crops	7			7 targets	7	7 Pests or path	7										
				8 crops	8			targets	8	8 Pests or path	8										
				9 crops	9					9 Pests or path	9										
				10 or mor	10					10 or more	10										

The scoring in the benchmarking was highlighted using colours, when scoring was relatively low; the colour was red, while a higher scoring was denoted with a green colour (Table 2). This highlighting helped to distinguish the technologies with high scores. The scoring for each attribute ranged from one to 10.

2.2.2 Common advanced criteria

The **common advanced criteria** (Table 3) consisted of variables to gather information on socioeconomic aspects, maintenance of the technology, whether the method is free or has to be purchased. All of this is very useful information for the user (i.e. farmer, agronomist, technician or other stakeholder). The **common advanced criteria** were modified for the diagnosis and detection Sub-group to include the mode of operation and form of support. This group of advanced criteria consisted in its basic version of two scores: 'positive' or 'negative' or 'higher' or 'lower' with 5 and 10 as the lower and higher scores respectively (Table 3).

a) The **Mode of operation** variable for evaluation in the 'Diagnosis and Detection' sub-groups with sensors and without-sensors considered the option of manual operation (score 5), automated operation (score 10) and in cases where information was unavailable (n/a).
b) The **Mode of operation** parameter for evaluation in the 'Spraying Drones' sub-group consisted of the options of: operated by the company (score 3), manual operability (score 5) and automatic operability (score 10).

The scoring was adapted when needed for specific sub-groups. The criterion for evaluating "accuracy" was used as following

a) The **Accuracy** parameter for evaluation in 'Sprayer Technology' was considered for drift reduction – interpreted as a lower amount of product loss and thus influence on the surrounding environment during application in the field.
b) The **Accuracy** variable for evaluation in the 'Spraying Drones' sub-group was interpreted as the efficiency of the spraying rate.

The **Working speed** parameter for evaluation consisted in m/s or km/h for instance for the speed, a Sprayer' is pulled by a tractor over a row of plants. For the case of 'Spraying Drones', the working speed variable was considered as the time needed to spray one hectare.

Table 3 – Description of each advanced common criterion used for technologies

Working speed	Benchmark Score	Accuracy	Benchmark Score	Acreage covered	Benchmark Score	Mode of Operation	Benchmark Score	Support (free, available and useful)	Benchmark Score
Lower than average	5	Lower	5	Lower	5	By company staff	3	No	5
Higher than the average	10	Higher	10	Higher	10	Semi-automated	5	yes	10
n/a		n/a		n/a		Automated	10	n/a	

2.2.3 Bar chart on total benchmarking score

The total scores for individual technologies in each group were displayed in bar charts (Figure 1). The bar chart and scoring show the differences between technologies according to their total score. The bar chart can help to identify the technologies which have higher scores based on the evaluation criteria.

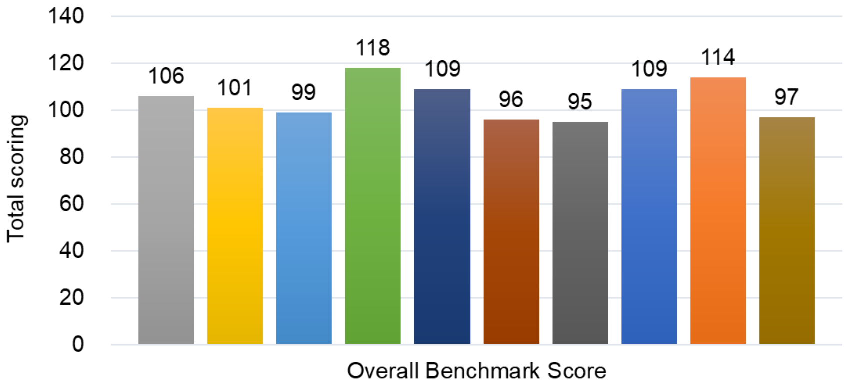


Figure 1 – Technologies displayed in a bar chart and the total benchmarking score

2.2.4 Spider net diagram to compare criteria

Withing each group, basic and advanced common criteria scores for the tools/technologies/methods were displayed in a spider net diagram (Figure 2). This diagram summarises the scores for both types of criteria. The variables/parameters are displayed according to their total scores. When the parameters are not displayed with coloured lines, it means that no score was introduced in the benchmarking template. Within the EXCEL menu options, the spider diagram can be modified by selecting and deselecting the parameters according to the basic and advanced common criteria to depict differences among technologies. Each line represents a technology and can have a similar color to that used in bar charts.

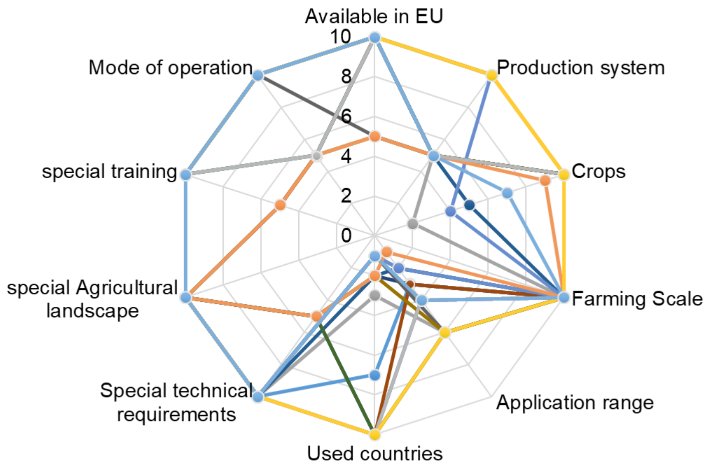


Figure 2 – Common basic and advanced criteria displayed in spider net diagram. Each coloured line represents a different technique/technology/method.

2.2.5 SWOT analysis of technologies

The SWOT analysis methodology was used to evaluate all the information gathered about a type of technology/method. The advantages and disadvantages of technologies were assessed and described in a matrix through internal factors (strengths and weaknesses), and external factors (opportunities and threats). Each Sub-group prepared a SWOT matrix according to their respective type of technique.

3 Results

This section summarises the results. The sub-groups worked for a month and half via online and through weekly online meetings. Each sub-group presented the benchmark results at the final online “Benchmarking and SWOT Analysis Workshop”, on 16 December 2021. Spider net diagrams (i.e., section 3.1.1.3) described selected technologies/methods that obtained high scores. The advantages and disadvantages were described and discussed in the SWOT matrix

3.1 Monitoring technologies group

3.1.1 ‘Crop monitoring’ sub-group

3.1.1.1 Benchmarking EXCEL Table

The benchmarking Table (in EXCEL) is uploaded in the folder for Workpackage 3 in the SharePoint database belonging to the SmartProtect project.

3.1.1.2 Description of the technologies

The ‘Crop Monitoring’ sub-group evaluated 15 technologies using the benchmarking method. Eleven **basic criteria** and five **advanced criteria** were used to assess and score the features of each technology. Table 4 presents a summary based on the information from the EXCEL sheet Table.

Table 4 – Brief description of 'Crop monitoring' technologies evaluated by the benchmarking method

Technology	Description	Crops	Application range	Operation mode	Total Scoring
Agras MG1 Drone	Agras MG-1 is an octocopter designed for precision variable rate application of liquid pesticides, fertilizers, and herbicides, bringing new levels of efficiency and manageability to agriculture. The MG-1 's powerful propulsion system allows the aircraft to carry up to 10 kg liquid payloads.	Any	Bacteria; Fungi; Viruses; Others	Manual	74
AgroNet Platform	agroNET is a cloud-based platform acting as a hub for all farm operations, enabling complete farm asset management (tractors, machinery, irrigation systems, diesel generators, weather stations, insect traps, sensors etc.) and activity management and monitoring, which is the basic building block of digital farming.	Vineyards; Orchard; Arable Crops; Vegetables	Insects	Automated	85
AKERSCOUT	AkerScout is a directed crop scouting application to help identify and prioritize crop damage to address problem areas needing immediate attention.	Bell pepper; Tomato	Bacteria; Fungi; Insects; Mites; Viruses; Others	Manual	66
Campogest	CampoGest is a mobile App with a wide range of functionalities that can be configured according to the agronomist's needs.	Orchard; Vegetables	Bacteria; Fungi; Insects; Mites; Viruses; Others	Manual	**91**
CropScanner App	This App provides fast and direct entry of scouting-data in a smartphone or Tablet; real-time overview of a greenhouse at any time; structured view of the scouting data via pc or web; visualization of pest pressure and population build-up of beneficial; extensive data-analysis; direct contact with a Biobest advisor for personalised IPM advice.	All crops in greenhouse	Fungi; insects; Mites	Manual	80
Cropwise Imagery	Cropwise Imagery is a digital farming tool that uses imaging technology to monitor crop health. The user can easily access all data via Tablet, phone, or computer. The data is easy to interpret and can be used to detect anomalies in the field.	Arable Crops	Insects; Nematodes	Manual	68
eBEE SQ Drone	The eBee SQ is a reliable, affordable fixed-wing drone that helps farmers, agronomists and service map provider to monitor crops quickly and easily.	All crops	Others	Manual	65
EOS Satellite crop monitoring	EOS Crop Monitoring is an online satellite-based precision agriculture platform for near-real-time field monitoring created by EOS Data Analytics (EOSDA).	All crops	Others	Automated	88
Farmshots	FarmShots™ is a satellite imagery service that provides solutions to help growers maximize yield, efficiency, and profits.	All crops	Range of species	Automated	77
PhytoAgro Drone	This company focuses on control of a wide range of pests and their products including a drone, which accurately approaches each target and performs the treatments in a way that drift is non-existent.	All crops	Insects, Mites, Viruses, Bacteria, Fungi, Others	Manual	68

Gearsense	GearSense is a digital advisor which analyses the growing environment with smart cameras and sensors.	Bell pepper, Cucumber, Tomato, Chrysanthemum, Gerbera	Fungi, Others	Automated	**74**
iMETOS stations and disease models	The Pessl Instruments models provide the best information possible and allow you to make a conscious decision and use the best tools to produce more, both in terms of quantity and quality.	Asparagus, Beet, Carrot, Cucumber, Eggplant, Lettuce, Melon, Onion, Pepper, Potato, Pumpkin, Tomato, Watermelon, Zucchini	Insects, Bacteria, Fungi, others	Automated	**86**
Natutec Scout app	Natutec Scout is a quick and easy platform App that provides insight into the status of a greenhouse. Growers can use the mobile App to collect data and perform extensive analyses using the dashboard.	Bell pepper, Cucumber, Lettuce, Tomato	Insects, Mites	Automated	72
P4 Multispectral Drone	P4 Multispectral – a high-precision drone with a seamlessly integrated multispectral imaging system built for agriculture missions, environmental monitoring, and more.	Bell pepper, Cucumber, Tomato, Brussels sprout, Cauliflower, Head cabbage, Leek, Lettuce, Onion	Others	Manual	57
Taranis	Complete digital agronomy solution to identify, analyze and treat early signs of crop threats to make informed decisions, lower costs and maximize yield.	All crops	Bacteria, Fungi, Insects, Weeds	Manual	84
Margaret (Previously Named Thales)	Margaret (previously named Thales) is an artificial intelligence platform 100% oriented to the entire agri-food value chain. At the farm level, Margaret allows the farmer to integrate multiple Internet of Things (IoT) devices from the same or different vendors into one solution after data standardization.	All crops	Bacteria; Fungi; Insects; Mites; Viruses; Others	Automated	**96**
WiseCrop	The Plant Health App includes a set of tools to optimize the management of the crops with regard to diseases, pests and phytosanitary treatments/spraying. One of the tools available is for disease and pest prediction models.	Pepper, Bell pepper, Tomato, Apple, Pear, Olive, Vineyards	Others	Automated	**77**

3.1.1.3 Description of spider net diagram

Spider diagrams do not represent the technologies very well due to the overlapping of lines for particular criteria, thus hiding the location of some lines. Therefore, detailed and clear division of technologies in the spider net is difficult, but it is clear that the criteria `crops` and `application range` are the most discriminating criteria for the majority of technologies, which shows that many of the benchmarked technologies are specific for a particular narrow range of crops or pathogens.

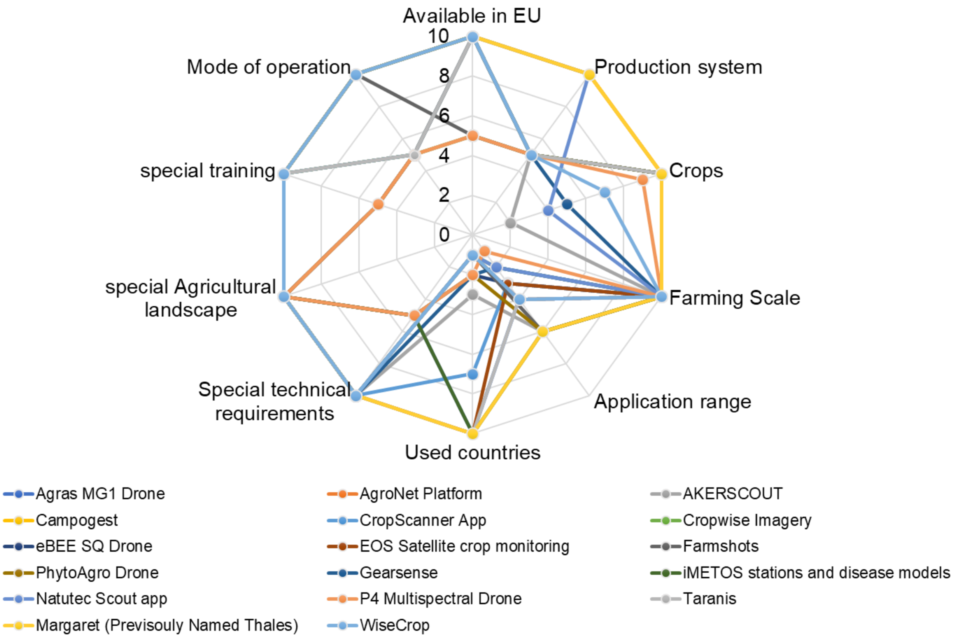


Figure 3 – Representation of 'Crop monitoring' technologies in spider net diagram

Common advanced criteria, including the two criteria: mode of operation and support, were used to score the technologies. For 'support' scores were based on 'yes' or 'no', and in the case of there being no information available, no scoring was done (Table 5).

Table 5 – Common advanced criteria scoring on 'Crop monitoring' technologies

Working speed	Benchmark Score	Accuracy	Benchmark Score	Acreage covered	Benchmark Score	Mode of Operation	Benchmark Score	Support (free, available and useful)	Benchmark Score
Lower than average	5	Lower	5	Lower	5	By company staff	3	No	5
Higher than the average	10	Higher	10	Higher	10	Manual	5	yes	10
n/a		n/a		n/a		Automatic	10	n/a	

3.1.1.4 In-depth SWOT analysis of *'Crop monitoring'* technologies

Table 6 – In-depth SWOT analysis matrix of 'Crop monitoring' technologies

Strengths	Weaknesses

• Many technologies are in use in Europe and there are **no major legal limits** or regulations with regard to their use. • Most technologies can be used on a **wide variety of crops**. • Most technologies have extra potential because they **can cover a wide range of crop protection methods** – not linked to any specific PPP. • Many technologies **can be used in different EU and non-EU countries.** • Many technologies can be widely used **and do not need any special technical requirements**. • Most of the technologies can be used in **all types of terrain**. • High use of technologies – do not require a specific training request – **easy access for the farmers**. • Most of the technologies **speed up work**. • Great **time efficiency**. • Most technologies **enable cost savings** and profit increase due to improved crop yield and quality. • Some **technologies enable wide-area monitoring**. • Most technologies enable **remote advising** – most farmers require external agricultural advice about pest situations in their fields and can easily share their information with advisors. • Some technologies with wide coverage at EU level **enable access to national and regional advisory services and agencies** (e.g., Germany, Italy) and even general policy makers on an EU level.	• Some technologies have weaknesses in operation and can only be used on a **small scale**. • Some technologies can only be used in one **or limited types of crop.** • Some technologies can only be used for one or **limited numbers of pests**. • Some technologies **do not provide costs**. • **Cost of technologies** may pose a limitation to purchase by the farmer. • **Mistrust – Misinformation** (overpromise) given by some of the technologies and not delivering on promises builds distrust in users and impedes adoption of a technology among the majority of the users. • Some technologies **lack precision** - less interest, more mistrust in using these technologies. • Most technologies can monitor **only insects and beneficials**. There is a lack of technologies for smaller pests and diseases. • Even if information about pests is precise, most farmers usually still need **external advice** about PPP applications. In some countries, this is even mandatory (e.g., France). It is **not an expert system** as such. • Only **basic monitoring information on a single monitoring point** without deeper statistical analytics is usually not enough to base PPP decisions. • When using a large number of devices on a larger scale, making decisions becomes more complex and difficult. **Most technologies do not provide analytical features on a larger scale**. • Some technologies have difficulty to demonstrate **return of investment** (compared to the traditional technologies or products).
Opportunities	**Threats**
• Many technologies can be used in **different crops and at different scales.** • In most of the countries (EU), there is **agricultural funding** to finance the purchase of these technologies. • Most technologies **can be sold in different countries.** • **Setting the price of the technology in line with the benefit for the grower**. • Global agricultural and legislation policies are supporting greener technologies (e.g., EU **Green deal**). • Price flexibility - dialogue - (possibility to have **tailor-made prices** – price - interest from farmers). • Growth of **alternative/biological PPP market** – these PPP require more precise application timing. • For large-coverage technologies, technology **sharing among stakeholder groups** (farmers) can be established. • Strong global growth of **Agriculture 4.0** in general helps promote novel technologies in agriculture. • **New business models** provide new opportunities to make these technologies more accessible for farmers • Lack of a work force in agriculture pushes farmers to optimize workloads – looking for **technologies that simplify or reduce work**.	• Barrier to selling the product in countries strongly relying on using **conventional pesticides** (e.g., US, Brazil). • In some countries, there is **no agricultural funding** to finance the purchase of these technologies. • With some technologies it is difficult to demonstrate **return on investment** (compared to the traditional technologies or products). • Large **multinational companies** (especially chemical and seed companies) are consolidating the technologies (buying smaller companies) making access to technology harder for smaller farmers. • **Long sales cycles of the technology** – if the beginning of the season is missing, the technology will most likely be adopted only in the following season. • **Increasing average age of the farmers** – older farmers are less interested in adopting new technologies. • The dependence of the farmer on **third parties**. • Underdeveloped or **immature products from new entrants** (competitors) in the market **build mistrust** in the users and do damage to the whole market.

3.1.1.5 Selected technologies

Three technologies were proposed for testing:

1. **<u>Campogest</u>** and **<u>Margaret</u>** (as a platform) are both distributed by our partner Hispatec. The score was high and they can be tested together.
2. The **<u>iMetos</u>** weather station: more than 80 disease models for more than 35 crops available, which can be accessed directly through the www.FieldClimate.com platform. It is immensely broad, but it works on weather data rather than actual measurements on plants. It would be interesting to see what such a system can do.
3. Although not scoring very highly because of its targeted use, the **<u>Gearsense</u>** system looks interesting and allows for real-time follow-up of crop growth / status.

