Brassica Fact Sheet

Authors: Alex Kelly, Rosemary Collier

Warwick Crop Centre, School of Life Sciences,

The University of Warwick

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 862563.

Disclaimer

Copyright message

Table of Contents

1 Introduction

This document is designed for use by brassica farmers and agronomists in Europe to inform them on smart technologies and methodologies available to them for Integrated Pest Management (IPM) solutions in open-field systems. The SMART IPM technologies are divided into four main technique types each with subsections of their own: Monitoring (Pest monitoring, Crop Monitoring, Others), Diagnostics and detection (ELISA, RNA and DNA, Mobile disorder detection, Others), Decision support (With sensors, Without sensors), Application (Sprayers, Sprayer drones, Mechanical weeders, UV techniques, Distribution system for beneficials, others).

Disclaimer: In some cases, it may have been difficult to obtain information from the company on whether the technology works for this particular crop. In such a case the technology may still have been included, based on the judgement of its potential relevance. Therefore, we cannot guarantee that every technology is relevant for this particular crop.

2 Monitoring

2.1 Pest Monitoring

2.1.1 Iscout

- **What is it?** IScout is an automated pest monitoring system that lets you remotely monitor insect pressure in fields. Images are sent via LTE to the FieldClimate platform where they are analysed with artificial intelligence software which is able to recognize the target insects. The photos are then available to see with rectangles around the target insects as well as summarised data of daily count, targets in total and development of insect populations during the season. IScout has been tested by SmartProtect partners for the detection of *Plutella xylostella* in Cabbage and Cauliflower crop.
- **TRL:** 9
- **Pest target:** Many – Diamond back moth (*Plutella xylostella*), Turnip moth (*Agrotis segetum*), Silver Y moth (*Autographa gamma*), Black cutworm (*Agrotis ipsilon*), Cabbage moth (*Mamestra brassicae*) - iSCOUT Pheromone trap.
- **Technology used:** Automated AI image recognition camera system, modem, power source with solar panel and sticky plate

2.1.2 Trapview

- **What is it?** Trapview is an automated pest monitoring system that can be used to remotely monitor any kind of insect that can be lured into a trap. Data is continuously streamlined into your TrapView cloud, analysed, and structured with AI technology. Reports are then prepared for your business decisions. Trapview is used by a large crop consulting company from Germany to gather real time information on the moth situation over entire growing area and to support with decisions for a large cabbage producer. Trapview has been tested for *Plutella xylostella* monitoring by SmartProtect partners.
- **TRL:** 9
- **Pest target:** Diamond back moth (*Plutella xylostella*), Silver Y moth (*Autographa gamma*).
- **Technology used:** Automated AI image recognition camera system, power source with solar panel and sticky plate

2.1.3 CapTrap

- **What is it?** Cap 2020 has developed a range of automatic and connected CapTrap traps and a dedicated web interface www.captrap.io to help with decision-making. The use of these connected traps makes it possible to monitor pest pressure and make the right decision at the right time thanks to real-time access to information returned by the traps.

- **TRL:** 9
- **Pest target:** Beet moth **(***Scrobipalpa ocellatella*), Cabbage moth (*Mamestra brassicae*), Silver Y moth (*Autographa gamma*), Turnip moth (*Agrotis segetum*), Black Cutworm (*Agrotis ipsilon*).
- **Technology used:** Automated AI camera system, power source with batteries, solar panel and sticky plate

2.1.4 Fauna Photonics: Volito

- **What is it?** Camera system that detects flying insects from up to 1-2 metres away using infrared light with no pheromones. Insect observations are automatically extracted and transmitted along with environmental data, location, and situational photos, to the cloud via a GSM connection. Using a solar panel and battery, the sensor is capable of unsupervised, long-term monitoring in remote locations. Currently performs four packages: General insect activity (total insect activity, Specific species activity (identification and count of individual species), insect group activity (insight into groupings i.e., beneficials/ non-beneficials, biodiversity overview).
- **TRL:** 9
- **Pest target:** Cabbage stem flea beetle (CSFB), Peach potato aphid (*Myzus persicae*) – Specific species activity
- **Technology used:** Automated AI camera system image recognition using infrared LED lights, power source with batteries and solar panel.