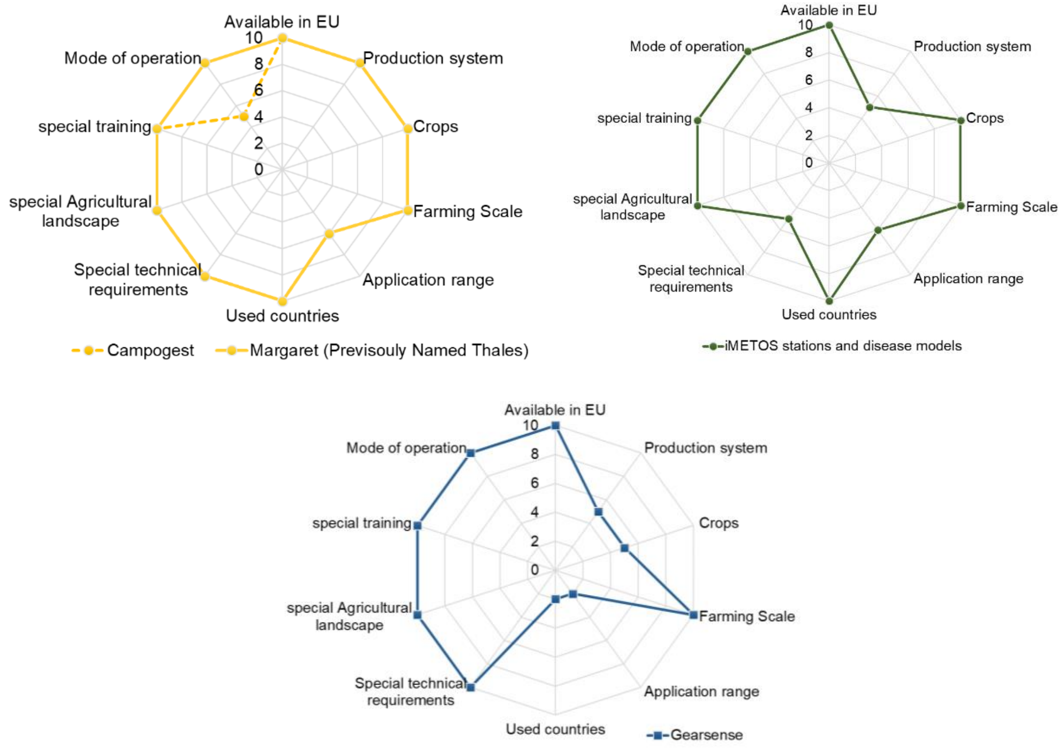


Figure 4 – Representation of selected 'Crop monitoring' technologies in spider net diagrams

3.1.2 'Insect monitoring' sub-group

3.1.2.1 Benchmarking EXCEL Table

The benchmarking Table (in EXCEL) is uploaded in the folder for Workpackage 3 in the SharePoint database belonging to the SmartProtect project.

3.1.2.2 Description of the technologies

The sub-group for 'Insect monitoring' evaluated 10 technologies using the benchmarking method. Eleven **basic criteria** and five **advanced criteria** were scored for each technology. Table 7 presents a summary based on the information from the benchmarking table.

Table 7 – Brief description of 'Insect monitoring' technologies evaluated by the benchmarking method

Technology	Description	Crops	Application range	Operation mode	Total Scoring
CapTrap	Cap2020 offers 3 connected traps designed for trapping different types of pests. To count pests, performant algorithms use deep learning to integrate into the trap.	Brussels sprouts, Cauliflower, Corn, Head cabbage (white, red, savoy), (mentioned: all crops)	Insects	Semi-automated	**106**
eGleek	e-GLEEK is an automatic trapping system that counts insects automatically. It detects and sends alerts when many flies are present and the threshold is crossed or when the glued sheet is oversaturated.	Groundnut, Oilseed rape (canola), Potato, Vines, Sugar beet	Insects	Semi-automated	101
FaunaPhotonics	The device transmits infrared, invisible light across flying insects and automatically detects the back reflected light of each individual insect. The technique can scout for many insect species at once providing real-time insights into in-field insect populations and activity.	Independent of crop	Insects	Automated	**104**
Futurcrop	FuturCrop predicts the biological development of 179 pests and calculates the best moment to treat them. In addition, images can be recorded on a mobile phone.	179 pests of more than 280 crops	Insects, Nematodes, Mites	Automated	118
iSCOUT®	iSCOUT® is an insect trap with integrated electronics (camera system, modem, power source with solar panel) and sticky plate.	Many; Brussel sprouts; Cabbage; Lettuce;	Insects	Automated	**112**
Natutec Scout app	Natutec Scout is a platform to provide insight quickly and easily into the status of a greenhouse. Growers can use the mobile App to collect data and perform extensive analyses using the dashboard.	Bell pepper; Cucumber; Lettuce; Tomato; Raspberry	Insects	Manual	96
Scoutbox	The Scoutbox uses image-based insect recognition for sticky plates. It revolutionizes insect scouting by combining image recognition and sophisticated machine learning algorithms.	Bell pepper, Cucumber, Lettuce, Tomato; all crops affected by whitefly	Insects	Manual	95
Semios	The Semios platform is a powerful tool in yield improvement that helps growers assess and optimize their response to insect, disease and plant health conditions in real-time.	Citrus and fruit crops, Fruit trees, Orchards (pears, peach, pistachio), Almonds, Apple,	Insects	Semi-automated	109
Trapview	TRAPVIEW is an automated pest monitoring system that can be used for monitoring remotely any kind of insect that can be lured into a trap (camera system, modem, power source with solar panel) and captured on a sticky plate.	Many	Insects	Semi-automated	**114**
Xarvio Scouting App	This is a system to help manage crop pathogens. It is a web based DSS that helps to time spray applications and calculates the right dose for each situation.	Many	Insects	Manual	**111**

3.1.2.3 Description of spider net diagram

Spider diagrams do not represent the technologies very well due to the overlapping of lines for particular criteria, thus hiding the location of some lines. Therefore, detailed and clear division of technologies in the spider net is difficult, but it is clear that the criteria `crops` and `application range` are the most discriminating criteria for the majority of technologies. This shows that many of the benchmarked technologies are specific for a particular narrow range of crops or pathogens. In addition, the mode of operation ranges from full automation to manual usage.

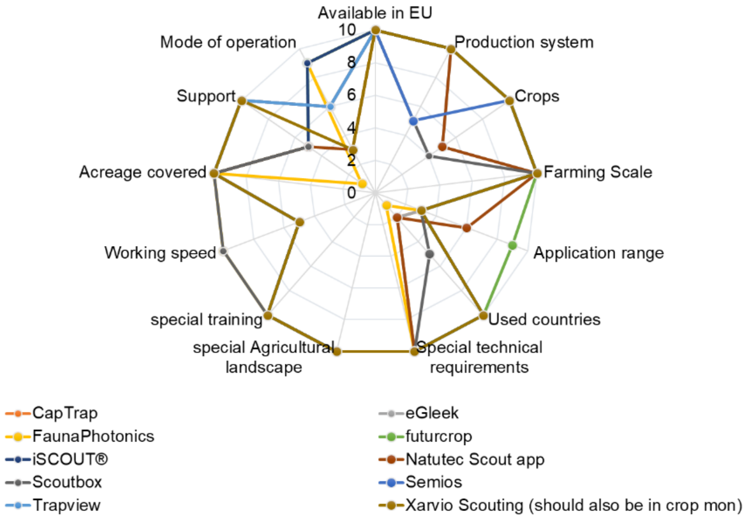


Figure 5 – Representation of 'Insect monitoring' technologies in spider net diagram

Common advanced criteria, including the two criteria: mode of operation and support, were used to score the technologies. In the case of there being no information available, no scoring was done (Table 8).

Table 8 – Common advanced criteria used for scoring 'Insect monitoring' technologies

Working speed	Benchmark Score	Accuracy	Benchmark Score	Acreage covered	Benchmark Score	Mode of Operation	Benchmark Score	Support (free, available and useful)	Benchmark Score
Lower than average	5	Lower	5	Lower	5	Manual	5	No	5
Higher than the average	10	Higher	10	Higher	10	Automated	10	yes	10
n/a		n/a		n/a		n/a		n/a	

3.1.2.4 In-depth SWOT analysis of 'Insect monitoring' technologies

Table 9 – In-depth SWOT analysis matrix for 'Insect monitoring' technologies

Strengths	Weaknesses
• Many technologies can be used in Europe and there are **no major legal limits** or regulations on their use (except Semios). • Most technologies can be used on a **wide variety of crops**. • Most technologies have extra potential because they **can cover a wide range of crop protection methods** – not linked to any specific PPP. • Many technologies **can be used in different EU and non-EU countries**. • Most of the technologies can be widely used. They **do not require any specific technical requirements**. • Most of the technologies can be used in **all types of terrain**. • High use of technologies – no specific training is required – **easy access for the farmers**. • Most of the technologies **speed up work**. • Great **time efficiency**. • Most technologies **enable cost savings** and profit increase due to improved crop yield and quality. • Some **technologies enable wide-area monitoring**. • Most technologies enable **remote advising** – most farmers require external agricultural advice about pest situations in their fields and can easily share their information with advisors. • Some technologies with wide coverage at EU level **enable access to national and regional advisory services and agencies** (e.g., Germany, Italy) and even general policy makers on an EU level.	• Some technologies can only be used on a **small scale**. • Some technologies can only be used in one **or limited types of crop.** • Some technologies can only be used for a **limited number of pests**. • Some technologies **do not provide costs**. • **Cost of technologies** may pose a limitation to purchase by the farmer. • **Mistrust – Misinformation** (overpromise) given by some of the technologies and not delivering on promises builds distrust in users and impedes adoption of technology among the majority of the users. • Some technologies **lack precision** - less interest, more mistrust in using these technologies. • Most technologies can monitor **only insects and beneficials**. There is a lack of technologies for smaller pests and diseases. • Even if information about pests is precise, most farmers usually still need **external advice** about PPP applications. In some countries, this is even mandatory (e.g., France). It is **not an expert system** as such. • Only **basic monitoring information on a single monitoring point** without deeper statistical analytics is usually not enough to base PPP decisions. • When using many devices on a larger scale, making decisions become more complex and difficult. **Most technologies do not provide analytical features on a larger scale**. • For some technologies it is difficult to demonstrate **return on investment** (compared to the traditional technologies or products).

Opportunities	Threats
• Many technologies can be used in **different crops and at different scales** • In most of the countries (EU), there is **agricultural funding** to finance the purchase of these technologies. • Most technologies **can be sold in different countries.** • **Setting the price of the technology in line with the value added for the grower**. • Global agricultural and legislation policies are supporting greener technologies (e.g., EU **Green deal**). • Price flexibility - dialogue - (possibility to have **tailor-made prices** - buying interest from farmers). • Growth of **alternative/biological PPP market** – these PPP require more precise application timing. • For large-coverage technologies, technology **sharing among stakeholder groups** (farmers) can be established. • Strong global growth of **Agriculture 4.0** in general helps promote novel technologies in agriculture. • **New business models** provide new opportunities to make these technologies more accessible for farmers • Lack of a work force in agriculture pushes farmers to optimize workloads – looking for **technologies that simplify or reduce work**.	• Barriers to selling the product in countries using **conventional pesticides** (e.g., US, Brazil). • In some countries, there is **no agricultural funding** to finance the purchase of these technologies. • For some technologies it is difficult to demonstrate **return on investment** (compared to the traditional technologies or products). • Large **multinational companies** (especially agrochemical and seed companies) are consolidating the technologies (buying smaller companies) making access to technology harder for smaller farmers. • **Long sales cycles of the technology** – if the beginning of the season is missing, the technology will probably only be used and adopted in the following season. • **Increasing average age of farmers** – older farmers are less inclined to adopt new technologies. • The dependence of the farmer on **third parties**. • Underdeveloped or **immature products of new entrants** (competitors) in the market **build mistrust** in the users and do damage to the whole market.

3.1.2.5 Selected technologies

Selection of technologies depends on the goal of further testing. As is clear, the number of technologies that use camera systems to detect insects dominates this Sub-group. Besides these technologies, there are smartphone apps and one technique (Faunaphotonics) that is completely different from the others.

After the experience of some partners with several of these systems (Fig. 6), the following technologies are proposed:

1. Camera-based systems - Trapview, iScout, CapTrap
2. Scoutbox as a dedicated tool for use in the greenhouse
3. The Xarvio App which is very broad

Remark: Faunaphotonics is an interesting system but seems to be rather for biodiversity and on the edge of TRL9.

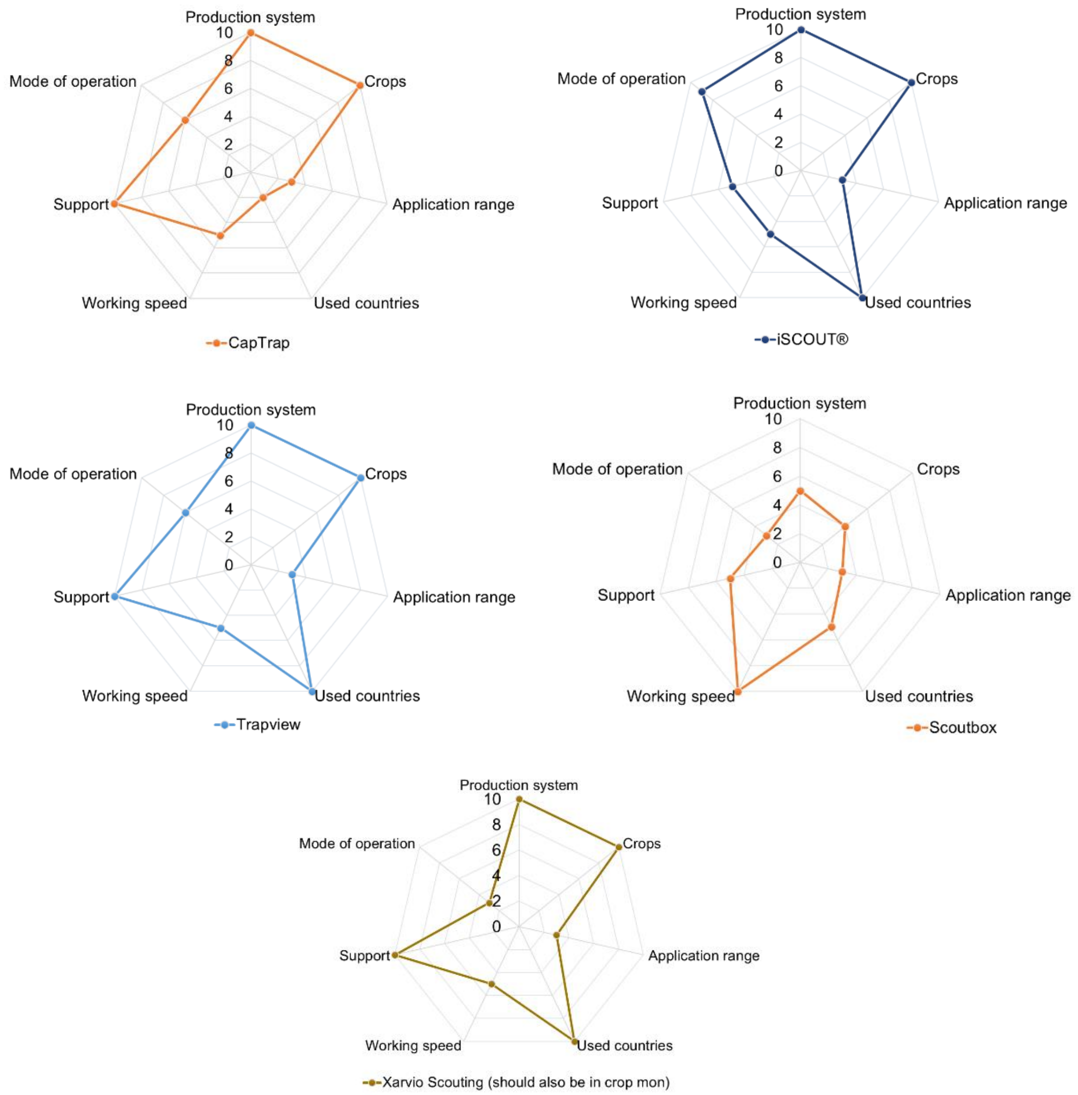


Figure 6 – Representation in spider net diagrams of selected 'Insect monitoring' technologies

3.2 Diagnosis and detection group

3.2.1 Sub-group: ‘ELISA, RNA and DNA technologies’

3.2.1.1 Benchmarking EXCEL Table

The benchmarking Table (in EXCEL) is uploaded in the folder for Workpackage 3 in the SharePoint database belonging to the SmartProtect project.

3.2.1.2 Description of the technologies

The Sub-group for ‘ELISA, RNA and DNA technologies’ analyzed 15 technologies through the benchmarking method. Eleven **basic criteria** and five **advanced criteria** were used to score the features of each technology. Table 10 presents a summary based on the information from the benchmarking table.

Five operational/technology groups represent the technologies within this sub-group:

(1) ***Lateral flow technologies*** - capture and detection of antibodies (in racks or just strips) (Biosense Laboratories, Pocket Diagnostic, ImmunoStrip® Tests, AgriStrip, LOEWE®FAST Lateral Flow Kits)

(2) ***ELISA*** (enzyme-linked immunosorbent assay) tests – a plate-based assay technique using a visualisation device (colorimetric, fluorimetric, chemiluminescent) (Creative Diagnostics, Bioreba, Loewe ELISA kits)

(3) Fast ***isothermal amplification method*** – employs target detection in a portable and easy-to-use format, at a single operating temperature (OptiGene Genie II, AmplifyRP® XRT (real-time fluorometer), AmplifyRP ACCELER8 (end-point isothermal NA amplification and detection in Detection Chamber))

(4) ***PCR tests*** (PCR and qPCR tests powered by Qualiplante & BIOREBA, Loewe Molecular Diagnostics - DNA and RNA PCR kits)

(5) ***Service platform*** using own laboratories (VegAlert)

Table 10 – Brief description of 'ELISA, RNA and DNA technologies' evaluated by the benchmarking method

Technology	Description	Crops	Application range	Operation mode	Total Scoring
Creative Diagnostics	ELISA technology, with its rather broad range of applications, is very good for viruses and bacteria, sometimes there is cross-reactivity between fungal species	Bean, Cowpea, Potato, Radish, Shallot, Soybean, Squash, Sugarcane, Tomato, Turnip, Watermelon	Viruses, *Fungi: Phytophtora* sp.; *Fusarium* sp.; *Pseudomonas* sp.	automated	86
OptiGene Genie II	Fast isothermal amplification method – employs target detection in a portable and easy-to-use format, at a single operating temperature; real-time fluorometer necessary	All	Range of species; *Botrytis cinerea*	automated	101
Agdia - AMPLIFYRP ACCELER8	Fast isothermal amplification method – employs target detection in a portable and easy-to-use format, at a single operating temperature; end-point isothermal NA amplification and detection in Detection Chamber	Tomato, Vines, Banana, Cherry	TCDVd	automated	86
Agdia - AmplifyRP® XRT	Fast isothermal amplification method – employs target detection in a portable and easy-to-use format, at a single operating temperature; real-time fluorometer necessary	Beans, Beet, Bell pepper, Tomato	Tomato brown rugose fruit virus, *Ralstonia solanacearum*	automated	89
VegAlert	Service platform using their own laboratories	All	All	manual for farmer	96
Biosense Laboratories	Lateral flow technology - captures and detects antibodies (in racks)	Tomato, Potato	*Phytophthora ramorum*	manual	81
Pocket Diagnostic®	Lateral flow technologies - capture and detect antibodies (in rack)	Tomato, Bell pepper	*Phytophthora sp., Ralstonia solanacearum*, Potato virus Y	manual	83
Agdia - ImmunoStrip® Tests	Lateral flow technologies - capture and detect antibodies (strips)	Cucumber, Melon, Pepper, Squash, Tomato	Cucumber green mosaic virus, Cucumber mosaic virus, Melon necrotic spot virus, Melon severe mosaic virus, Cucumber mosaic virus, Pepper mild mottle virus, *Phytophthora*, Tomato spotted wilt virus	manual	**96**
BIOREBA - AgriStrip	Lateral flow technologies - capture and detect antibodies (strips)	Beet, Bell pepper, Cucumber, Lettuce, Maize, Melon, Pumpkin, Squash, Tomato		manual	**100**
BIOREBA - ELISA kits	ELISA technology, with a broad range of applications and high accuracy.	All	All	automated	91
PCR and qPCR tests powered by Qualiplante & BIOREBA	PCR based DNA and RNA tests with high accuracy	Tomato, Bell pepper, Cucumber, Melon, Onion, Potato, Fruit trees	*Pseudomonas corrugata, Pseudomonas medi-terranea, Monosporascus cannonballus*, Cucumber mosaic virus, Cucumber mosaic virus, Tomato infectious chlorosis virus, Tomato chlorosis virus, *Xanthomonas axonopodis* Allii	automated	88
LOEWE - Plant Pathogen ELISA Kits	ELISA technology, with a broad range of applications and high accuracy.	All	All	automated	91
LOEWE®FAST Lateral Flow Kits	Lateral flow technologies - capture and detection antibodies (in racks)	All	All	manual	**101**
LOEWE Molecular	PCR based DNA tests with high accuracy	Pepper, Tomato, Pea	Pea Necrotic Yellow Dwarf Virus, Tomato Leaf Curl New Delhi V., Tomato Yellow Leafcurl Virus, *Ralstonia solanacearum*	automated	80

Diagnostics - DNA PCR kits					
LOEWE Molecular Diagnostics - RNA PCR kits	PCR based RNA tests with high accuracy	Cucumber, Melon, Tomato, Turnip, Zucchini	Tomato, Pepper, Cucumber and Turnip viruses	automated	86

3.2.1.3 Description of spider net diagram

Spider net diagrams do not represent the technologies very well due to the overlapping of lines for particular criteria, thus hiding the location of some lines. Therefore, detailed and clear division of technologies in the spider net is difficult, but it is clear that the `crops` and `application range` are the most discriminating criteria for the majority of technologies and shows that many of the benchmarked technologies are specific for a particular narrow range of crops or pathogens.

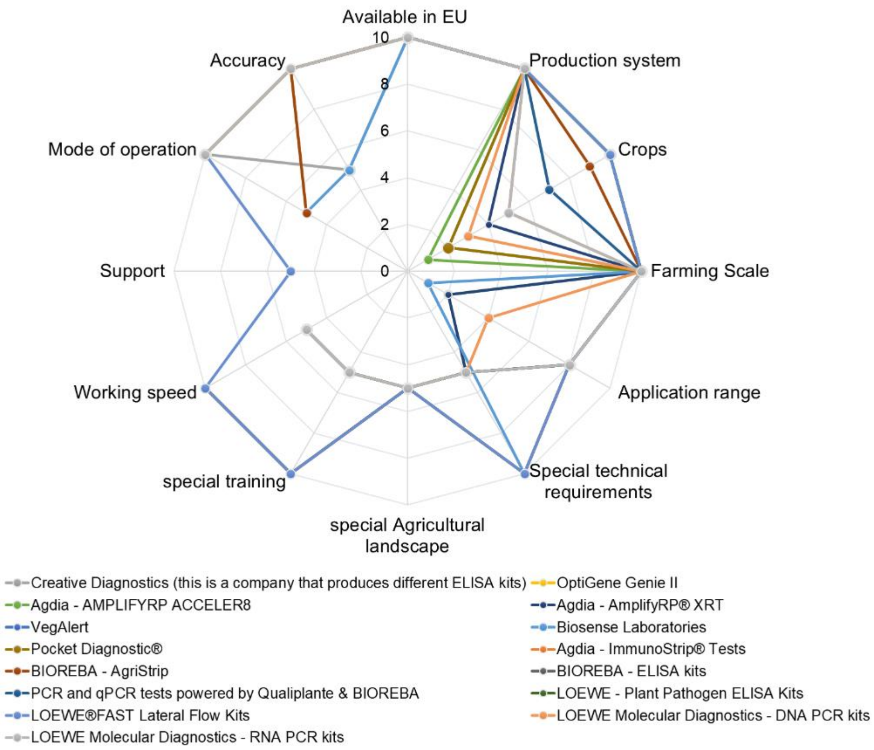


Figure 7 – Representation of 'ELISA, RNA and DNA technologies' in a spider net diagram

The scoring and criteria for the common advanced criteria for 'ELISA, RNA and DNA technologies' were as described in Table 1. In the case of there being no information available, no scoring was done (Table 11).

Table 11 – Common advanced criteria scoring on 'ELISA, RNA and DNA technologies'

Working speed	Benchmark Score	Accuracy	Benchmark Score	Acreage covered	Benchmark Score	Mode of Operation	Benchmark Score	Support (free, available and useful)	Benchmark Score
Lower than average	5	Lower	5	Lower	5	Manual	5	No	5
Higher than the average	10	Higher	10	Higher	10	Automated	10	yes	10
n/a		n/a		n/a		n/a		n/a	

3.2.1.4 In-depth SWOT analysis of 'ELISA, RNA and DNA technologies'

In this sub-group, there are innovative solutions based on the fast isothermal amplification method, which employs target species detection in a portable and easy-to-use format, at a single operating temperature. For these technologies special equipment is necessary – real-time fluorometer (for OptiGene Genie II, AmplifyRP® XRT) and end-point isothermal NA amplification and detection chamber (for AmplifyRP ACCELER8). Otherwise, these emerging technologies are rather simple, fast, and precise. All other technologies are based on well-known and widely used biotechnological tools – DNA and RNA amplification in PCR, antibody-based lateral flow and ELISA (Table 12).

Table 12 – In-depth SWOT analysis matrix on 'ELISA, RNA and DNA technologies'

Strengths	Weaknesses
• Detection of a significant number of pathogens. • Technologies are available worldwide as they can be purchased via the internet and used in any region of the world. • Technologies are precise and pathogen specific. It can be assumed as strength and as weakness. • There are two approaches to speed for these technologies– fast detection in the field or slow in the laboratory. • Fast detection in the field can be performed by lateral flow tests, which are not so precise, and by portable heat block equipment, which ensures high precision. This technology is rapidly expanding. • ELISA and PCR tests are extremely precise, but performed in laboratories, which takes a longer time, often one day.	• Training is needed for the laboratory technologies. Technologies used under field conditions do not require special training and knowledge. • The range of application depends on the company producing the test kits. Such companies as Loewe, Bioreba and Agdia are offering detection of a wide range of pests. • Accuracy often is linked with equipment needed. • For ELISA and PCR tests special knowledge and equipment is necessary. • ELISA and PCR tests require a longer time to get a result. • ELISA and PCR tests are more expensive in comparison to the lateral flow-based (strip-tests) technologies and have special requirements (premises and skilled staff) for use.
Opportunities	**Threats**
• The technologies offered in the sub-group are already developed and widely used technologies, which can be used by the cooperatives or service centres. Such an approach is offered by VegAlert, which is a company providing detection and DSS services. Unfortunately, due to the specific conditions for transporting the samples, it is assumed that this product is applicable in limited regions, where fast and controlled delivery of samples is possible. • Often, specific products are used on the equipment, which can be exploited also for detection of other pests and pathogens (for fruit crops, ornamentals or field crops). • The products offering a fast, field-usable approach do not need specific laboratory equipment and it is considered as an opportunity to use rather precise, but fast technology. • There is an opportunity for using these technologies in combination with DSS. • There is also a possibility to integrate the technologies for instance into existing laboratories.	• An external factor influencing the evaluation of technologies is their environmental load. As many of them are performed in the laboratory, they often use quite a broad range and considerable amounts of laboratory consumables and reagents, which in many cases are disposed of after each analysis. • In addition, pocket diagnostic kits are often held in a plastic rack, which also is thrown away after each test. • The transportation of samples for the laboratory analyses is a significant threat. The samples should be transported over a short period and in controlled conditions. • Laboratory tests are often performed with reagents that are harmful to human health. Safety conditions must be considered and regulated according to EU rules for laboratory work.

3.2.1.5 Selected technologies

Strip tests LOEWE®FAST Lateral Flow Kits (total score 101), **AgriStrip (Bioreba)** (total score 100) and **ImmunoStrip® Tests (Agdia)** (total score 96) were chosen for testing on farms, as they had the highest scores amongst technologies requiring no special technological equipment, and they cover detection of a wide range of pathogens (mostly viruses) and they have low costs (usually). A very important aspect is that no special training, knowledge and equipment are needed, in comparison with other technologies. They also give fast results (in 10 - 15 minutes) which is an important parameter.

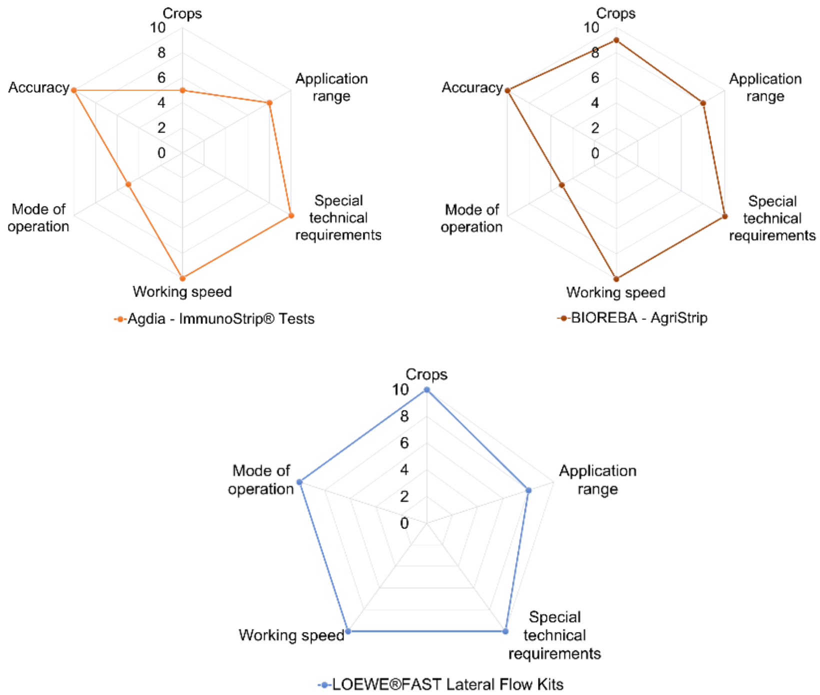


Figure 8 – Representation in spider net diagrams of selected 'ELISA, RNA and DNA technologies'

3.2.1.6 Selected technologies for field testing

Strip tests LOEWE®FAST Lateral Flow Kits, **AgriStrip (Bioreba)** and **ImmunoStrip® Tests (Agdia)** will be used in demonstration trials in 2022, in greenhouse and/or open field farms producing tomatoes, cucumbers and lettuce. As these technologies do not demand special equipment or knowledge, they are appropriate to test in the commercial production environment with limited costs. Lateral flow strip tests detect mostly viruses and bacteria; therefore, it would be advisable to test these in a broad range of locations and on a diversity of farms – organic, integrated, and conventional.

3.2.2 Sub-group: *'Disorder detection using mobile phone'*

3.2.2.1 Benchmarking EXCEL Table

The benchmarking Table (in EXCEL) is uploaded in the folder for Workpackage 3 in the SharePoint database belonging to the SmartProtect project.

3.2.2.2 Description of the technologies

Nine technologies in the sub-group 'Disorder detection using mobile phone' were evaluated using the benchmarking method. Fourteen distinct criteria were assessed through scoring the features of each separate IPM technology.

The 14 assessment criteria consisted of:

1. Regulatory zone (Available in EU or not)
2. Production system (open field, greenhouse)
3. Crops (number of vegetable crops where technology is used)
4. Farming scale (small scale, a large scale)

5. Application range (number of possible different targets)
6. Countries used (number of countries where technology is used)
7. Special technical requirements (yes/no)
8. Special agricultural landscape (yes/no)
9. Special training (yes/no)
10. Cloud requirement for data processing (yes/no)
11. Buying costs (price in Euro)
12. Equipment requirements (yes/no)
13. Working speed
14. Ability to work offline

Table 13 presents the nine technologies accompanied by their description and the three main criteria that differentiate and shape the final total scoring per technology.

Table 13 – Brief description of 'Disorder detection using mobile phone' technologies evaluated by the benchmarking method

Technology	Description	Crops	Application Range	Buying costs	Total Scoring
Planticus (App by Ask Attis)	Planticus is a human-driven technology to improve food and plant growth. Planticus is an innovative sustainable agriculture App for crop protection and crop monitoring.	Tomato, Bell Pepper, Cucumber	Fungi, Insects, Mites	Free	121
Plantix App	Plantix is a free mobile phone App to identify pests, diseases and deficiencies on crops. Images can be uploaded on WhatsApp.	Bell Pepper, Brussel Sprouts, Cauliflower, Cucumber, Head Cabbage, Leek, Lettuce, Onion, Tomato	Bacteria, Beneficials, Fungi, Insects, Mites, Nematodes, Viruses	Free and a paid version for special services	**126**
Cropalyser App	Cropalyser App is a practical tool to identify major pests, diseases and disorders in vegetable crops. This App provides instant information on the health and growth of a crop. The search function "Cropalyse" guides users to analyse irregularities, recognize symptoms, follow growth developments and advise on control and prevention of pests and diseases.	Bell Pepper, Brussel Sprouts, Carrots, Cauliflower, Head Cabbage, Leek, Onion, Tomato	Bacteria, Fungi, Insects, Nematodes, Viruses	Free	**128**
Buntata App	Buntata is an Android application designed to help users identify plant pests and diseases with no a-priori knowledge. Buntata provides a visual key for the identification of diseases by displaying example images of symptoms. The user can select the part of the plant that is affected and Buntata shows images of recorded symptoms.	Potato	Bacteria, Beneficials, Fungi, Insects, Mites, Nematodes, Viruses	Free	**123**
Agrix Tech App	Agrix Tech App detects crop fungal diseases at the primary stage and proposes adequate treatment. This App identifies plant diseases from a photograph. Agrix Tech's AI can be embeded in 3rd parties' Apps.	Bell Pepper, Cauliflower, Cucumber, Head Cabbage, Tomato	Fungi	10-15 EUR (depending on country)	112
Crop-scanner App	This App provides fast and direct entry of scouting-data into a smartphone or tablet; gives a real-time overview of the user's greenhouse at any time; a structured view of the scouting data via pc or web; visualization of pest pressure and population buildup of beneficiasl; extensive data-analysis; direct contact with a Biobest advisor for personalized IPM advice.	Bell Pepper, Cucumber, Tomato	Beneficials, Fungi, Insects, Mites	Free	112
GoMicro Examine	GoMicro Inspect is one of the best-in-class clip-on magnifiers that clips onto any smartphone, tablet or iPad producing clear crisp images. It is a great tool for detecting leaf disease and pests early. It accompanies the GoMicro Examine App.	Tomato	Insects	45 EUR for GoMicro Inspect lens	93
Cropwise Imagery	Cropwise Imagery is a digital farming tool that uses imaging technology to monitor crop health. The user can easily access all data via a tablet, phone, or computer. The data is easy to interpret and used to detect abnormalities in the field. This farming tool signals the user when something is harming the crops.	Bell Pepper	Insects, Nematodes	n/a	108
Cropify a Plant Disease identifier	Users can upload an image of (tomato, potato) plants and identify diseases and learn about remedies with a practical video explanation to prevent further loss of plants.	Tomato, Potato	Fungi, Viruses	n/a	109

3.2.2.3 Description of spider net diagram

The three criteria included in Table 13 shape the result of the benchmarking process. The rest of the criteria are less significant in determining the final score for the technologies. The spider net charts (Fig. 9) presented below illustrate this.

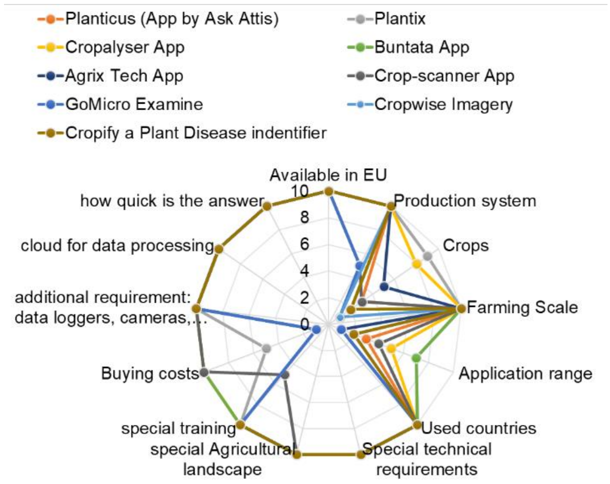


Figure 9 – Representation of ‘Disorder detection using mobile phone’ technologies in spider net diagram

3.2.2.4 In-depth SWOT analysis of ‘Disorder detection using mobile phone’ technologies

Based on the benchmarking process, three technologies had high scores:

- **Plantix App** (total score 126)
- **Cropalyser App** (total score 128)
- **Buntata App** (total score 123)

Technologies with lower scores were relevant to a limited number of crops due to buying costs and targeted a small number of pests and diseases.

To achieve a good understanding of the advantages and disadvantages of this category of technologies, a SWOT analysis probed the Strengths, Weaknesses, Opportunities, and Threats for this group of solutions. Table 14 presents the results.

Table 14 – In-depth SWOT analysis matrix on ‘Disorder detection using mobile phone’ technologies

Strengths	Weakness
• Detection of a great number of disorders. • Technologies are available worldwide as they are online applications. • Reduce time in the field. • Increase the working speed. • Provide effective guidance (solution) in case of lack of advisory support	• Limited crop types. • Applications only work online with internet connection. • Lack of ability to find uncharacterized disorders such as quarantine pathogens or unknown/new species. • A mobile device with a good camera is needed to capture photos of acceptable quality.
Opportunities	**Threats**
• Use in both open field and greenhouse production systems • Add training sessions • Reduce the cost to the producer for in situ detection by specialists	• In some countries it is not easy to develop such systems, thus some local pests/pathogens may not be included • Difficulties in disseminating such tools in countries where producers are not familiarized with IoT • Farmers may act upon their judgement without the opinion of an advisor. Thus, spraying sessions applied may be

• Create online communities/groups for knowledge and experiences' sharing and transfer • Mobile disorder detection technologies can be incorporated in DSS that will allow practical support for the producers	increased unreasonably • Producers in developing countries may not have access to equipment/tools/devices in order to use such applications, or internet access for using them

3.2.2.5 Selected technologies

Plantix App lacks only information on buying costs and application range, while **Cropalyser App** and **Buntata App** (Figure 10) lack information on crops and application range. However, as they have the highest scores, they were selected for further analysis.