2.1.5 Agrobotica Spyfly

- **What is it?** SpyFly combines colour attraction & pheromone lures with sticky plastic to trap flies. It has automated algorithm driven image recognition for identifying harmful pests as well as using data and its own climatic parameters for developing predictive models on the spread of harmful agents.
- **TRL:** 9
- **Pest target:** Flies (*Diptera*) & moths (*Lepidoptera*).
- **Technology used:** Pheromone lure & sticky trap

2.1.6 BeeCAM

- **What is it?** A smart camera and a variety of software that record and identify flying and crawling insects as well as their interactions with flora and fauna nearby. Primarily developed as an alternative IPM approach for monitoring pollinators, the technology has many available functions such as photographing sticky traps or analysing spray droplet coverage of crop leaves following application.
- **TRL:** 9

- **Pest target:** Flying insects (unspecified).
- **Technology used:** Automatic pest trap status updates from imagery, Disease imagery automatic recognition, Pesticide application performance imagery

2.1.7 Koppert: traps, lures & beneficials

- **What is it?** Koppert offers a range of traps and suitable beneficials for the monitoring and control of common brassica pests. The company's website is simple to navigate and contains a useful search feature.
- **TRL:** 9
- **Pest target:** Diamondback moth (*Plutella xylostella*), Silver Y moth (*Autographa gamma*), Cutworms (*Agrotis spp*.), Cabbage leafroller (*Clepsis spectrana*), Cabbage moth (*Mamestra brassicae*), Peach Potato aphid (*Myzus persicae*).
- **Technology used:** Range of traps, lures and suitable beneficials

2.1.8 AlphaScents: traps & lures

- **What is it?** A company that provides an array of traps and species-specific lures. Lures are sold separately to traps. Traps are UV resistant coloured meaning they will not fade and are also waterproof and resistant to heavy winds when properly hung.
- **TRL:** 9
- **Pest target** Banded Cucumber Beetle (*Diabrotica balteata*), Cabbage Moth (*Mamestra brassicae*), Cabbage Looper (*Trichoplusia ni*), Cabbage Leafroller (*Clepsis spectrana*), Beet Armyworm (*Spodoptera exigua*), Black cutworm (*Agrotis ipsilon*), Diamondback Moth (*Plutella xylostella*), Cabbage Root Fly (*Delia radicum*), Silver Y moth (*Autographa gamma*), Turnip moth (*Agrotis segetum*) – Lures.
- **Technology used:** Pheromone lure & sticky trap or water trap

2.1.9 Ag-bio: Thrips lure

- **What is it?** Thrips-Lure is a controlled release dispenser of potent attractant to attract thrips in close proximity to a blue or yellow sticky card. Use it to monitor thrips in low population situations or early before thrips become established. Thrips-Lure has the potential to mass trap thrips and keep populations low in crops.
- **TRL:** 9
- **Pest target:** Western Flower Thrips (*Franklinella occidentalis*), Tobacco thrips (*Franklinella fusca*), Flower thrips (*Franklinella tritici*) & other thrips
- **Technology used:** Pheromone lure & sticky trap

2.1.10 Trap Manager

- **What is it?** This insect management and control tool informs you continuously about the status of the traps, performs insect counts automatically and provides access to data (photos and statistics). It performs 5 photos and data acquisition per day and warns in case of predefined anomalies.
- **TRL:** 9
- **Pest target:** Unspecified
- **Technology used:** Automated camera system providing pest trap status updates

2.2 Crop Monitoring

2.2.1 eBEE AG -The Advanced Agriculture Drone

- **What is it?** The eBee Ag is a reliable, affordable fixed-wing drone that helps farmers, agronomists and service providers to map and monitor crops quickly and easily. With its fixed Duet M multispectral/RGB camera, automated flight and vast coverage, eBee Ag delivers accurate and timely plant health insights for making better decisions to improve crop yields, save on inputs, allocate resources and achieve greater profit potential. The multispectral sensor achieves higher data accuracy than using a modified NIR sensor.
- **TRL:** 9
- **Function & targets:** Mapping & monitoring for plant health insights & identifying problem areas
- **Technology used:** Drone imagery (Multispectral NDVI, RGB)

2.2.2 DJI P4 Multispectral

- **What is it?** High precision drone built for agriculture missions. Plan flights, execute automated missions – Capture data, collect multispectral images across large areas and gain overview of problem areas, Analyse data, applying plant-specific metrics and parameters for results of plant health, Act on data, implement targeted treatments on areas that need attention.
- **TRL:** 9
- **Function & targets:** Monitoring imagery for plant health insights & identifying problem areas
- **Technology used:** Drone imagery (NDVI, RGB)

2.2.3 AkerScout

- **What is it?** AkerScout is a directed crop scouting application to help identify and prioritize crop damage to address problem areas needing immediate attention. It can be used as a free application to support GPS enabled scout task coordination as well

containing a comprehensive database on pests and diseases. Premium features include aerial drone imagery, agronomy reviews and prescription maps. Available for cabbage and broccoli.

- **TRL:** 9
- **Function & targets:** Geo-referenced scouting & coordination platform, Monitoring imagery for plant health insights & identifying problem areas.
- **Technology used:** Drone imagery (RGB, NDVI), Satellite field mapping.

2.2.4 FarmShots™

- **What is it?** As an expert in high resolution satellite imagery analysis, FarmShots will analyze satellite and drone imagery to help detect diseases, pests and poor plant nutrition. Satellite imagery allows growers to pick out problem areas on their farm, keep track of the locations of issues, share information about changes to a field and set up agronomists, suppliers, and farmers in a hierarchy.
- **TRL:** 9
- **Function & targets:** Monitoring imagery for plant health insights & identifying problem areas
- **Technology used:** Satellite and drone imagery (NDVI, SAVI, EVI, Visual)

2.2.5 OneSoil Scouting: Farming tool

- **What is it?** OneSoil is a free app and web service to remotely observe your crop development, monitor the weather, and find problem areas in your fields. Using Copernicus Sentinel data and Artificial Intelligence, the platform offer high resolution and frequent farm insights, helping the user to monitor the development in their crops, spot problem areas, plan crop rotations, create and download prescription maps for variable-rate seed or fertilizer application, check the weather forecast for optimal spraying conditions and much more. Can be used offline for the viewing of NDVI imagery from the past six months, making notes and editing field information.
- **TRL:** 9
- **Function & targets:** Monitoring imagery for plant health insights & identifying problem areas.
- **Technology used:** Satellite imagery (NDVI), weather data, machine learning

2.2.6 Agrio

- **What is it?** Agrio is an artificial intelligence-based precision agriculture solution that helps you to remotely monitor, identify, and treat plant diseases and pests in your field, farm, and garden. The app leverages and deploys proprietary artificial intelligence and computer vision algorithms. The algorithms contain the knowledge of numerous agronomists and agriculture experts and continuously improve. Because

the system is constantly learning, the online library on their website only shows a subset of what it can identify. Available in a number of languages.

- **TRL:** 9
- **Function & targets:** Disease recognition examples (Grey mould - *Botrytis cinerea*, Downy mildew - *Peronospora parasitica subsp. brassicae*, Root rot – *Rhizoctonia spp.*, White mould - *Sclerotinia sclerotiorum*, Verticillium wilt - *Verticillium dahliae* & *Verticillium albo-atrum*). Pest recognition examples (Aphids, Western Flower Thrips - *Franklinella occidentalis*). Treatment intervention, Alerts, Warning notifications.
- **Technology used:** Satellite imagery (NDVI, leaf chlorophyll content), Weather data, Mobile imagery, Collaboration + advisory tool, Scouting reports, Workgroups, Pest life-cycle tracking.

2.2.7 Arable - Arable Mark 2

- **What is it?** Winner of 'Crop Monitoring Solution of the Year' award from AgTech breakthrough. An all-in-one weather station and crop monitor, the Arable Mark 2 synthesizes climate and crop data for actionable insights in all growing conditions. Height placement guide for low vegetables & row is available online.
- **TRL:** 9
- **Function & targets:** Disease, pest, spray timing and application management
- **Technology used:** Imagery (NDVI, Chlorophyll index), Climatic parameters (Temperature, Humidity, Pressure Solar Radiation, Precipitation, Daily Evapotranspiration (ETc).

2.2.8 Campogest

- **What is it?** CampoGest is a mobile APP, designed by and for agricultural technicians, with a wide range of functionalities that can be configured according to the agronomist needs. One of these functionalities is the scouting and recommendations, which allows a fluid communication between advisors and farmers related to the identification of pests and diseases and the use of the most efficient treatment solution. This application can be used on various species of vegetables (leeks, lettuce, cauliflower, onions, tomatoes, cabbage, Brussels sprouts, cucumber). The app is currently only available in Spanish and requires that the Cooperative or Company have ERPagro installed.
- **TRL:** 9
- **Function & targets:** Many (Field notebook, farm maps, weather forecast, personalised recommendations, phytosanitary treatment management).
- **Technology used:** Integrated application.

2.2.9 Margaret

- **What is it?** By combining IoT devices, information from the farm operations and AI, growers can easily identify the pest or disease and therefore can get the list of authorized plant protection product suggestions. Plant protection suggestions are not affiliated with any specific company.
- **TRL:** 9
- **Function & targets:** Pests and disease
- **Technology used:** Artificial intelligence platform

2.3 Other monitoring

2.3.1 LumiGrow Sporecam

- **What is it?** Automated sensor that can capture, inspect, and classify harmful airborne spores for diseases such as Powdery Mildew and Botrytis.
- **TRL:** 9
- **Function & targets:** Fungal spores (Powdery mildew, Botrytis and more)
- **Technology used:** Automated spore capture device.

2.3.2 Burkard DNA auto spore trap

- **What is it?** The device collects particles from the air, such as fungal spores. At the end of the user-defined sampling period, the sample is moved through a series of different processes, which enables the instrument to detect the number of spores of a target species that were in the air during the sampling period.
- **TRL:** 9
- **Function & targets:** Fungal spores (unspecified)
- **Technology used:** Spore capture device.