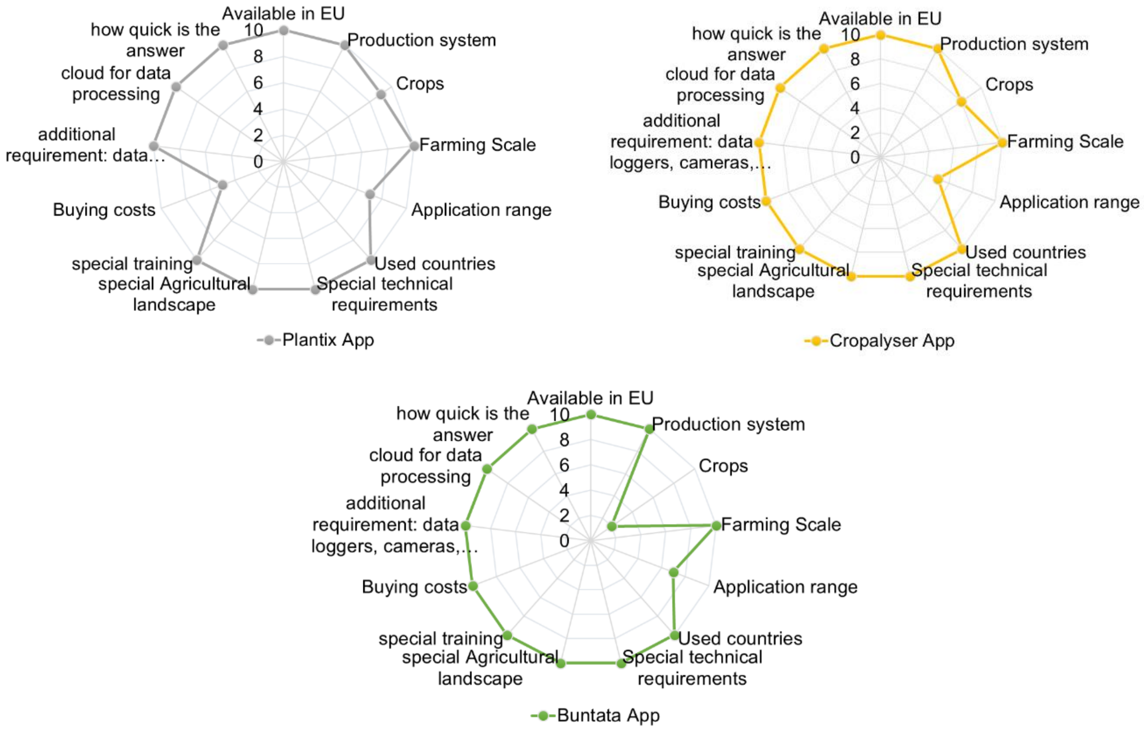


Figure 10 – Representation in spider net diagrams of selected 'Disorder detection using mobile phone' technologies

3.2.2.6 Selected technologies for the field experiments

Plantix App, Cropalyser App and **Buntata App** are of interest for use in demo trials in 2022. All three applications are available in Europe and can be both used in greenhouses and in open field production systems. They are used worldwide, have no special technical requirements, no special agricultural landscape requirements, and need no special training. **Buntata** and **Cropalyser** are free to buy, while **Plantix** has a paid version depending on the number of crops applied. All three solutions have no equipment requirements, they are all cloud based, provide instant results, and work only online. Finally, regarding the crops, **Plantix** can be applied in bell pepper, Brussel sprouts, cauliflower, cucumber, head cabbage, leek, lettuce, onion and tomato. **Cropalyser** can be used in bell pepper, Brussel sprouts, carrots, cauliflower, head cabbage, leek, onion, tomato; and **Buntata** works in potato cultivation. **Planticus App** can be selected as the third technology to be used. **Planticus** is available in Europe for greenhouses and open fields, for big and small-scale farms. Finally, it can target Fungi, Insects, and Mites in tomato, bell pepper, cucumber cultivations.

3.3 Decision support group

3.3.1 Sub-group: 'Decision support (no sensors)'

3.3.1.1 Benchmarking EXCEL Table

The benchmarking Table (in EXCEL) is uploaded in the folder for Workpackage 3 in the SharePoint database belonging to the SmartProtect project.

3.3.1.2 Description of the technologies

The group 'Decision support (no sensors)' evaluated twelve technologies, and sixteen criteria were evaluated with scores. Table 15 presents a summary from the EXCEL spreadsheet.

Table 15 – Brief description of the 'Decision support (no sensors)' technologies evaluated by the benchmarking approach

Technology	Description	Crops	Countries used	Production system	Total Scoring
Crop-scanner App	This App provides fast and direct entry of scouting-data into a smartphone or tablet; real-time overview of your greenhouse at any time; structured view of scouting data via pc or web; visualization of pest pressure and population buildup of beneficials; extensive data-analysis; direct contact with a Biobest advisor for personalized IPM advice.	3	7	5	119
Farmapp - Digitising IPM	An Integrated Pest Management (IPM) software-based service for crops. The software includes a combination of scouting and fumigation Apps with sensors and brings automation (IOT) devices to the agriculture sector.		4	10	107
Bioline App	Bioline Agrosciences has developed the Bioline App to help growers in their daily activities. With this App, growers have all they need to have instant, consistent and clear answers to all the questions they may have concerning Bioline's bio solutions.	3	10	5	**125**
FarmShots™	FarmShots™ satellite imagery service is a solution to help growers maximize yield, efficiency, and profits. FarmShots will analyze satellite and drone imagery to help detect diseases, pests and poor plant nutrition.	6	1	5	105
My IPM	Clemson University for South Carolina developed the MyIPM smartphone application in 2012. It was originally developed for peach and strawberry growers but has since expanded into a tool that serves all fruit growers along the east coast.	0	1	5	104
App - Agrio Technology to help you grow in the future	Agrio is an artificial intelligence-based precision agriculture solution that helps growers to remotely monitor, identify, and treat plant diseases and pests in their field, farm, and garden.	6	10	10	**132**
Taranis	Complete digital agronomy solution to identify, analyze and treat early signs of crop threats to make informed decisions, lower costs and maximize yield. Growers can spot the first signs of harmful insects using submillimeter resolution imagery to gain precise identification. Early detection and identification of lesions, spots or abnormal crop behavior.	0	8	5	116
Crop Diagnosis	The aim of the CropDiagnosis mobile application is the integrated management of pathogens from the successful recognition of the problem to the selection and application of the appropriate plant protection products.	5	1	10	119
Xarvio™ Scouting	Xarvio™ SCOUTING is developed for agronomists and farmers to automatically identify problems in their crops. Users can just take a picture and instantly receive a result. SCOUTING supports more than 50 crops globally and helps growers to document in-field stress easily.	6	10	10	**135**
Scan Bean	Scan Bean is a diagnostic tool intended to survey phytosanitary treatments at the times when they are most necessary and most effective.	0	1	5	102
Natutec Scout	Natutec Scout is a platform to provide insight quickly and easily into the status of a greenhouse. Growers can use the mobile App to collect data and perform extensive analyses using the dashboard. This allows them to see at any moment what is happening in the greenhouse and intervene when necessary, resulting in healthy crops.	4	10	5	117
Sprayer vision	Sprayer vision hardware can be mounted on the header and back of farm machinery to capture, and geo-tag, an image every 5 seconds. E.g., the hardware works on a sprayer and can be used to take images that assist pest and disease identification; plant counts; growth stage (crop height); weed detection (see and spray); % application coverage; nozzle performance.	6	2	5	116

3.3.1.3 Description of spider net diagram

The range in the scores was not very large (102 -135). For most of the criteria, the responses were similar. Tables 17 and 18 summarize the technologies in more detail with respect to the target crops for the SmartProtect project, availability in Europe and the tasks that the tools will assist with – which are different and diverse (Fig. 11).

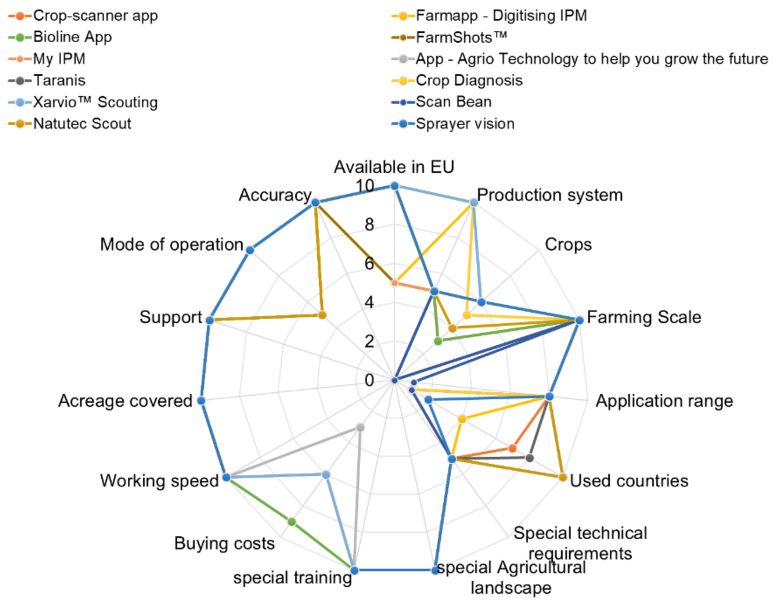


Figure 11 – Representation of 'Decision support (no sensors)' technologies in spider net diagram

The **common advanced criteria** for the technologies in '*Decision support (no sensors)*' were not modified. The scoring ranged from '*lower to higher*' and from '*manual to automated*', and when no information was available it was not included in the template (Table 16). The criteria consisted of working speed, accuracy, acreage covered, mode of operation, and support from the provider or manufacturer.

Table 16 – Common advanced criteria scoring on 'Decision support (no sensors)' technologies

Working speed	Benchmark Score	Accuracy	Benchmark Score	Acreage covered	Benchmark Score	Mode of Operation	Benchmark Score	Support (free, available and useful)	Benchmark Score
Lower than average	5	Lower	5	Lower	5	Manual	5	No	5
Higher than the average	10	Higher	10	Higher	10	Automated	10	yes	10
n/a		n/a		n/a		n/a		n/a	

Table 17 – Comparison of 'Decision support tools (no sensors)' use on crops and their availability in Europe

Technology / Crop	Brassica	Lettuce	Allium	Cucumber	Tomato	Pepper	Available in EU	Score
Crop-scanner App				*Yes*	*Yes*	*Yes*	*Yes*	119
Farmapp - Digitising IPM								107
Bioline App				*Yes*	*Yes*	*Yes*	*Yes*	**125**
FarmShots™	*Yes*	*Yes*	*Yes*					105
My IPM							*Yes*	104
App - Agrio Technology	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	**132**
Taranis							*Yes*	116
Crop Diagnosis	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	119
Xarvio™ Scouting	*Yes*	*Yes*	*Yes*				*Yes*	**135**

Scan Bean							Yes	102
Natutec Scout				Yes	Yes	Yes	Yes	117
Sprayer vision							Yes	116

Table 18 – Tasks that the 'Decision support tools (no sensors)' can assist with

Technology / Crop	**Pest identification**	**Disease identification**	**Pest models**	**Disease models**	**Scouting data entry**	**Overview of crop situation**	**Pesticide advice**	**Spray diary**	**IPM advice**	**Link to advisor**	**Crop imagery**	**GPS tracking**	**Linked to traps**	**Scans traps**	**SMS or other alerts**	**Score**
Crop-scanner App					Yes	Yes			Yes	Yes						119
Farmapp - Digitising IPM					Yes	Yes		Yes								107
Bioline App							Yes		Yes							**125**
FarmShots™											Yes	Yes				105
My IPM	Yes	Yes					Yes		Yes							104
App - Agrio Technology	Yes	Yes	Yes	Yes		Yes			Yes		Yes				Yes	**132**
Taranis						Yes					Yes					116
Crop Diagnosis	Yes	Yes					Yes									119
Xarvio™ Scouting	Yes	Yes												Yes		**135**
Scan Bean				Yes											Yes	102
Natutec Scout					Yes				Yes	Yes				Yes	Yes	117
Sprayer vision	Yes	Yes									Yes	Yes				116

3.3.2 In-depth SWOT analysis of 'Decision support (no sensors)' technologies

- The **Xarvio Scouting App** obtained the highest score and is available in Europe. It seems only to be applicable to outdoor crops and can assist with a limited range of tasks.
- The **Agrio Technology App** had the second highest score. It is available in Europe and can be used on all the target crops, and can support quite a range of tasks.
- The **Bioline App** has quite a high score and is available in Europe but only applicable to greenhouse crops. It can assist with a limited range of tasks.

Table 19 – In-depth SWOT analysis matrix on 'Decision support (no sensors)' technologies

Strengths	**Weakness**
• Pest and disease identification, data collection, model outputs, overview of crop situation, alerts, advice, contact with experts. • Assists with making decisions. • Can lead to more informed and reliable decision making. • Some are very accessible and affordable (some are free) and linked to companies e.g., Koppert. • Some are available in the EU.	• No tool does everything. • There is some information about them but often not a lot of detail. • You need to try them to be sure of how useful they will be. • No way of checking their accuracy and usefulness without trying them. • Range of crops not wide enough.
Opportunities	**Threats**
• Lots of scope to improve these tools and make them useful on more crops. • Opportunity to make USA tools etc. available in Europe.	• Might be considered to not be very useful/accurate so not used. • Range of crops not wide enough.

• Scope to make information about them clearer on web sites. • Examples of validation of information would be useful.	

3.3.2.1 Selected technologies – *'Decision support (no sensors)'*

- The **Xarvio Scouting** tool has the highest benchmarking score and is available in Europe. It seems only to be applicable to outdoor crops at the moment and can assist with a limited range of tasks (Fig. 12).
- The **Agrio Technology App** obtained the second highest score, and is available in Europe and can be used on all the target crops. It can also assist with quite a wide range of tasks.
- The **Bioline App** has quite a high score and is available in Europe but only applicable to greenhouse crops. It can assist with a limited range of tasks.

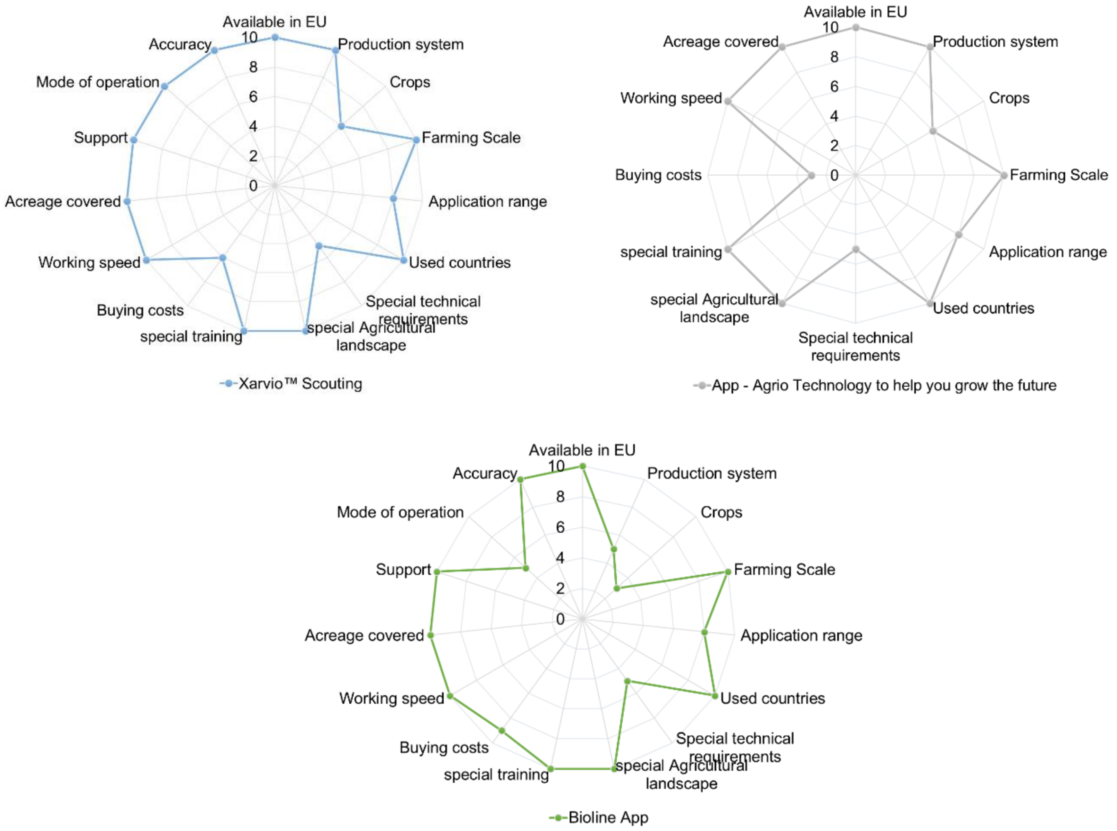


Figure 12 – Representation in spider net diagrams of selected 'Decision support (no sensors)' technologies

3.3.2.2 Selected technologies – *'Decision support (no sensors)'* for the field tests

Table 20 – Selected technologies 'Decision support (no sensors)' for field testing

Mobile applications	***Production system***	***Accessibility***	***Platform***
Xarvio Scouting App	Field crops	Free app	SCOUTING (xarvio.com)
Agrio Technology App	All crops	Free app	Agrio: Smart Plant Protection on the

			App Store (apple.com)
Bioline App	Greenhouse crops	Free app	Bioline App (biolineagrosciences.com)

3.3.3 Sub-group: 'Decision support (with sensors)'

3.3.3.1 Benchmarking EXCEL table

The benchmarking table from the EXCEL spreadsheet is uploaded in the folder for Workpackage 3 in the SharePoint database for the SmartProtect project.

3.3.3.2 Description of the technologies

The group 'Decision support (with sensors)' evaluated nine technologies, and sixteen criteria were assessed through scores. Table 21 presents a summary from the EXCEL spreadsheet.

Table 21 – Brief description of 'Decision support (with sensors)' technologies evaluated by the benchmarking approach

Technology	Description	Crops	Countries used	Available in EU	Total Scoring
Biz4intellia Solution - IoT for Smart Farming	Intellia IoT is an end-to-end Industrial IoT (Internet of Things) business solution, which is currently empowering several industries across the globe. Options include weather monitoring and forecasting and smart pest management with detailed analytics predicting swarm patterns and alerts on the health of crops.		1	no	102
OPI Support System	OPI is a grower support system based on smart agriculture sensors, artificial intelligence and advanced agronomic models. A few models are available to predict plant disease e.g., downy mildew and powdery mildew. However, the company is also happy to work with growers and/or research organizations to develop/adapt other models.	10	2	yes	**120**
PLANTCT™	PLANTCT™ is a site-specific management system, which continuously monitors the weather and crop plants. Used as a disease/pest warning system, the DSS helps users to determine when to apply control measures to suppress diseases and pests.		1	yes	104
Hub@grimeteo	This decision support platform uses a range of tools to gather information on weather, crops, pests etc. The models for field vegetables are the result of international scientific cooperation with research institutes and universities.	10	1	yes	**120**
Arable- Arable Mark 2	This device combines weather and plant measurements, which are uploaded into the cloud for retrieval anytime, anywhere. Data can be accessed in real time with the Arable software platform. Plant-related metrics include NDVI, Chlorophyll Index, Evapotranspiration (Dynamic Kc, Forecasted Crop ET), Leaf Wetness, Growing Degree Days, and Crop Water Deficit.		4	no	103
AgroNet	AgroNET is a cloud-based platform acting as a hub for all farm operations, enabling complete farm asset management (tractors, machinery, irrigation systems, diesel generators, weather stations, insect traps, sensors etc.) and activity management and monitoring, which is the basic building block of digital farming. It includes environmental monitoring, connection to smart traps and disease prediction.	10	1	yes	**119**
Weenat	Using a mobile application and a range of connected agro-weather sensors, Weenat offers farmers reliable and easy to use solutions to monitor in real time the weather and agronomic conditions of their fields from sowing to harvesting. Weenat sensors are compatible with more than 20 reference DADs (decision support tools) on the market.	1	1	yes	110
Mileos®	Mileos® is a reference Decision Support Tool in France to manage the risk of potato downy mildew (*Phytophthora infestans*). The model possesses 4 segments: contamination and survival of spores in the environment that can either germinate and contaminate, survive or die; incubation and potential sporulation of each contamination; modeling of real sporulation; spore dispersion.	1	1	yes	106
Xarvio™ Spray Timer	This is a system to help manage crop pathogens. Web based DSS that helps to time spray applications and calculates the right dose for each situation. Field Manager is a complete tool for planning applications, optimizing your crop inputs and maximizing crop health at both the field and zone level.		1	no	104

3.3.3.3 Description of spider net diagram

The range of the scores varied from 102 to 120. For most of the criteria, the responses were similar. The greatest differences were the crops and the countries in which the tools are used. Tables 22 and 23 summarize the technologies with sensors in more detail with respect to the target crops for SmartProtect, availability in Europe and the tasks that the tools will assist with – which are very different and diverse (Fig. 13).