3 Diagnostics and detection

3.1 ELISA, RNA and DNA

3.1.1 Creative Diagnostics

- **What is it?** ELISA kits with high test performance characteristics to allow accurate, rapid, simple and high-throughput identification of the organisms that cause plant disease. Often have good accuracy for viruses and bacteria, sometimes cross-reactivity between fungal species.
- **Technical requirements:** Cost effective, can be performed by non-specialists in one day with lab equipment.
- **TRL:** 9
- **Relevant targets:** Virus (Cauliflower mosaic virus - CaMV, Broccoli Necrotic yellow virus - BNYV, Turnip mosaic virus - TuMV, POTY group test). Fungal (*Phytophthora* spp., *Botrytis cinerea*).
- **Technology used:** ELISA kit

3.1.2 BIOREBA - ELISA kits

- **What is it?** BIOREBA ELISA reagents were developed and optimized for application in the DAS-ELISA format (double antibody sandwich enzyme-linked immunosorbent assay).
- **Technical requirements:** Cost effective, can be performed by non-specialists in one day with lab equipment.
- **TRL:** 9
- **Relevant targets:** Virus (Cauliflower mosaic virus - CaMV, Turnip yellow mosaic virus - TYMV, POTY group test).
- **Technology used:** ELISA kit

3.1.3 LOEWE – Plant Pathogen

- **What is it?** Complete ELISA kits containing all components to perform ELISA assay
- **Technical requirements:** Cost effective, can be performed by non-specialists in one day with lab equipment.
- **TRL:** 9
- **Relevant targets:** Virus (Turnip Yellows Polerovirus - TuYV, Turnip Yellow Mosaic Tymovirus - TYMV, Turnip Mosaic Potyvirus - TuMV, Cucumber mosaic virus - CMV). Bacteria (*Xanthomonas campestris pv. campestris*). Fungal (*Rhizoctonia solani*, *Phytophthora* spp.)
- **Technology used:** ELISA kit

3.1.4 Agdia – ELISA

- **What is it?** This product is intended for the qualitative detection of the target analyte via a direct, double antibody sandwich protocol known as DAS-ELISA.
- **Technical requirements:** Cost effective, can be performed by non-specialists in one day with lab equipment.
- **TRL:** 9
- **Relevant targets:** Virus (Cucumber mosaic virus - CMV, Cauliflower mosaic virus – CaMV reagent kit, POTY group). Bacteria (*Xanthomonas* spp. reagent kit).
- **Technology used:** ELISA kit

3.1.5 BIOREBA – Agristrip

- **What is it?** The rapid one-step assay AgriStrip, developed and manufactured by BIOREBA, is based on lateral flow immunochromatography. The AgriStrip test has been developed to confirm the presence of a plant pathogen in samples with suspicious symptoms.
- **Technical requirements:** No special technological equipment or training required. Low costs (provisionally). Fast results (in 10 - 15 minutes).
- **TRL:** 9
- **Relevant targets:** Virus (Cucumber mosaic virus - CMV)
- **Technology used:** Lateral flow kit

3.1.6 Agdia - ImmunoStrip® Tests

- **What is it?** ImmunoStrip tests are a rapid means of screening crops for the presence of pathogens. ImmunoStrip tests require no equipment or expertise to run. Results are obtained in as little as a few minutes making them perfect for use in the field or greenhouse.
- **Technical requirements:** No special technological equipment or training required. Low costs (provisionally). Fast results (in 10 - 15 minutes).
- **TRL:** 9
- **Relevant targets:** Virus (Cucumber mosaic virus – CMV, Poty - group level). Bacterial (*Xanthomonas* - Genus level). Fungal (*Phytophtora* spp., *Rhizoctonia solani*)

3.1.7 LOEWE®FAST Lateral Flow Kits

- **What is it?** The LOEWE®FAST rapid test series allows reliable and specific detection of plant pathogens within minutes. As stand-alone diagnostic tool these tests provide quick and easy assessment of suspicious plant material in the field or greenhouse without the need of a laboratory.

- **Technical requirements:** No special technological equipment or training required. Low costs (provisionally). Fast results (in 10 - 15 minutes).
- **TRL:** 9
- **Relevant targets:** Virus (Cucumber mosaic virus – CMV). Fungal (*Botrytis cinerea*).
- **Technology used:** Lateral flow kit

3.1.8 LOEWE – Plant Pathogen

- **What is it?** The reaction is carried out in one tube starting with the reverse transcription of virus RNA and subsequent cDNA amplification. The amplicon can be visualized on a standard agarose gel. Each kit is provided with detailed instructions and product specifications and quality validation data. Please note that reagents for RNA isolation are not included with this kit.
- **Technical requirements:** Complex, requires expert staff and appropriate measures, can be performed in 1 day.
- **TRL:** 9
- **Relevant targets:** Virus (POTY - group level, Turnip Yellows Virus - TuYV).
- **Technology used:** RNA PCR kit

3.1.9 OptiGene Genie II

- **What is it?** Genie® II is a sophisticated instrument that enables the sensitive detection of bacteria and viruses at a molecular level. This powerful and extremely flexible platform allows isothermal amplification of DNA and RNA to take place in a compact device designed to run any isothermal amplification method that employs target detection by fluorescence measurement.
- **Technical comments:** Easy-to-use, robust, portable instrument; invaluable for use in the field.
- **TRL:** 9
- **Relevant targets:** Supports any isothermal DNA / RNA amplification method employing fluorescence readout
- **Technology used:** DNA & RNA isothermal amplification device

3.1.10 SporSenz

- **What is it?** An early season in-field detection sensor for soil-borne plant diseases such as Phytophthora spp. that alerts farmers of pre-planting or in-crop infection risk. This helps guide evidence-based, accurately timed fungicide applications throughout the crop growing season. It also provides information on soil microbiome health to guide management practices.

- **Technical comments:** Pushed directly into the soil, the over ground chamber changes colour to alert the farmer to send the sensor to the lab for analysis in 2-5 days.
- **TRL:** 9
- **Relevant targets:** Unspecified - 2059 SporSenz samples analysed (4432 unique soil microbes, 47 crops, 14 countries).
- **Technology used:** Service platform using DNA sequencing

3.1.11 VegAlert

- **What is it?** Service by which grower collects sample from the field, the sample is then sent to the VegAlert lab, this is then processed, and the pathogens are identified, an online tool then supports the end user in management and decision making. A cauliflower crop plot has been used for a VegAlert trial.
- **Technical comments:** Easy to use sampling kit for sample collection by non-specialized technicians.
- **TRL:** 9
- **Relevant targets:** Unspecified but it covers diseases of the main vegetable crops (more than 90 bacteria and fungi).
- **Technology used:** Service platform using DNA sequencing

3.2 Mobile disorder detection techniques

3.2.1 Plantix

- **What is it?** The user sends pictures of the crop on WhatsApp and the Plantix 'crop doctor' diagnoses infected crops and offers treatments for any pest, disease or nutrient deficiency problems. The app also has a community feature where you can interact with other farmers and is currently the largest social network for farmers worldwide.
- **TRL:** 9
- **Relevant targets (cabbage & cauliflower):** Fungal (Fusarium Wilt, Powdery mildew, Botrytis blight, Verticillium wilt, White rust, Clubroot, Ring spot, Downy mildew, Alternaria spot, Bottom rot, Stem rot, Foot and Collar rot). Bacteria (Bacterial soft rot of cabbage – *Pectobacterium carotovorum subsp. carotovorum*, Aster yellows phytoplasma – *Phytoplasma asteris,* Black rot – *Xanthomonas campestris pv. campestris*). Mite damage (Spider mite). Pest damage (Cabbage moth, Diamondback moth, Black cutworm, White butterfly – large, Thrips, Aphids and many more)
- **Technology used:** Mobile imagery recognition

3.2.2 Xarvio scouting

- **What is it?** The user sends pictures of the crop on WhatsApp and the Plantix 'crop doctor' diagnoses infected crops and offers treatments for any pest, disease or nutrient deficiency problems. The app also has a community feature where you can interact with other farmers and is currently the largest social network for farmers worldwide.
- **TRL:** 9
- **Relevant targets:** Cabbage & Cauliflower Disease (Alternaria leaf spot - *Alternaria brassicae*, Black rot - *Xanthomonas campestris pv. Campestris*). Cabbage and Cauliflower Pest damage (Aphids - Aphis, Cabbage White Butterfly – *Pieris brassicae*, Cotton leafworm – *Spodoptera litura*, Leaf-miner flies - *Agromyzidae*, Whitefly - *Aleyrodidae*).
- **Technology used:** Mobile imagery recognition, Community radar alert system. Aphids

3.2.3 Agrio

- **What is it?** Agrio is an artificial intelligence-based precision agriculture solution that helps you to remotely monitor, identify, and treat plant diseases and pests in your field, farm, and garden. The app leverages and deploys proprietary artificial intelligence and computer vision algorithms. The algorithms contain the knowledge of numerous agronomists and agriculture experts and continuously improve. Because the system is constantly learning, the online library on their website only shows a subset of what it can identify. Available in a number of languages.
- **TRL:** 9
- **Function & targets:** Disease recognition examples (Grey mould - *Botrytis cinerea*, Downy mildew - *Peronospora parasitica subsp. brassicae*, Root rot – *Rhizoctonia spp.*, White mould - *Sclerotinia sclerotiorum*, Verticillium wilt - *Verticillium dahliae* & *Verticillium albo-atrum*). Pest recognition examples (Aphids, Western Flower Thrips - *Franklinella occidentalis*. Treatment intervention, Alerts, Warning notifications.
- **Technology used:** Satellite imagery (NDVI, leaf chlorophyll content), Weather data, Mobile imagery, Collaboration + advisory tool, Scouting reports, Workgroups, Pest life-cycle tracking.