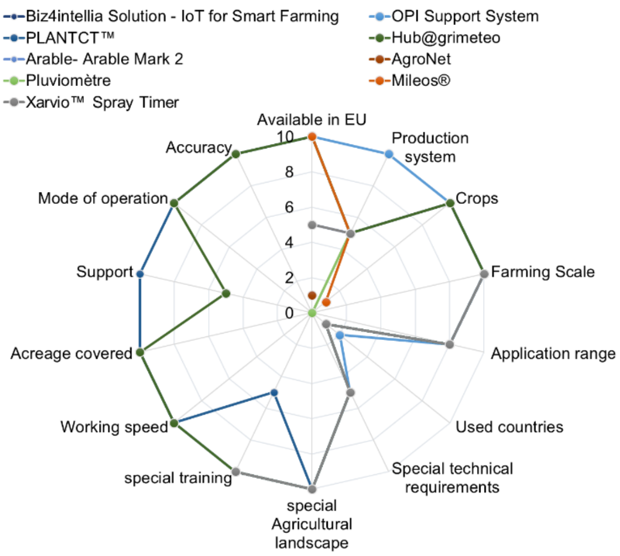


Figure 13 – Representation of 'Decision support (with sensors)' technologies in spider net diagram

Table 22 – Comparison of 'Decision support (with sensors)' technologies by crops on which were used and available are in Europe

Technology / Crop	**Lettuce**	**Cucumber**	**Tomato**	**Pepper**	**Available in EU**	**Total score**
Intellia IoT for Smart Farming						102
OPI Support System	*Yes*	*Yes*	*Yes*		*Yes*	**120**
PLANTCT™					*Yes*	104
Hub@grimeteo	Probably	Probably	Probably	Probably	*Yes*	**120**
Arable- Arable Mark 2						103
AgroNet			*Yes*	*Yes*	*Yes*	**119**
Pluviomètre					*Yes*	110
Mileos®					*Yes*	106
Xarvio™ Spray Timer						104

Table 23 – 'Decision support (with sensors)' technologies and tasks that they can assist with

Technology / Crop	Linked to sensors	Disease identification	Pest models	Disease models	Scouting data entry	Overview of crop situation	Pesticide advice	Crop imagery	GPS tracking	Linked to traps	Scans traps	SMS or other alerts	Total score
Intellia IoT for Smart Farming	Yes				Yes	Yes			Yes			Yes	102
OPI Support System	Yes			Yes		Yes						Yes	**120**
PLANTCT™	Yes			Yes									104
Hub@grimeteo	Yes		Yes	Yes									**120**
Arable- Arable Mark 2	Yes												103
AgroNet	Yes		Yes	Yes		Yes	Yes	Yes		Yes	Yes		**119**
Pluviomètre	Yes			Yes									110
Mileos®	Yes			Yes									106
Xarvio™ Spray Timer	Yes	Yes		Yes	Yes	Yes		Yes	Yes			Yes	104

3.3.3.4 In-depth SWOT analysis of 'Decision support (with sensors)' technologies

- **OPI Support System** had the highest score, is available in Europe, and applicable to several crops (Fig. 14).
- **Agronet** had a similar score, is available in Europe, and applicable to several crops
- **Hub@grimeteo** had a high score but there is no information on crops on which it can be used.

Table 24 – In-depth SWOT analysis matrix of 'Decision support (with sensors)' technologies

Strengths	Weakness
• Pest and disease identification, data collection, model outputs, overview of crop situation, alerts, advice, contact with experts. • Assists with making decisions. • Can lead to more informed and reliable decision making. • Some are very accessible and affordable (some are free) and linked to companies. • Some technologies are available in the EU.	• Not every tool does everything. • There is some information about them, but often not a lot of detail available. • You need to try them to be sure of how useful they will be. • No way of checking their accuracy and usefulness without trying them. • Not sure there are many for outdoor vegetables – although there are national DSS that are not on SmartProtect platform. • Range of crops not wide enough. • No routine production and systematic support across the EU in place.
Opportunities	**Threats**
• Lots of scope to improve these tools and make them useful on more crops. • Opportunity to make USA tools etc. available in Europe. • Scope to make information about them clearer on web sites. • More models e.g., pest and disease forecasting models could be included in the tools. • Examples of validation of information would be useful. • Opportunity for local companies to combine current knowledge and requirements of local farmers.	• Might be considered to not be very useful/accurate so not used. • Range of crops not wide enough. • Not available for vegetables. • Other tools for decision support that are available (including national tools that are supplied by research organizations e.g. UK forecasts and may be free) – the market may get too full.

3.3.3.5 Selected technologies

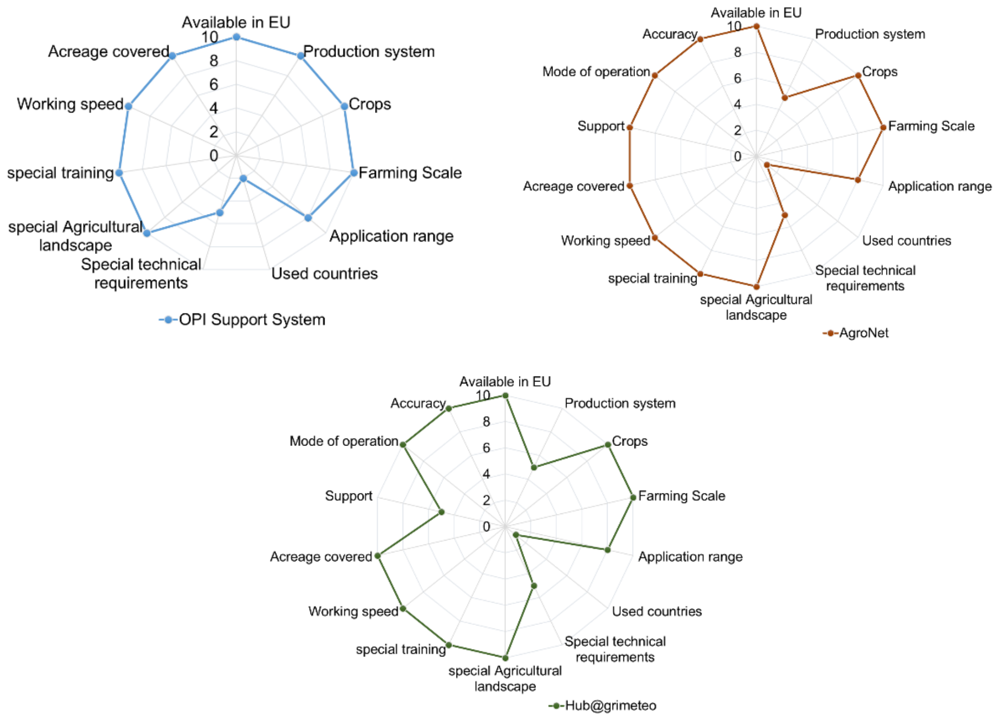


Figure 14 – Spider net diagrams for selected 'Decision support (with sensors)' technologies

3.3.3.6 Selected technologies 'Decision support (with sensors)' for field trials

- ✓ **OPI Support System** had the highest score, is available in Europe and applicable to several crops.
- ✓ **Agronet** had a similar score, is available in Europe and applicable to several crops
- ✓ **Hub@grimeteo** had a high score but there is no information on crops on which it is used (Fig. 14).

3.4 Application Technologies Group

3.4.1 Sub-group: ‘Sprayers’

3.4.1.1 Benchmarking EXCEL table

The benchmarking table from the EXCEL spreadsheet is uploaded in the folder for Workpackage 3 in the SharePoint database for the SmartProtect project.

3.4.1.2 Description of the technologies

Thirteen different sprayers were evaluated in the Sub-group of ‘Sprayers’, namely: red-ball hooded sprayers, Dubex wave sprayers, Cropsurfer, Wingsprayer, Dropleg Beluga, Dropleg Lecher, Dropleg Hardi, Smartomizer, ESS Electronic spraying system 80 R, Greenhouse spray robot with vertical booms S55, Robotic spray robot OPRS 202 hybride, spraying robot SPE 200/236, Trailed sprayer Whirlwind M612 ‘Albatros’. Evaluation of sprayers was done according to the benchmarking method using eleven criteria (regulatory zone, production system, crop variety, countries used, if there are any technical requirements, if there are any special agricultural requirements, if free support available, is special training is needed, working speed, if operated automatically or manually (Table 25)).

Table 25 – Brief description of ''Sprayers' evaluated by the benchmarking method

Technology	Description	Accuracy (interpreted as reduction of drift)	Working speed	Free support	Total Scoring
Dropleg Lechler	DroplegUL is an under-leaf application technique that enables plant protection products to be distributed within the crop. Upward, horizontal and top-down spray applications are possible. It is a light device and can be mounted on most boom sprayers.	Droplegs hang into the crop, spray is from below and angled slightly upwards, drift is strongly reduced	7 km/h (average)	Free Lechler agrar App (google play, App store)	**95**
Dropleg Hardi	This is a Snap-On drop-leg designed for spraying low-density crops up under the leaves. It has easily adjusted nozzle angles.	Droplegs hang into the crop, spray is from below and angled slightly upwards, drift is strongly reduced	7 km/h (average)	Free product guide, instructional video	**90**
Wingsprayer	The Wingssprayer is an innovative system that ensures optimum dispersal of every spray fluid.	Crop is opened by metal plates; spray can penetrate better, and drift is reduced	7 km/h (average)	Free, website	89
Dubex Wave sprayer	Dubex sprayers with WAVE methodology are sprayers that open the crop and spray the solution exactly in the required spot.	Crop is opened by metal plates; spray can penetrate better, and drift is reduced	7 km/h (average)	Manual on internet	88
Dropleg Beluga	Dropleg® Beluga system is a flexible towing pipe for row spraying in crops using field sprayers. Completely equipped with attachment and nozzle. Dropleg® Beluga system is easy and quick the installation.	Droplegs hang into the crop, spray is from below and angled slightly upwards	7 km/h (average)	Payed central support	87
Robotic spray robot OPRS 202 HYBRYDE	The robot smoothly travels on heating pipelines driven by an electric motor.	Manometer on the spraying bar. Easy system for switching from row to row	5,1 km/h	Free videos on the internet	83
Cropsurfer	Cropsurfer™ / Släpduk™ are shielded systems and are able to mount on new or existing sprayer booms. They can operate with low water rates and small droplets for reduced drift and increased coverage	Crop is opened by metal plates; spray can penetrate better and drift is reduced	7 km/h	On website, free	81
Smartomizer	Smartomizer is an air blast sprayer for specific crop protection reducing pesticide needs and fuel consumption.	Drift reduction by smart sensing system - gaps in crop wall are not sprayed	5 km/h	After subscription and by email	80
Spraying robot SPE 200/36	The device can be used remotely, semi-automatically and with an autonomous robot.	Control panel with pressure control and manometer.	5 km/h	Technical support upon email	79
Trailed sprayer WHIRLWIND M612 "ALBATROS"	The Whirlwind M612 "Albatros Field Crop" Sprayers are sprayers with a special boom configuration for the application of fungicide/insecticide treatments on vegetables and nursery crops.	All the air sucked in by the dual intake blower is used.	10-12 km/h	Free technical assistance upon email.	71
Redball-Hooded Sprayers	The sprayers reduce spray drift and spray along field borders and buffer zones.	Directed spray nozzles enclosed inside the spray helps to prevent damage to plants.	7–14 km/h	Support is only available in the US.	70
Greenhouse spray robot with vertical booms s55	The S55 is a spray robot with batteries, made for automatic spraying. The spray robot uses the pipe rail system to move through the greenhouse.	Nozzles are housed in this sprayer, a strong reduction in drift is expected	No data	Free demo videos	67
ESS Electrostatic spraying system 80 R	This is a tractor-mounted sprayer assisted with electrostatic nozzles. It is an efficient and effective ultra-low volume sprayer. Compatible with most conventional chemicals and fungicides.	The technique is expected to work at low air humidity.	5 km/h	Manual on internet	64

3.4.1.3 Description of spider net diagram

Among selected criteria for the evaluation of 'Sprayers', we have detected the highest scoring for the most promising sprayers amongst the **advanced criteria** (accuracy (as drift), mode of operation, support). These criteria had the highest impact on identifying the most effective sprayer (Fig. 15).

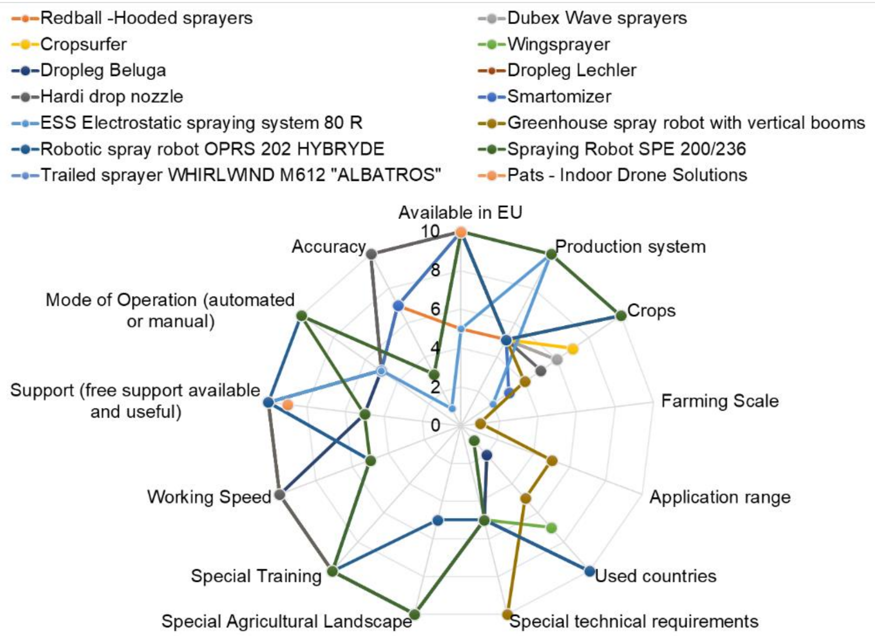


Figure 15 – Spider net diagram for criteria evaluated for 'Sprayer' technologies

The **common advanced criteria** were modified for 'Sprayers' following advice from an expert during an online meeting with experts on 'Application Technologies – Sprayers' (devices working with tractors) from the Julius Kühn Institute, Braunschweig. Table 26 presents the specific criteria used for evaluating the sprayers. Indicators such as 'drift reduction' and 'increase efficacy' were included for evaluating the sprayers.

Table 26 – Common advanced criteria modified for evaluating 'Sprayer' technologies using the benchmarking method

Working speed	Benchmark Score	Accuracy	Benchmark Score	Acreage covered	Benchmark Score	Mode of Operation	Benchmark Score	Support (free, available and useful)	Benchmark Score
Lower than average	5	Lower	5	Lower	5	By company staff	3	Lower	1
Higher than the average	10	Higher	10	Higher	10	Manual	5	Standard	3
n/a		n/a		n/a		Automatic	10	Drift reductions	7
						n/a		Reduce drift + increase efficacy	10

3.4.1.4 In-depth SWOT analysis of 'Sprayers'

We have included the characteristics of 13 different sprayers in our research. All technologies can be used against insects, fungi, and bacteria. Almost all of them are available (except Redball-Hooded sprayers) in at least one European country. The majority are available in the Western part of Europe (Table 27). All sprayers have no specific agricultural demands, except spraying robots (s55), which can be used only on flat surfaces (greenhouses). There are different technologies (sprayer parts), some can be applied to existing booms. Almost all technologies (sprayers), have very good accuracy, and reduced drift. The lowest ranking during the benchmarking consisted of spraying robots that can only be used in greenhouses.

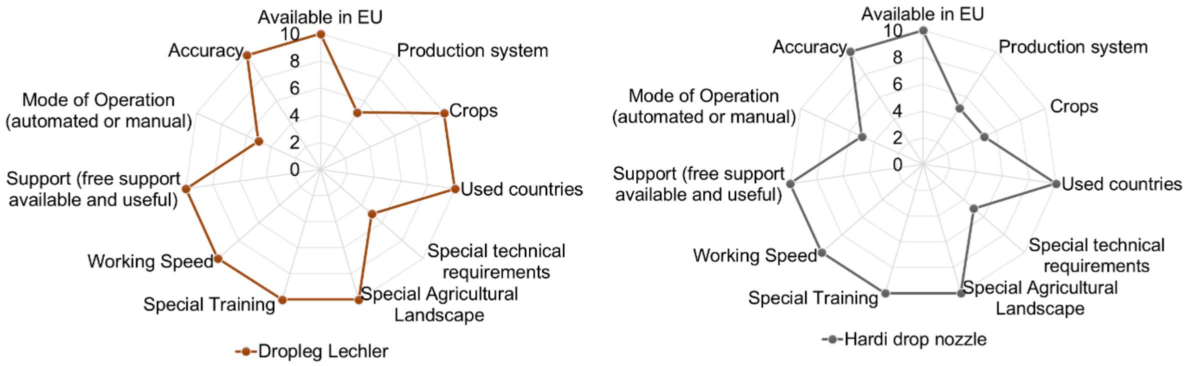
Farm size is important for only one of the spraying systems; otherwise, all technologies can be used on small and large-scale farms.

Table 27 – In-depth SWOT analysis matrix of 'Sprayers'

Strengths	Weakness
• Selected technologies used can be in most EU countries. • The technologies can be used in all types of production systems (greenhouses, field production). • All these technologies can combine with machinery that is already present on the farm. • The working speed can be regulated (up to a maximum speed). • These technologies offer regulation of drift. • The characteristics of the technologies can help to define their accuracy. • Technical guidelines are available and no special training is required. • Combination with other smart technologies is possible.	• The machinery already present on the farm needs special adjustment for the use of certain technologies. • Demonstration (before buying) in vivo is not possible. • Manufacturer/suppliers do not provide enough information on the website. • Technical assistance/guidelines are not available in all national languages. • The way the plants grow (vertical, horizontal) is important for the use of certain technologies.
Opportunities	**Threats**
• It is possible to expand the sale of technologies to new countries due to the wide demand. • The technologies can be used in the same growing season. • The technologies can be used for different liquid products, not only chemical pesticide products.	• Due to the relatively high costs of sprayer technology, the purchaser will decide whether they are value for money. • Application of some selected technologies is not possible in all EU countries. • The farm scale matters. The use of many technologies is only possible on large farms. • Due to the costs of energy and fuel, use may be more limited in future.

3.4.1.5 Selected technologies

Eight technologies out of 13, achieved more than 80 points during the benchmarking process. **Dropleg Lecher** and **Dropleg Hardi** had the highest scores (Fig. 16). The most successful technologies are widely available in all European countries. They can work under classical booms and give a high reduction in drift. The average working speed is the same for both technologies.



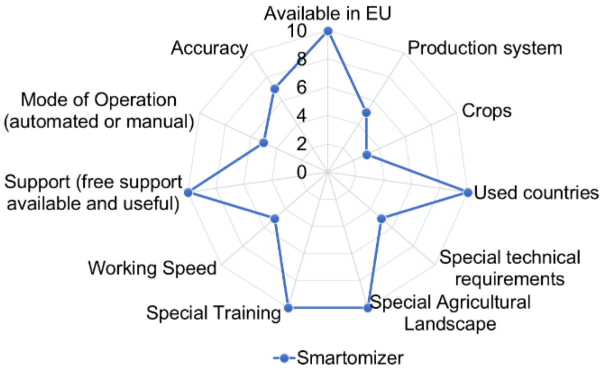


Figure 16 – Spider net diagrams for selected 'Sprayers'

3.4.1.6 Selected technologies for field experiments

Although the **Dropleg Lecher** and **Dropleg Hardi** sprayers were the most promising, we would also select **Smartomizer** as a possible technology to test in field experiments. It would be an interesting sprayer, and not so widely known. Perhaps it would be interesting to test it in tomato cultivation.