3.2.4 Agrobase

- **What is it?** AgroBase is an app containing information on pests, weeds, diseases and all registered pesticides in a chosen country. Easily identify weeds, diseases and insects or pests in your fields and check which crop protection product will help you to solve farming problems and to grow good yield with less spending on pesticides, fungicides or herbicides.
- **TRL:** 9

- **Relevant targets:** Pests (Many), Disease (Many), Weeds (Many): https://agrobaseapp.com/
- **Technology used:** Knowledge database with images

3.2.5 Weed ID App

- **What is it?** Based on the acclaimed Encyclopedia of Arable Weeds and developed in association with ADAS, the BASF. Weed ID app aims to provide an easy-to-use reference guide to the major broad-leaved weeds and grass-weeds in the UK supporting weed identification of 140 species.
- **TRL:** 9
- **Relevant targets:** Weeds (Over 140): https://www.agricentre.basf.co.uk/en/Services/Mobile-Tools/Weed-ID-app/
- **Technology used:** Knowledge database with images

3.2.6 Dino-Lite

- **What is it?** Dino-Lite digital microscopes provide a powerful, portable and feature-rich solution for microscopic inspection at up to 900x magnification and 5-megapixel resolution. With these products, farmers and experts are able to identify insects quickly and efficiently in order to take the right measures
- **TRL:** 9
- **Relevant targets:** Pests (Mites, lice, parasites). Disease (spores and other disease carriers)
- **Technology used:** Digital microscope connected to smartphone or tablet

3.2.7 IPM Scope - portable digital microscope

- **What is it?** Handheld portable device which allows up to 140x zoom on plant material which is projected through to your computer screen allowing for image storing, marking, annotating and editing for easy identification of pests and diseases in plants.
- **TRL:** 9
- **Relevant targets:** Pest and disease
- **Technology used:** Digital microscope connected to computer

3.3 Other diagnostics and detection

3.3.1 Cyranose

- **What is it?** The Cyranose® 320 utilizes the NoseChip® array of nanocomposite sensors and advanced pattern recognition algorithms to detect and recognize the

chemical vapor of interest via its smellprint. It also utilizes the versatile and intuitive PCnose software to “learn” the chemical profile of vapours of interest. Research into electronic nose efficacy as a means of portable crop pest and disease recognition has proven effective however challenges do still remain.

- **TRL:** 9
- **Relevant targets:** Pests and Disease (Any)
- **Technology used:** Volatile organic compound sensor

4 Decision support

4.1 Decision support (With sensors)

4.1.1 Dacom Farm Disease Management

- **What is it?** With Dacom Disease Management you will know when and where you need to apply a plant protection product, and which type. It has been developed and validated for most crops and diseases in cooperation with scientific experts. Savings of more than 40% in practice have been demonstrated.
- **Extra capabilities:** Farm intelligence and business intelligence insights.
- **TRL:** 9
- **Relevant targets:** Cabbage disease prediction examples (Sclerotinia rot - *Sclerotinia sclerotiorum*, Downy mildew - *Hyaloperonospora brassicae.* Broccoli disease prediction examples (White blister – *Albugo candida*, Downy mildew - *Hyaloperonospora brassicae*, headrot).
- **Technology used:** Predictive disease modelling based on personal weather station data, soil monitor, weather forecast and growth observations.

4.1.2 AkerScout

- **What is it?** AkerScout is a directed crop scouting application to help identify and prioritize crop damage to address problem areas needing immediate attention. It can be used as a free application to support GPS enabled scout task coordination as well containing a comprehensive database on pests and diseases. Premium features include aerial drone imagery, agronomy reviews and prescription maps. Available for cabbage and broccoli.
- **TRL:** 9
- **Function & targets:** Geo-referenced scouting & coordination platform, Monitoring imagery for plant health insights & identifying problem areas.
- **Technology used:** Drone imagery (RGB, NDVI), Satellite field mapping.

4.1.3 Farmapp - Digitising IPM

- **What is it?** An Integrated Pest Management (IPM) software-based service for crops. The software allows satellite map recorded points of your scouting results for heatmaps and reports of incidence and severity of pests and disease. The web portal allows optimal spraying routes to be visualised and tracked. Modelling from sensors allows for real time pest and disease alerts. This saves money with precision spraying and release of beneficials.
- **Extra capabilities:** Greenhouse automation
- **TRL:** 9

- **Relevant targets:** Pests and disease alerts (unspecified)/ scouting support. Spraying application support.
- **Technology used:** Geo-referenced scouting information (personal manual scouting), pest and disease alerts based on sensors (soil sensor, weather station).

4.1.4 Weenat

- **What is it?** 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.
- **Extra capabilities:** Precise piloting - predefined thresholds (works for all crops): Connected to Weenat tensiometers by setting type of soil in plot - alert warnings as soon as water availability of a horizon changes.
- **TRL:** 9
- **Relevant targets:** Optimal timing for phytosanitary treatments.
- **Technology used:** Personal Weather station (measures rain, temperature and humidity), Anemometer (measures wind speed, direction, and gusts), Leaf wetness sensor (duration and intensity of wetting under plant cover).

4.2 Decision support (Without sensors)

4.2.1 Agrio

- **What is it?** Agrio is an artificial intelligence-based precision agriculture solution that helps you to remotely monitor, identify, and treat plant diseases and pests in your field, farm, and garden. The algorithms contain the knowledge of numerous agronomists and agriculture experts and continuously improve. Because the system is constantly learning, the online library on their website only shows a subset of what it can identify. Available in a number of languages.
- **Extra capabilities:** Nitrogen application optimisation. Farm management tool for crop advisors.
- **TRL:** 9
- **Relevant targets:** Disease recognition examples (Grey mould - *Botrytis cinerea*, Downy mildew - *Peronospora parasitica subsp. brassicae*, Root rot – *Rhizoctonia spp.*, White mould - *Sclerotinia sclerotiorum*, Verticillium wilt - *Verticillium dahliae* & *Verticillium albo-atrum*). Pest recognition examples (Aphids, Western Flower Thrips - *Franklinella occidentalis*. Treatment intervention, Alerts, Warning notifications.
- **Technology used:** Predictive modelling based on satellite imagery (NDVI, leaf chlorophyll content) and weather data. Disease and pest damage recognition supported by mobile imagery & collaboration + advisory tool

4.2.2 FuturCrop

- **What is it?** Using Artificial intelligence search pattern techniques, data clustering and phenological models. FuturCrop predicts the biological development of 179 pests up to 10 days in advance and thus calculates the best moment to treat them. Claims of up to Up to 30% reduction in chemical insecticide usage and more than 40% in biopesticides.
- **Extra capabilities:** Record scouting captures and treatments on the app. Carry out annual comparisons of incidence of pests.
- **TRL:** 9
- **Relevant targets:** Listed on their website - Cabbage aphid (*Brevicoryne brassicae*), Swede midge (*Contarinia nasturtii*), Cabbage root fly *(Delia radicum*), Peach-potato aphid (*Myzus persicae*), Cabbage white butterfly (*Pieris rapae*), Diamondback moth (*Plutella xylostella*), bean seed fly (*Delia platura*), cotton bollworm (*Helicoverpa armigera*), Beet armyworm (*Spodoptera exigua)*, Tobacco budworm (*Helicoverpa virescens*), Corn earworm (*Helicoverpa zea*), Mustard/turnip aphid (*Lipaphis erysimi*), Leafminer (*Liriomyza huidobrensis*), , Pandemis leafroller moth (*Pandemis pyrusana*), Flea beetles (*Phyllotreta cruciferae*), Cabbage Caterpillar, Cabbage Looper (*Trichoplusia ni*).
- **Technology used:** Predictive pest modelling based on weather data

4.2.3 Agrivi Farm Management

- **What is it?** Get an instant overview of a 7-day weather forecast or 3-year history for every field. Advanced detection algorithms alarm farmers if there is a risk of an insect pest or disease occurrence on their fields. A built-in database of pests, protection products, and active substances helps inform timely scouting and crop protection activities.
- **Extra capabilities:** Crop rotation planning, profitability insights, record keeping, crop traceability etc.
- **TRL:** 9
- **Relevant targets:** Pest and disease (unspecified)
- **Technology used:** Satellite based imagery, weather data, scouting layers. Also available with personal sensors

4.2.4 Spray Assist

- **What is it?** The simple to use app links to live local weather data to analyse the factors that influence accurate application and potential risk of spray drift, including wind, rain or frost. The app suggests techniques to enable sprayer operators to mitigate risks or alter practices. The app contains over 45 application timings and targets, more than 10 leading nozzle manufacturers and over 600 different nozzle types.
- **Extra capabilities:** N/A
- **TRL:** 9

- **Relevant targets:** Optimal spray timing and application support
- **Technology used:** Weather data