3.4.2 Sub-group: 'Spraying drones'

3.4.2.1 Benchmarking EXCEL Table

The benchmarking table from the EXCEL spreadsheet is uploaded in the folder for Workpackage 3 in the SharePoint database for the SmartProtect project.

3.4.2.2 Description of the technologies

Eight technologies in the Sub-group 'Spraying drones' were evaluated using the benchmarking method. Eleven **basic criteria** and five **advanced criteria** were assessed through scoring the features of each technology. A summary is presented in Table 23.

3.4.2.3 Description of spider net diagram

Unmanned aerial vehicles (UAV) can be utilized for a number of tasks (i.e. aerial photo making, monitoring natural disasters, remote sensing) and in the last decade drones have been used widely for spraying. They are also useful for geographical and remote sensing tasks, and can spray products that control insects and diseases in field crops. Although they are available globally, their use for crop protection in Europe is not feasible. According to the "EU Directive 128/2009", related to aerial application of Plant Protection Products (PPPs), the use of spraying drones or aerial spraying is only allowed in exceptional circumstances if no other technique can be used and it should have an advantage in terms of reduced impact on human health and the environment when compared with the land-based application of pesticides.

Comparison of technologies according to their scorings (Figure 17) shows high scoring in the **advanced criteria** (working speed, accuracy, acreage covered, mode of operation and support). The **basic criteria** represented by eleven variables did not have many high scores. Some technologies had lower scores and there were clear differences between technologies.

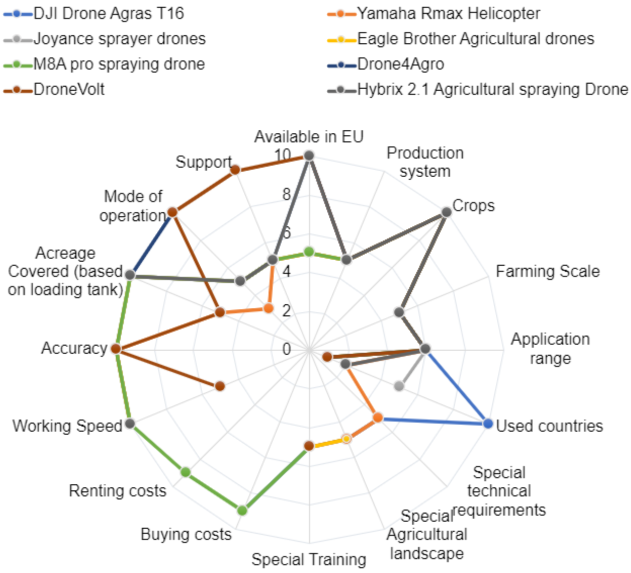


Figure 17 – Representation of 'Spraying drones' and criteria evaluated in spider net diagram

The **common advanced criteria** assessed factors such as 'mode of operation' by the company staff, or if the spraying drone is operated manually or automatically. Other factors related to technical or software support - if this is free or needs a payment. If no information was available on any criterion, it was not included in the template (Table 28).

Table 28 – Common advanced criteria utilized to assess 'Spraying drones' technologies using the benchmarking method

Working speed	Benchmark Score	Accuracy	Benchmark Score	Acreage covered	Benchmark Score	Mode of Operation	Benchmark Score	Support (free, available and useful)	Benchmark Score
Lower than average	5	Lower	5	Lower	5	By company staff	3	No	5
Higher than the average	10	Higher	10	Higher	10	Manual	5	Yes	10
n/a		n/a		n/a		Automatic	10	n/a	
						n/a			

The technologies that had the higher scores were the DJI Drone Agras T16 and the M8A pro spraying drones with 110 and 95 points respectively (marked in green) in Table 29. Four drones (Yamaha Rmax Helicopter, Joyance Sprayer drone and Eagle Brother Agriculture drone) had scores of 81 or 82 because they are not available in the EU, and only the Drone Volt is available and has been tested in France. In contrast, the spraying drones Drone4Agro and Hybrix 2.1 Agricultural drone had lower scores (highlighted in red), because no information was found on their technical, landscape and training requirements (Table 29).

Table 29 – Brief description of 'Spraying drones' technologies evaluated by the benchmarking method

Technology	**Description**	**Working speed (used as the time needed for spraying in 1 ha)**	**Accuracy (used as efficiency of spraying rate)**	**Acreage covered (used on loading cap.)**	**Total Scoring**
DJI Drone Agras T16[a, b]	Drone which is allowed only for applying pesticides in vineyards in Germany. However, it is widely used in China and in other parts of the world. It works in open field vegetable crops grown at a large scale. The manipulation of this drone requires a previous training (~months) and the performance could vary depending on environmental conditions (T, H and altitude).	ha/6 min	4.8 L/min	16 L	**110**
Yamaha Rmax Helicopter [a, b]	Mini helicopters, which are not available in Europe. They work in open fields and for all kinds of vegetables grown on a large scale in Japan and the US. Their operability in the field requires two people, and the performance may depend on specific environmental and landscape conditions. This device requires a flying license.	ha/8 min	1.3–2 L/min	8 L	81
Joyance Sprayer Drone [a, b]	This sprayer drone is available in China, but not yet available for use in the EU. It is used in open field production systems in all vegetables at a large scale. There is no information on technical, landscape and training requirements.	ha/10–12 min	2–2.5 L/min	10–32 L	81
Eagle Brother Agricultural Drone [a, b]	This model of spraying drone is not available in Europe, but is available in China and used most for open field vegetable production at a large scale. These drones can work in windy landscapes but require at least half a month of training.	ha/7.5–8.8 min	3.2 L/min	14 L	82
M8A pro spraying drone [a, b]	These spraying drones are available and used only in the US, applied in vegetable production in open fields and on a large scale. Training to operate these drones is online or in person. However, there is no further information on landscape and technical requirements.	ha/4.4–5.5 min	5 L/min	20 L	**95**
Drone4Agro [a, b]	This flying drone is available in the Netherlands and other EU countries and can work in open field vegetable production at a large scale. For the moment, its usage is only in the Netherlands. There is no other information on technical, landscape and training requirements.	n.a.	n.a.	15 & 80 L	57
DroneVolt[a]	This flying drone is available and used in France only and can be used in open field vegetable production at a large scale. Thus, there is no other information on technical, landscape and training requirements.	ha/20–60 min	3 L/min	6 L	82
Hybrix 2.1 Agricultural Spraying Drone [a, b]	This flying drone is available, applied in Spain and the United Arab Emirates, and can operate in open field vegetable production at a large scale. There is no other information on technical, landscape and training requirements.	Ha/10 min	n.a.	10 L	68

a) The devices can spray products to control bacteria, fungi, insects, mites, nematodes, viruses according to user needs.
b) The flying drones work using remote control and technical support is not free.

3.4.2.4 In-depth SWOT analysis on 'Spraying drone' technologies

'Spraying drone' technologies have many advantages in supporting vegetables grown in the open field at small and large scales. In Latin American countries, spraying drones help to control insects and diseases, especially in challenging landscapes. The adoption of spraying drones in these countries is due to agricultural policies and regulations, which are not well tested and not rigorous. In contrast, in Europe, implementation is taking time, particularly with regulations. In Table 30, an in-depth SWOT analysis matrix describes the advantages and disadvantages in relation to European countries.

Table 30 – In-depth SWOT analysis matrix on 'Spraying drone' technologies

Strengths	Weakness
• Spraying drones are available and have been assessed in Europe. • Spraying drones can spray products in small to large scale production systems depending on the crop and user needs. • The use of spraying drones can reduce the amount of product applied and improve control of insects, diseases, bacteria, spider mites and viruses by spot spraying. • Many spraying drones can work in any type of landscape. Some of them can fly in crop systems grown on slopes. • Spraying drones are accurate and can spray product from two to 5 liters in one minute.	• Drones are not yet available for spraying crops in Europe in general. There are only particular crop-landscape-combinations where use of spraying drones is permitted by local governments and according to flying regulations. Usage requires specific and formal procedures. • The use of spraying drones is in the test phase. One major problem is the penetration to the lower parts of crops, spray pattern and distribution. Thus, efficacy is comparably low to date in forestry and other tree crops. • At a large farm scale, spraying drones have a direct competitor in the field with the large sprayers pulled by tractors, where there consolidated information on their use is already available. In contrast, spraying drones are still in the early stages of development and wind turbulence can be a disadvantage. • Flying drones need a Flying License document in Europe issued by the competent authority. Its content would depend on the size and weight of drone.
Opportunities	**Threats**
• Regulation for flying drones is in progress in Europe. Flying drones are currently under development for many different applications, such as transport and delivery of goods. It is possible that with growing experience, and more drone applications in crop protection and the market, drones for spraying pesticides will be more readily allowed in future. • As the amount of pesticide applied is more and more restricted in the EU, spot spraying applications could become more relevant in future and can be done effectively by drones. • One scenario for future agriculture is the development of smaller mixed cropping systems, where big machinery cannot be used. In this scenario, spot spraying with drones would become more relevant. • Some SMEs in the EU have started manufacturing spraying drones on a small scale and can supply spraying drones which are easily assembled. It seems that in future, they might not be so complicated to set up and use, and accessories might be available for fieldwork. • Spraying drones are not available in Europe, but in the US, there are companies, which provide services using spraying drones, e.g., mini helicopters for the control of pests in vineyards. Europe has potential here with areas of production that machinery cannot access, and a spraying drone service might be a practical option. • A big opportunity is the combination of monitoring and mapping of pest/disease occurrence with the application of pesticides by one type of drone. • Spraying drones can be flown by remote control. There	• At the EU level, adoption of 'flying drones' is in the testing phase, and the rules are in preparation. The current rules for flying drones in Europe are rigorous and the operator must have a Flying License issued by a competent authority. Spraying drones are heavy weight aerial devices, which use specific products which are not the same as, or at least regulated differently, from products used by a manual sprayer or tank tractor sprayer. • Currently at the EU level, and specifically in Germany, the use of spraying drones is permitted only in vineyards (grown on slopes). Regulations have been created for use in Spain, but no actual use has been reported yet. If there are no changes to these strict regulations, there is no real market for spraying drones in the EU, and therefore development towards effective application schemes is limited. In addition, companies' interest in approving pesticides for drones can be low, if the application range is limited. • Technical support in person does not exist, support is only through virtual routes, which can be a disadvantage for any problem. • Remote control is still required to operate a spraying drone; thus, it means that work in open fields requires technical skills. • Because the drones need to be flown by an expert this means that they cannot be used by everybody.

are fewer drones under development that can work autonomously, but these drones might be useful for applying products in farming/crop/vegetable systems located over large areas.	

3.4.2.5 Selected technologies

Two spraying drones with high scores were selected: DJI Drone Agras T16 (110 points) and M8A spraying drone (95 points) (Figure 18). The first drone is available in Europe including Germany, but is not used in open field crops. Its advantages are its working speed, accuracy and the acreage covered (Table 23), which all had higher scoring. The second drone is often used in the US. This drone had higher scores for working speed, accuracy, acreage covered, and accessible renting and buying costs (Figure 18).

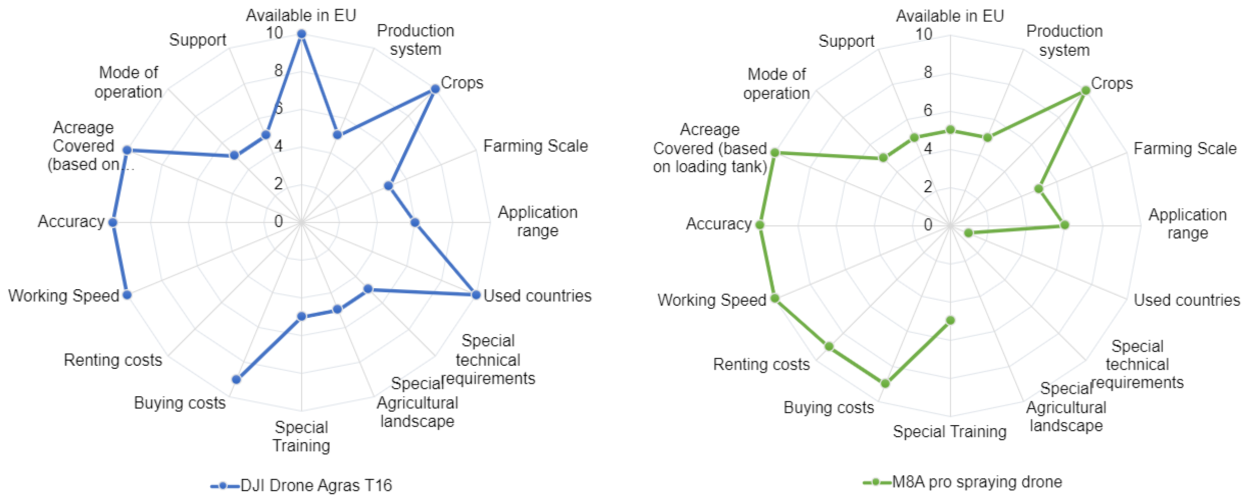


Figure 18 – Representation in a spider net diagram of 'Spraying drones'

Both spraying drones can be used in many open field crops.

3.4.2.6 Selected technologies for field experiments

In principle, the DJI Drone Agras T16 could be used in trials, because it has the highest score and is available in the EU. It would be interesting to compare handling, efficacy and the reduction in pesticide use through spot spraying as compared to spray applications with conventional spray equipment. The crop in this trial could be cabbage, as it is the outdoor model crop for trials, or alternatively any other low-growing field vegetable. However, due to the high costs it is not clear if the tool is available for trials.

3.4.3 Sub-group: 'UV systems'

3.4.3.1 Benchmarking EXCEL Table

The benchmarking table from the EXCEL spreadsheet is uploaded into the folder for Workpackage 3 in the SharePoint database for the SmartProtect project.

3.4.3.2 Description of the technologies

In the category 'UV systems', five technologies were evaluated using benchmarking. Thirteen criteria were assessed. A summary is presented in Table 31.

The thirteen criteria evaluated for 'UV systems' are as follows:

1. Availability in the EU (yes/no)
2. Production system (open field, greenhouse)
3. Crops (number of vegetables where technology is used)
4. Farming scale (small scale, a large scale)
5. Application range (number of possible different targets)
6. Number of pests and pathogens (number of possible detailed targets)
7. Countries used (number of countries where technology is used)
8. Special technical requirements (yes/no)
9. Special agricultural landscape (yes/no)
10. Special training (yes/no)
11. Support (yes/no)
12. Mode of operation
13. Accuracy

Table 31 – Brief description of 'UV systems' evaluated by the benchmarking method

Technology	**Description**	**Production System**	**Used countries**	**Mode of operation**	**Total Scoring**
UV-C Dragon unit	A tractor pulls the Dragon delivery system at a precise speed in the field to deliver the required dose. The optimal dose and schedule will vary for different crops and pathogen systems. When designing to accommodate a new crop-pathogen system, the optimal procedure is determined through a combination of laboratory and field studies to ensure disease control and crop protection.	Greenhouse and open fields	USA, Canada, Norway	Person needed for operating the tractor and implementing,	80
Lumion UV-C robot	The company Octinion (merged with Priva to Kompano in 2021) makes robotic platforms. Their Xenion robotic platform outfitted with UV-C lights is Lumion. Lumion helps to manage powdery mildew on strawberries using UV-C light. The fungus specific DNA absorbs UV-C light, thus avoiding crop damage. The robot can move around the crop. The platform can operate on rails or tyres.	Mostly greenhouse	Belgium, The Netherlands, Germany and Canada	Automatic system, robot has own SIM-card, but for smooth follow-up Wi-Fi is desirable.	**86**
Micothon Flora UVC	The Micothon Flora UVC is an add-on UV system for the treatment robot made by Micothon. The Micothon tube/rail spraying robot is available in a semi-automatic or a fully automatic version. The fully automatic spraying robot takes care of completely automatic spraying in a greenhouse.	Greenhouse and football stadiums	The Netherlands, Canada, Russia, Germany, Spain, France, UK	System with automatic power	**93**
Cleanlight UV implements	CleanLight supplies complete customized UV-application systems, fully automated or moved by hand, to control diseases such as powdery mildew, Botrytis, Pseudomonas, EHEC, and so on.	Greenhouse, vertical farming and open field	Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, China, Croatia, Costa Rica, Colombia, Denmark, Ecuador, England, Estonia, Ethiopia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Kenya, Latvia, Lebanon, Luxemburg, Mexico, Marocco, Netherlands, New Zealand, North Macedonia, Norway, Panama, Peru, Poland, Portugal, Scotland, Slovenia, South Africa, South Korea, Spain, Sweden, Switzerland, Turkey, Taiwan, Tunesia, Uganda, Ukraine, United States of America, United Arab Emirates, Uruguay, Wales.	Manual, semi-automated, fully automated, autonomous	**107**
Thorvald	Thorvald is a robot for applying shortwave UV radiation to crops. It can be adapted for greenhouses, polytunnels and field crops. Weekly exposure of strawberries to shortwave UV light is highly effective in suppressing powdery mildew, but the treatments must be applied at night to avoid damaging the plants. The robots can carry relatively lightweight lamp arrays and work all night. Thorvald is equipped with an array of UV lamps and applies the UV treatment autonomously, without a human labor requirement. Commercial solutions for glasshouse-grown crops such as tomatoes and cucumbers are currently under development.	Greenhouse and open air	Norway, United States of America, United Kingdom, Italy	Automatic system, the robot requires a power-source and can operate in areas with good cellular network coverage.	**96**

3.4.3.3 Description of spider net diagram

Only a few criteria attracted different scores. These criteria are: countries used, production system, mode of operation and farming scale. The number of pests and the number of crops is highly dependent on the age of the company. This is especially the case for **Cleanlight,** who was the pioneer in using UV radiation to control plant health (Figure 19).

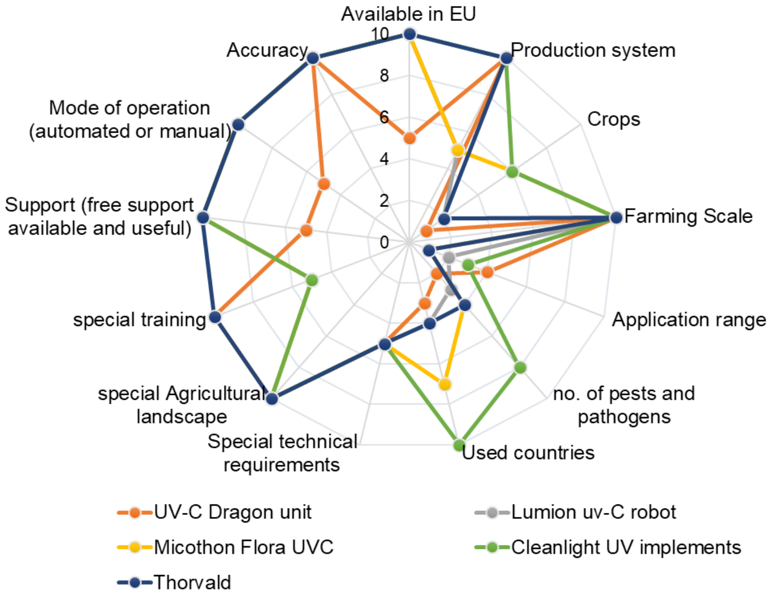


Figure 19 – Representation of 'UV systems' technologies in spider net diagram

The common advanced criteria for 'UV systems' consist of mode of operation, support and accuracy. These factors are important for the user when 'UV systems' are used as application technologies. If no information was available nothing was included in the template (Table 32).

Table 32 – Common advanced criteria utilized to assess 'UV systems' using the benchmarking method

Accuracy	Benchmark Score	Mode of Operation	Benchmark Score	Support (free, available and useful)	Benchmark Score
Lower	5	By company staff	3	No	5
Higher	10	Manual	5	Yes	10
n/a		Automatic	10	n/a	
		n/a			

3.4.3.4 In-depth SWOT analysis on 'UV systems'

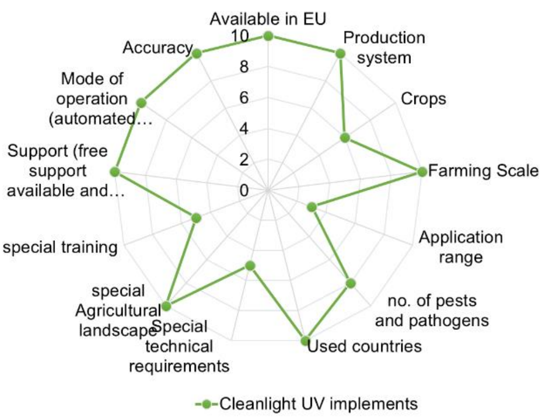
Table 33 – In-depth SWOT analysis matrix on 'UV systems'

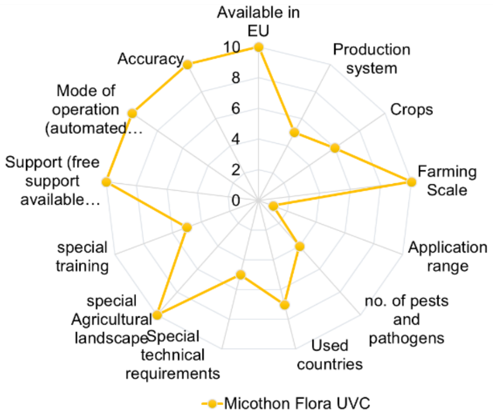
Strengths	Weakness
• Compatibility with existing equipment • Lower use of pesticides • Wide range of targets • Non-invasive to plants • No residue left • Elicitor effect • UV installations proved for some solutions to be very compatible with existing farming equipment. For use in glass greenhouses, compatibility is available with the concrete pavements and/or heating rail systems. For full field implementation, some systems make use of a standard triangular tractor coupling system.	• Susceptible to overdose or phytotoxicity (e.g. young plants). UV radiation is not visible • High investment cost • Uncharted target/crop combinations • Safety for user (UV radiation)/environment caused by mercury in lamps • Difficulty demonstrating return on investment • Need for connectivity • As UV radiation is not visible, this can provide some safety issues, for the user as well as the object treated. UVC is highly irritating and causes burning, also in the end, there is a carcinogenic effect. The eyes are especially susceptible (ref. welding eyes).

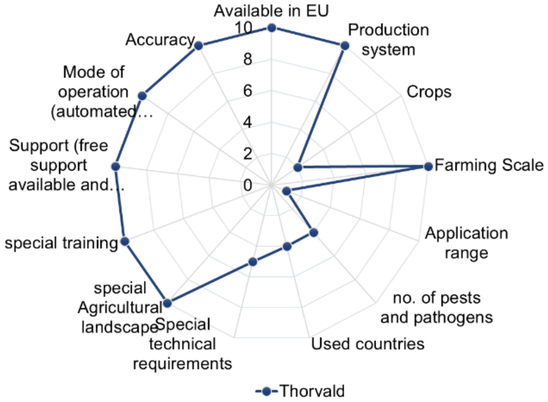
• There are no residues related to the use of UV radiation. The application is not invasive to plants and is efficient. In an IPM context, these characteristics are advantageous. A wide range of target pests and diseases are likely to be susceptible to UV radiation, especially UVC. • UV radiation has an elicitor effect, activating plant defense. This could be of interest as the plant could be less susceptible to pests and disease.	• Over dosage can occur and cause phytotoxicity on the treated plants. In addition, different plants and stages are less or more susceptible (e.g. young plants). • The UV lights use mercury (Hg) to emit the radiation when an electrical current runs through them. Mercury vapour is poisonous and acts on the nervous system. When lamps break, mercury releases into the environment, which is harmful. • Many target/crop combinations are not tested (yet), which makes it difficult for farmers to assess if the solutions will work to solve their problem. Some of the systems also have high investment costs, making it difficult to demonstrate a positive return on investment. • The need for connectivity of some automated systems is a weakness, as network coverage is not provided to everywhere. • Lower wavelengths are sometimes counted as ionizing and ionizing radiation is forbidden by EU regulation.
Opportunities	**Threats**
• Upscale possible • UV treatments seem easy to use on other target/crop combinations, as it is possible to conduct selectivity, efficacy and minimum effective dose trials in a similar manner as with pesticides. • The EU Green Deal could be an important external driver as it strives towards a reduction of chemical pesticides. Non-chemical control measures like these UV solutions could profit from this. • Due to the physical nature the growing market of organic farming could be interesting as the UV solutions are possible allowed interventions, given the UV is above the ionizing spectrum • Future improvements in robotics and automation are an opportunity for lowering costs and increasing efficiency of the robotic systems used for UV treatment.	• Sub-lethal (mutagenic) effects on microorganisms (both target and non-target) remain unclear to date and need additional studies. • As a (semi)-preventative treatment, UV application must compete with the chemical fungicide market with a lower cost. This is a major hurdle for technology to take. • The Restriction of Hazardous Substances (RoHS) Directive Legislative still exempts vapour from the ban of mercury UV lights use, but the pressure to ban mercury is increasing. • By investing in a UV solution, the farmer could increase their dependency on this technology provider. In an incomplete market, price setting is not optimal for the farmer. • Phytotoxicity - as there is a risk of overdosing because the radiation is not visible to the farmer.

3.4.3.5 Selected technologies

The ‘UV systems’ solutions are rather limited, but the selection is as follows: **Cleanlight UV implements, Thorvald, Micothon Flora UVC and Lumion UV-C robot.** All four technologies have quite similar scores of which the **Cleanlight** has the highest score with 107. The **Cleanlight** system has been on the market for the longest time and there are a high number of user cases and also countries in which the company is active (Figure 20). In addition, **Cleanlight** has the most experience with different crops and with different pathogens.







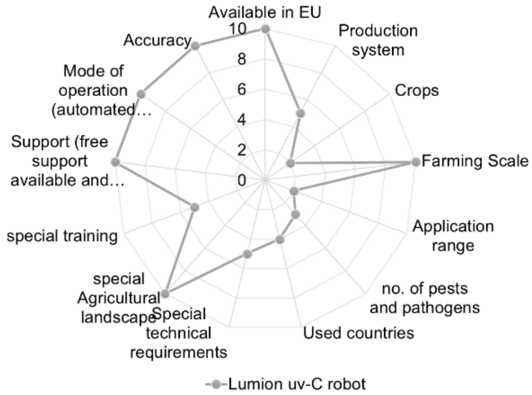


Figure 20 – Representation of selected ‘UV systems’ technologies in spider net diagrams

3.4.3.6 Selected technologies for the field experiments

From a practical point of view, **Lumion UV-C robot, Cleanlight UV** and **Thorvald** systems can operate on a robotic platform and be compared in demonstration experiments (Fig. 20). Although **Micothon** obtained a high score, it was not selected for further demonstration. **Micothon** does not provide a self-operating robotic platform, and it is hard to compare this in a demonstration trial with the others that are.

The UVC Dragon was also not selected, because the system must be constructed from scratch and it does not work automatically. However, from a farmer's point of view, the UVC Dragon is the least expensive of the UV application technologies identified. It was not possible to evaluate costs in the benchmarking process due to the diversity of cropping systems in which the systems operate.

3.4.4 Sub-group: Drones & Sprays – 'Distribution systems for beneficials'

3.4.4.1 Benchmarking EXCEL Table

The benchmarking table from EXCEL spreadsheet is uploaded in the folder for Workpackage 3 in the SharePoint database for the SmartProtect project.

During the benchmarking activity for 'Distribution systems for beneficials' several elements were analyzed such as: regulatory zone, utilization, crops, farming scale, the countries used, training, buying cost, renting cost, working costs, acreage covered, mode of operation and support, to evaluate each technology objectively.

3.4.4.2 Description of the technologies

In the Sub-group of 'Distribution systems for beneficials', six technologies were evaluated, including three drones and three spray systems, using the benchmarking method. Fifteen basic and five advanced criteria were used. Table 34 presents a detailed summary.

Table 34 – Brief description of 'Distribution systems for beneficials' evaluated by the benchmarking method

Technology	Description	Crops	Application range	Acreage covered	Total Scoring
Trichogramma dropper	Trichogramma dropper is available and used in Germany. It is used more in the open field and on a large and small scale. This device also has a camera that guides it and the locations can be marked and viewed in Google Maps. It also does not need a special technique or training.	Maize	Sitotroga eggs, *Trichogramma*, *Habrobracon hebetor, Lariophagus distinguendus*	8 ha, tank 5L =1000 balls	83
Parabug drone	Parabug is a drone that is not available in Europe. It works in the open field and is used at small scales in Australia. The technology does not require any special technologies or training.	Strawberry, Vines, Almonds	*Chrysopa, Orius, Amblyseius*	120-200ha/ day	83
Natutec drone	The Natutec Drone is available in Europe, i.e. in the Netherlands and in the USA, it is used in several countries such as Brazil, Italy. It runs in open fields and at large and small scales and it can be used in different types of vegetables. This device does not need special technologies, can run in different agricultural landscapes and does not need training.	Tomato, Pepper, Cucumber, Zucchini, Eggplant, Melon, Watermelon, Green Beans, *Brassica sp*., Strawberry	*A. cucumeris, A. andersoni, A. swirskii, Phytoseiulus persimilis, Cryptolaemus montrouzieri, Chrysopa, Amblydromalus limonicus*	8 ha	**90**
Biospreader	Biospreader is available in Spain and works in several countries such as France, Italy, Holland, Portugal, Romania, Russia, Mexico and the USA. This bio-blower can spray products in all types of vegetables and is suitable for small-scale greenhouses as it is in the range for quick manual application. This bio-blower does not require initial training. In addition, this device can fly in different agricultural landscapes.	Tomato, Pepper, Cucumber, Zucchini, Eggplant, Melon, Watermelon, Green beans, *Brassica sp.*, Strawberry	*Nesidiocoris tenuis, Macrolophus sp, Regular mites, A. cucumeris, A. andersoni, A. swirskii, A. montdorensis, A. californicus, Phytoseiulus persimilis, Chrysopa*	Tank 5 l =125.000 mites /500.000 *A. cucumeris* 4-5 meters	**95**
Koppert Airbug	Koppert Airbug is available in the Netherlands and is used worldwide. The blower can be used in all kinds of vegetables. It is suitable for use in the greenhouse at a small scale. It needs no special technique, can work in different agricultural landscapes and does not need training.	Ornamentals, Tomato, Pepper, Cucumber, Zucchini, Eggplant, Melon, Watermelon, Green beans, *Brassica sp*., Strawberry	*A. cucumeris, A. swirskii, A. californicus, Phytoseiulus persimilis, Hypoaspis* spp	Tank 1 l =1000 *Nesidiocoris* - 2000000 mites	**91**
Alumaster 2.0	Alumaster 2.0 is available in the Netherlands and is used in several countries such as the UK, Belgium and Germany. It can be used in different types of vegetables and is suitable for use in both large- and small-scale greenhouses. This technology needs pre-installation, does not need training and runs in different agricultural landscapes.	Rose, Chrysanthemum, Amaryllis, Orchids, Pot plants, Cucumber	*A. cucumeris*, *A. andersoni, A. swirskii, A. montdorensis, A. californicus, Phytoseiulus persimilis*	Tank 20 l =2.500.000 mites	**91**

3.4.4.3 Description of spider net

Figure 21 shows a spider net diagram comparing technologies.

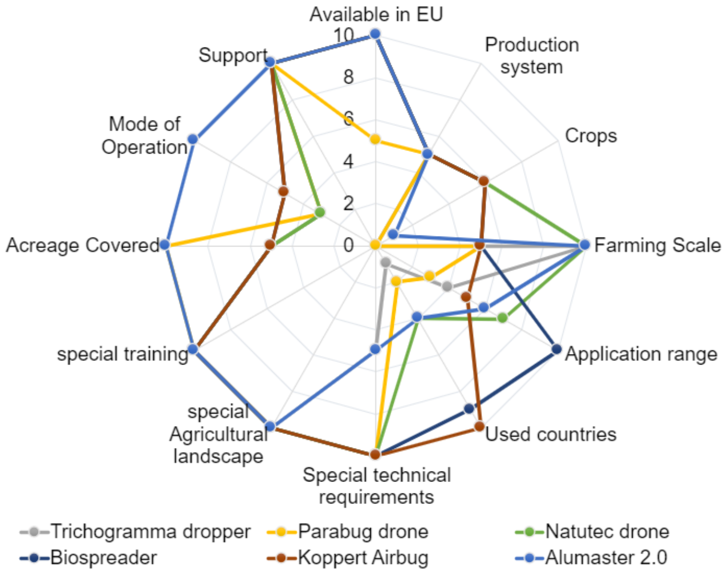


Figure 21 – Representation of 'Distribution systems for beneficials' technologies and criteria evaluated in a spider net diagram

Biospreader, Kopper Airbug & Alumaster obtained the highest scores - of 95 and 91 (marked in green and yellow in Table 34). The Trichogramma dropper and Parabug drone obtained scores of 83 because they are not used on vegetables and there is a lack of information about their accuracy and the way of working. Furthermore, the Trichogramma dropper is not available in Europe.

The common advanced criteria considered factors such as working speed, accuracy, acreage covered, mode of operation, and support from the manufacturer or supplier. If no information was available there was no entry in the template (Table 35).

Table 35 – Common advanced criteria used to assess 'Distribution systems for beneficials'

Working speed	Benchmark Score	Accuracy	Benchmark Score	Acreage covered	Benchmark Score	Mode of Operation	Benchmark Score	Support (free, available and useful)	Benchmark Score
Lower than average	5	Lower	5	Lower	5	By company staff	3	No	5
Higher than the average	10	Higher	10	Higher	10	Manual	5	Yes	10
n/a		n/a		n/a		Automated	10	n/a	
						n/a			

3.4.4.4 In-depth SWOT analysis on '*Distribution systems for beneficials'*

The subcategory entitled 'Distribution systems for beneficials' included drones and sprays. The evaluation showed that these technologies have many advantages in supporting vegetable production in open fields and greenhouses at small and large scales. Most of the spray technologies have additional potential because they can cover a wide range of biological control organisms. With regard to drones in Europe, it is difficult to use them because of current legislation, as national and local administration can establish no-fly zones. An in-depth SWOT analysis describes the advantages, disadvantages, opportunities and threats. To facilitate understanding, we created two separate SWOT tables, one for the drones (Table 36) and one for the sprayers (Table 37).

3.4.4.5 SWOT analysis of advantages and disadvantages of drone and sprayer technologies ('Distribution systems for beneficials' in relation to use in Europe countries)

Table 36 – In-depth SWOT analysis matrix for 'Distribution systems for beneficials' - drones

Strengths	Weakness
• Most technologies can be used on a variety of crops. • The technologies can work at different scales • Many technologies could be used in the EU and non-EU countries. • Certain technologies can work on a variety of terrains. • No specific training required – easy access for farmers. • The technologies can speed up work e.g." Trichogramma dropper & Parabug drone". • Great time efficiency.	• Not all technologies work inside of a greenhouse structure. • Current application limited to certain crops. • Some technologies work only in one country. • Most companies do not provide selling costs • Lack of cost details may pose a limitation to purchase by the farmer. • Lack of detailed information on accuracy – means less interest, more mistrust in using these technologies. • Some technologies with wide coverage would be difficult to use at EU level due to the fragmentation of farmland among many small farmers. • Many technologies are used in Europe where there is a legislative framework regulating their use in the member states (Spain does not allow the usage of drones). • Limited airtime due to battery capacity.
Opportunities	**Threats**
• Several technologies can be used in different terrains and at different scales. • Companies could decide to sell their products in more countries. • Price flexibility – there could be some dialogue - (possibility to have tailor-made prices – to increase interest from farmers). • Rental can help farmers to test the technology and then decide whether to invest. • For large-scale areas, technology sharing among stakeholders could be established. • Reduction of working time in the field.	• In some countries, there is no agricultural funding to finance the purchase of these technologies. • Difficulty to demonstrate return on investment (compared to the traditional technologies or products). • Lack of transparency (pricing). • Technologies lack information regarding support, accuracy. • The dependence of the farmer on third parties. • Lack of legislation - the consideration regarding legislation will be considered as a threat because drones are treated as airplanes. Other challenges include the risk attributed to unmanned systems (no pilot in the vehicle) and competing uses of airspace. National and local administration can establish no-fly zones.

Table 37 – In-depth SWOT analysis on 'Distribution systems for *beneficials' - sprayers*

Strengths	Weakness
• Most technologies can be used on a variety of crops • Most technologies can apply a variety of **BCO (Biological Control Organisms)**. • Most technologies have additional potential because they can cover a wide range of **Biological Control Organisms.** • Many technologies can be used in different EU and non-EU countries. • Certain technologies can work across all types of terrain (adaptability of the technology to the terrain). • None of the technologies requires specific training. • One of the technologies is very time efficient. • One of the technologies has autonomy. • Other technologies do not require pre-installation. • One of the technologies is very precise (homogeneous release).	• Some technologies have weaknesses in that they can only be used on a small scale • A low coverage of area with the manual technologies because the capacity is low. • Other technologies are less efficient in terms of application time. • One of the technologies needs pre-installation and a specific greenhouse structure. • Other technologies do not have autonomy • Some technologies can be used only in greenhouses

• One of the technologies can work in very high-density crops.	
Opportunities	**Threats**
• The possibility of using small-scale technologies in the open field. • Companies can decide to sell their products in different countries. • Reduction of working time in the field and greenhouse. • The technologies can be used with any product from any company • One of the technologies can be used on a wider range of horticultural crops • The use of these technologies reduces pesticide applications, favoring biodiversity and fulfilling several objectives of the Green Deal.	• Barrier to selling the product in countries strongly relying on conventional pesticides, e.g. US, Brazil. • Many technologies cannot work at a large scale • Some of the technologies depend on batteries (duration time and weight) • Difficulties with the application of biological control organisms from different companies

3.4.4.6 Selected technologies

Two sprayers obtained higher scores (**Biospreader** (95 points) and the **Alumaster 2.0** (91 points)) (Figure 22). The first is available in Europe and used in greenhouses and open fields. The advantage is easy usage and that it can be used with a wide range of beneficial organisms on most crops. The second is available in Europe and used in greenhouses. The advantage is that it can work in all crops including ornamental plants and disperses the natural enemies evenly (Figure 22).

For the drones, the **Natutec Drone** obtained the highest score (90 points) and it is available in and outside Europe e.g. in the Netherlands and the US. Its advantages are that it can work in different crops at small and large scales (Figure 22).

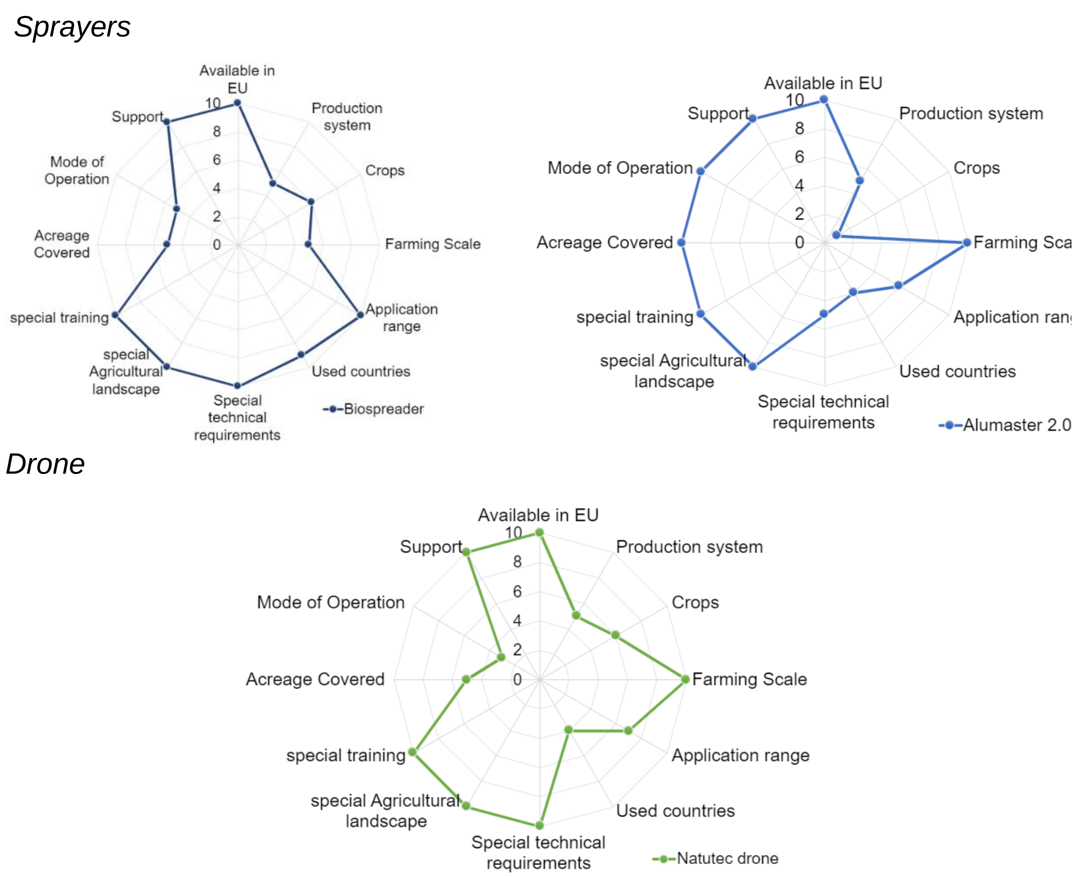


Figure 22 – Representation in spider net diagrams of selected sprayer and drone 'Distribution systems for beneficials' technologies

3.4.4.7 Selected technologies for field experiments

Regarding the sub-group of 'Distribution systems for beneficials', **Biospreader** and **Koppert Airbug** could be used in trials because they obtained higher scores and are available in Europe.

For Spain, the **Biospreader** and the **Koppert Airbug** are the best solutions due to the type of greenhouse structure, where it is not possible to install an automatic system for the distribution of beneficials. They are also faster solutions with more uniform results.

As a suggestion, the **Alumaster** is an ideal device for high-tech greenhouses in Northern Europe, with uniformity of beneficial dispersion and for crops with a high planting density.

4 Summarized outcomes

Vegetable protection against pests and diseases still relies on synthetic pesticides, while integrated pest management (IPM) recommends a combination of strategies and methods involving ecological, biological, and 'organic' forms of pest and disease control. One of the activities of the project and WP3 was to benchmark Smart technologies, which are described and available in the interactive platform of the project SmartProtect. Four main groups of technologies were considered: a) monitoring; b) diagnosis and detection; c) decision support and d) application technologies and these were subdivided into ten sub-groups for benchmarking and the selection of technologies for field testing:

a) 'Monitoring' technologies group:

a.1) The '*Crop monitoring*' sub-group selected three technologies to be tested: **Campogest** and **Margaret** (as a platform) and the **iMetos** weather station. Although not scoring very highly due to its targeted use, the **Gearsense** system seems interesting and allows for real-time follow-up of crop growth/status.

a.2) The '*Insect monitoring'* sub-group selected technologies using camera systems to detect insects based on smartphone apps and one special technique (Faunaphotonics). The main camera-based systems are Trapview, iScout, CapTrap; **Scoutbox** is a tool for use in the greenhouse; and **Xarvio,** is a very broad Smart application. **Faunaphotonics** is an interesting system but used to monitor biodiversity.

b) Diagnosis and detection group:

b.1) The '*ELISA, RNA and DNA technologies'* sub-group selected **Strip tests LOEWE®FAST Lateral Flow Kits**, **AgriStrip (Bioreba)** and **ImmunoStrip® Tests (Agdia)** options for field-testing. These had the highest scores between technologies requiring no special equipment, and they cover a rather wide diversity of pathogens (mostly viruses) and they have low costs (provisionally).

b.2) The '*Disorder detection using mobile phone'* technologies sub-group selected **Plantix, Cropalyser** and **Buntata**, which are of interest to use in demo trials in 2022. The applications are available in Europe and can be used in greenhouses and in open field production systems.

c) Decision support group:

c.1) The '*Decision support (no sensors)*' sub-group selected the **Xarvio scouting** App due to its applicability in outdoor crops and because it can identify several stressors in the field. The App - **Agrio Technology** can be used on all the target crops and can assist with a range of tasks. The **Bioline** App is only applicable to greenhouse crops.

c.2) The '*Decision support (with sensors)*' sub-group selected platforms with integrated weather stations: **OPI Support System and Agronet** which are applicable to several crops. Hub@grimeteo obtained a high score, and it is an interesting platform.

d) Applications technique group:

d.1) The '*Sprayers'* sub-group selected the **Dropleg Lecher** and **Dropleg Hardi** sprayers. The technologies can be all attached to classical booms and give a high reduction in drift, and a similar working speed. **Smartomizer** seems promising as a possible technology to test in field experiments and it would be interesting to test it in tomato cultivation, as it is not a widely known technology.

d.2) The '*Spraying drones'* sub-group selected two spraying drones **DJI Drone Agras T16** and the **M8A spraying drone**. The first drone is available in Europe including Germany, but cannot be used in open field crops. The second drone is currently in use in the US. However, due to the high costs it is not clear if the tool can be available for trials.

d.3) The products available in the *'UV Systems'* sub-group are rather limited, the selection made was **Cleanlight UV**, **Thorvald,** and **Lumion UV-C robot,** and they all operate on a robotic platform. **Micothon Flora UVC** does not provide a self-operating robotic platform, and it is hard to compare this in a demonstration trial with the others.

d.4) The '*Distribution systems for beneficials*' sub-group selected two sprayers. The **Biospreader** is easy to use in greenhouses and in open fields and has a wide range for applications and can be used on most crops. The second sprayer, **Alumaster 2.0,** can work in greenhouses and in all crops, including ornamental plants, and disperses natural enemies. For the category of drones, the **Natutec Drone** can work in different crops at the small and large scale.

In Spain, the **Biospreader** and **Koppert Airbug** are the best solutions in the typical greenhouse structures, and provide faster distribution of beneficial insects. As a suggestion, **Alumaster** is an ideal device for high-tech greenhouses in Northern Europe, with uniformity of dispersion and can be used for crops with a high planting density.

5 Challenges and perspectives

Technologies for crop protection in open field and greenhouse production systems have a wide range of availability. Table 38 presents the challenges and perspectives for the adoption of technologies at the European level.

Table 38 – Challenges and perspectives of benchmarked technologies

Technique groups		
Monitoring	**Challenges**	**Perspectives**
a) Crop monitoring	▪ With some technologies it is difficult to demonstrate return on investment when compared to traditional products/technologies. ▪ Older farmers are less interested in adopting new technologies. ▪ Barrier to selling the product in countries using conventional pesticides.	➢ Many technologies can be used in different crops and at different scales. ➢ In most of the EU countries, there is agricultural funding to finance purchase of the technologies. ➢ Growth of the alternative biological PPP market – these PPP require more precise application timing.
b) Insect monitoring	▪ In some countries, there is no agricultural funding to support purchasing these types of products. ▪ With some technologies it is difficult to demonstrate return on investment when compared to traditional technologies.	➢ Global policies/legislation are supporting greener technologies, e.g., Horizon 2020 EU Green Deal for AI robotic traps for real time pest monitoring. ➢ Possibility of tailored prices.
Diagnosis and detection	**Challenges**	**Perspectives**
a) ELISA, RNA and DNA technologies	▪ Many of the technologies perform in the laboratory and use quite a broad range and large amounts of laboratory consumables and reagents, which in many cases are thrown away after each analysis. ▪ Pocket diagnostic kits often run in a plastic rack, which is also thrown away after each test. ▪ The samples should be transported over a short period and in controlled conditions. ▪ Laboratory tests are performed in close contact with harmful reagents. Safety conditions must be considered and regulated according to EU rules for laboratory work	➢ The technologies are already developed and widely used, e.g., cooperatives or service centers. ➢ Often, the specific products could be used on the equipment that can detect other pests and pathogens, e.g., for fruit crops, ornamentals or field crops. ➢ The technologies offer a fast, field-usable approach, and do not need specific laboratory equipment and are precise and easy to use. ➢ There is a possibility to cooperate in the use of such technologies.
b) Disorder detection using mobile phone technologies	▪ In some countries it is not easy to develop such systems, thus some local pests/pathogens may not be included. ▪ Difficulties in uptake in countries where producers are not familiar with IoT. ▪ Farmers may act upon their own judgement without the opinion of an advisor. Thus, spraying can increase unreasonably. ▪ Producers in developing countries may not have access to equipment/tools/devices to use mobile applications, or internet access for using them.	➢ Use in both open field and greenhouse production systems. ➢ Reduces the cost to the producer compared with *in situ* detection by specialists. ➢ Create online communities/groups for knowledge and experience sharing and transfer. ➢ Mobile detection tools can be included in DSS that will provide practical support to producers.
Decision support	**Challenges**	**Perspectives**

a) No sensors	▪ Considered not to be very useful or accurate so not used. ▪ The range of crops is not wide enough.	➢ Lots of scope to improve these tools and make them useful on more crops ➢ Scope to make USA tools available in Europe. ➢ Need to make information on no-sensor technologies clearer on web sites ➢ Examples of validation of information would be useful.
b) With sensors	▪ The output models sometimes are not user friendly for farmers, it may need a researcher to explain. ▪ Range of crops not wide enough ▪ Not available for vegetables and its use is at field crop level. ▪ Other tools for decision support are available, e.g., including national tools supplied by research organizations - and are free – the market may get too full	➢ More models e.g., pest and disease forecasting models could be included in the tools. ➢ Examples of validation of information would be useful. ➢ There is an opportunity for companies to combine the knowledge and requirements of local farmers.
Application technologies	**Challenges**	**Perspectives**
a) Sprayers	▪ High costs of sprayer technology make decisions about purchasing or renting difficult. ▪ Application of large sprayers is not possible in all EU countries. ▪ Use of these technologies is only possible at a large farming scale. ▪ Due to the focus on plant protection in future, the equipment may not be so useful when different methods are used i.e., physical, biological, behavioural pest control.	➢ It is possible to expand the sale of technologies to new countries due to the wide demand. ➢ There are possible combinations of use among selected technologies and in the same growing season. ➢ The technologies can be used for different liquid products (e.g. biopesticides), not only chemical products.
b) Spraying drones	▪ Spraying drones are widely promoted for IPM, nevertheless at the EU level, their status is being evaluated, and the rules for adoption are in preparation. ▪ Currently at the EU level, e.g., in Germany, the use of spraying drones is only permitted in vineyards grown on slopes, after many tests. If there are no changes to these strict regulations, there is no real market for spraying drones in the EU, and therefore development towards effective application schemes is limited. ▪ Personalized technical support is still virtual, which makes it a little bit of a disadvantage for any problem. ▪ Remote control is still required to operate a spraying drone, which means having technical skills. ▪ Due to their manipulation by an expert, it means that they are not easy to use for everybody. ▪ Manipulation of drones requires certification from aviation institution that the driver has undertaken enough flying hours.	➢ Regulation for flying Drones in Europe is under development. ➢ As the amounts of pesticides that can be applied is more and more restricted in the EU, spot spraying applications could become more relevant in future and drones help with this. ➢ One scenario for future agriculture is to support smaller mixed cropping systems. In this scenario, spot spraying with drones would become very practical. ➢ SMEs in EU started manufacturing spraying drones, and could supply and assembly in an easy way in future. ➢ Spraying drones are not available in Europe, but in the US, there are companies, which provide services using spraying drones. Drones can be used to apply highly pest-specific low-risk biological products. ➢ The combination of monitoring and mapping of pest/disease occurrence with the application of pesticides in one drone is a big opportunity.
c) UV systems	▪ Competition with cheaper fungicides on market.	➢ The Green Deal: reduction in pesticide use needed. ➢ Easy to replicate for other targets/crop combinations. ➢ Opportunities in organic farming. ➢ Future improvement in robotics and automation. ➢ Possible to upscale technologies. ➢ UV treatments seem easy to replicate in other target/crop combinations, as it is possible to conduct selectivity, efficacy

	▪ Legislative issues. ▪ Presence of mercury in lamps (legislation). ▪ Dependence of farmer on third parties (companies). ▪ Sub-lethal (mutagenic) effects on microorganisms (both target and non-target) are not comprehensively studied. ▪ As a (semi)-preventative treatment, UV application must compete with the chemical fungicide market which has a lower cost. This is a major hurdle for technology uptake. ▪ The Restriction of Hazardous Substances (RoHS) Directive Legislation still exempts vapour from the ban on mercury use, but the pressure to ban mercury is increasing. ▪ By investing in a UV solution, the farmer could increase their dependency on this technology provider. In an incomplete market, price setting is not optimal for the farmer. ▪ Risk of farmers overdosing as the radiation is not visible to the farmer.	and minimum effective dose trials in a similar manner as with pesticides. ➢ The EU Green Deal could be an important external driver as it strives towards a reduction in chemical pesticides. Non-chemical control measures like these UV solutions could profit from this. ➢ Due to the physical nature of the approach, the growing market for organic produce could increase uptake - as UV solution interventions may be allowed, given that UV is above the ionizing spectrum ➢ Future improvements in robotics and automation are an opportunity for lowering costs and increasing efficiency of the robotic systems used for UV treatment.
d) Distribution systems for beneficials	▪ In some countries, there is no agricultural funding to finance the purchase of these technologies. ▪ It can be difficult to demonstrate return on investment (compared to the traditional technologies or products). ▪ Lack of transparency (pricing). ▪ Technologies lack information regarding support and accuracy. ▪ The dependence of the farmer on third parties. ▪ Lack of legislation - legislation can be considered as a threat because drones are treated as airplanes. ▪ Risk attributed to unmanned systems (no pilot in the vehicle) and competing uses of airspace. National and local administration can establish non-fly zones.	➢ Many technologies can operate in different terrains and scales. ➢ Companies could decide to sell their products in different countries. ➢ Price flexibility - possibility to have tailor-made prices. ➢ Renting can help farmers to test the technology and decide whether to invest. ➢ There could be technology sharing among stakeholders. ➢ Reduction of working time in the field.

6 Key findings and recommendations

- Key findings and recommendations are based on results from "Survey D3.1 – summarized outcome of interviews and questionnaires outputs" and "the benchmarking and SWOT analysis workshop (D3.4)".

- The survey (D3.1), indicated that governmental support is needed for farmers to use Smart technologies, but also at present the willingness of farmers to use Smart technologies is low. Most countries have programmes to support investment in Smart technologies. However, farmers felt they were poorly informed. Thus, targeted communication about investment programmes might help, and should be implemented by extension services and during education of the next generation of farmers.

- In the survey (D3.1), stakeholders mentioned that farmers need training to use Smart technologies. During the benchmarking process, we observed that information on many tools was hard to obtain, and many of the distributors, platform suppliers and manufacturers had no full description of their technologies on their webpages. In addition, support for infrastructure, hardware and operators is not well provided. So, companies should be advised to invest more in support and establish their products sustainably in the market – and not promise too much about their tools. The damage in the long run may be higher than the short time benefits on sales.

- Low availability was also mentioned in the survey – and can be linked to regulations, as in the case of drones that are regulated by European and national regulations. In many cases, the inclusion of drones in the broader group of aircraft is determined by national civil aviation authorities, which, through their regulations, identify the categories of drones, types of operations and establish the conditions of flight safety (security). For example, the European regulation sets some general limits for "visual" flight of drones up to 25 kg and the maximum height of 120 meters from the nearest point on the earth's surface. This rule can be waived especially by default, where there are special ground or terrain conditions or areas designated for flight operations of other aircraft, or densely populated areas or other conditions specifically identified.

- Decision support systems and monitoring technologies are only available in certain languages and limited by the numbers of crops/diseases covered each tool, as identified in the benchmarking and SWOT analysis.

- Low efficacy and profitability were mentioned by experts and stakeholders, and the problem of demonstrating return on investment was also identified in the SWOT analysis. These points could be tackled with 'pilot studies', where companies cooperate closely with farmers to show the benefits of their products.

- Although many technologies are available globally, not all the technologies for insect monitoring are disseminated and promoted. The survey showed that stakeholders and experts did use a couple of technologies, but the benchmarking and SWOT analysis showed a lack of knowledge and capability to demonstrate economic returns. Besides, stakeholders need technical support and advisory services to facilitate purchase decisions. There are programmes i.e. the EU Green Deal, which might support organic farming with low pesticide use and sustainable food production. Direct support is needed both at the national and local level so that farmers can have immediate access to funds to invest in new technologies and make the quantum leap to more targeted and effective approaches.

- Crop monitoring technologies are practical tools that can be installed in smartphones. Many of them are free, but a paid subscription is needed for better monitoring. in addition, mobile applications need Wi-Fi connection and therefore the internet should be ensured in remote rural communities to enable use of these tools.

- Rapid test kits such as diagnostic and detection technologies are not well known by stakeholders as reported in D3.1. Albeit these technologies work rapidly for plant pathogen detection, these technologies could be used more widespread e.g. also in cooperatives. Mobile applications are available, but stakeholders need training and many of mobile applications are available only in English, which might not be adequate, especially for older stakeholders.

- Technologies that can provide decision support to stakeholders are based on platforms and weather stations, and the outputs are models that forecast pest and pathogen attack. The outputs from these technologies should be more accessible and easier to understand by users, and be made available for more crops. Benchmarking and SWOT analysis demonstrated that many of these technologies can be purchased but not rented. There is a need to make other options like renting available when farmers do not have financial support.

- Some Smart pesticide application technologies, such as sprayers, have the potential to be used at a large scale, and can also be used for the application of organic products for pest and disease control. Thus, use at cooperative or farmer association scale should be supported.

- Aerial devices such as drones are promoted in the world for support geophysics and remote sensing tasks. These devices have also been adapted for product spraying in field crops. They are used widely in the US, Latin America and are being introduced little by little in Africa. Nevertheless, the regulations in Europe do not allow their use. It is expected that regulations and certifications will allow use in areas where large devices and workers do not have access. Besides, the prices are often unaffordable. If the restriction are reduced, it can become a good opportunity to upscale and special economic plans should be offered to interested stakeholders and cooperatives.

- Ecological and environmentally friendly technologies such as UV Systems have the opportunity to support organic farming. Nevertheless, legislative measures and prices make them unaffordable for farmers at present. Support for farmers to access this type of technology should be created and promoted.

- Technologies such as drones and sprays for the distribution of beneficial organisms appear practical for supporting organic farming. Nevertheless, prices for accessing these technologies are elevated and they are not affordable by farmers. Prices should be customized for farmer associations and be flexible.

- In benchmarking, it was often detected that technologies are applied to a low range of crops, pests and diseases. As there are also some technologies that cover many industrial field crops and pests, it should be fostered for the other technologies to broaden their range as for vegetables crops, open field and greenhouse cultivation. In some cases, it might be adequate to merge technologies or at least to provide their specific output on the same platform. As this often comes with high investments, smaller companies should be supported by project funding for these developments.

- Benchmarking indicated that, within the same group, there were often technologies available that offered a fully automated mode of operation, whilst others were manual or semi-automated. Depending on the intended use, it may be advisable for companies to invest in a higher degree of automation in order to exploit the full potential of their technologies. As this often needs considerable investment, smaller companies should be supported by project funds for these developments.

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