4.2.5 Effispray

- **What is it?** EffiSpray is a tool that calculates, depending on weather conditions (air temperature, air humidity, wind speed etc.) the ideal day and hour for spraying, making predictions for the next five days. Through EffiSpray's interactive map it is easy to find the area of interest and, by clicking on it, you can view the spraying calendar with the timeslots that are optimal for spraying operations for the following 5 days.
- **Extra capabilities:** N/A
- **TRL:** 9
- **Relevant targets:** Optimal spray timing support
- **Technology used:** Weather data

5 Application

5.1 Sprayers

5.1.1 Amaselect Row

- **What is it?** AmaSelect Row makes it possible to remotely switch any machine with an AmaSelect nozzle body from whole-area application to row-specific band spraying. Row-specific band spraying makes it possible to reduce the usage of plant protection agents by up to 65 %.
- **Benefits/ information:** Can be used in combination with drone imagery to only spray areas where weeds are present, reducing protection agents being sprayed by up to 80%.
- **TRL:** 9
- **Working speed:** 15km/ h
- **Technology used:** Horizontal row-specific boom sprayer

5.1.2 Micron Varidome

- **What is it?** Varidome is a range of shielded inter-row sprayers for eradicating weeds. The spray shields feature a unique patented double membrane skirt around the base which ensures that no spray comes into contact with the crop hence eliminating any risk of chemical transfer and subsequent crop damage. The sprayers range in working widths from 3m up to 12m.
- **Benefits/ information:** Over 95% drift reduction
- **TRL:** 9
- **Working speed:** 7km/ h
- **Technology used:** Horizontal inter-row hooded boom sprayer

5.1.3 Dropleg Lechler

- **What is it?** The dropleg lechler is a light device and can be easily mounted on most boom sprayers. The device undercuts the level of the crop flowers and sprays directly onto the stems and leaves, exactly where they are needed.
- **Benefits/ information:** Drift reduction up to 95% compared with conventional application techniques. Droplegs cannot be used on spray booms that fold vertically.
- **TRL:** 9
- **Working speed:** 7.km/ h
- **Technology used:** Dropleg sprayer

5.1.4 Dropleg® Beluga

- **What is it?** Under leaf spraying system for broadcast and row applications. Completely equipped with attachment and nozzle, Dropleg® Nozzles can be installed in any number and height using additional attachments as accessories.
- **Benefits/ information:** Study results on Onions show double the tracer dye application at top and bottom of canopy using a dropleg sprayer. Droplegs cannot be used on spray booms that fold vertically.
- **TRL:** 9
- **Working speed:** 7.km/ h
- **Technology used:** Dropleg sprayer

5.1.5 Dropleg Hardi

- **What is it?** This is a snap-on drop-leg sprayer designed for spraying low-dense crops up under the leaves. It has easily adjusted nozzle angles.
- **Benefits/ information:** Hang into the crop, spray is from below slightly upwards, drift is strongly reduced. Droplegs cannot be used on spray booms that fold vertically.
- **TRL:** 9
- **Working speed:** 7.km/ h
- **Technology used:** Dropleg sprayer

5.1.6 ESS Electrostatic spraying system 350RC & 450RC

- **What is it?** Efficient and effective ultra-low volume electrostatic sprayer with minimum drift. Compatible with most conventional chemicals and fungicides. Attaches to most tractors.
- **Benefits/ information:** Found to place over 4 times the amount of spray droplets onto the plant surface using 1/2 the amount of chemicals.
- **TRL:** 9
- **Working speed:** 10/12km/ h
- **Technology used:** Horizontal boom sprayer with electrostatic droplet release

5.1.7 Trailed sprayer WHIRLWIND M612 “ALBATROS”

- **What is it?** The Whirlwind M612 “Albatros Field Crop” Sprayers are sprayers with special boom configuration for the application of fungicide/insecticide treatments on vegetables and nursery crops. Application is delivered through fine electrostatic mist that penetrates foliage through their attraction to vegetation.

- **Benefits/ information:** Plant protection products are evenly distributed on both sides of the leaves. There is less loss through spray drift meaning less product required per hectare/acre. Jobs are completed faster and risk of operator being contaminated by pesticides is reduced by 70%.
- **TRL:** 9
- **Working speed:** 7km/ h
- **Technology used:** Horizontal boom sprayer with plates that open up crop

5.1.8 Wingsprayer

- **What is it?** Innovative system that ensures optimum dispersal of every spray fluid. The Wings come into contact with the crop, opening it up so that the spraying fluid can penetrate beneath the crop. Fine droplets ensure optimum coverage. The Wings provide shelter from hard wind and Prevent spray drift.
- **Benefits/ information:** Up to 99.8 % drift reduction. Saves time, water and up to 40% spraying fluid. Can be fitted to virtually any spraying equipment, both new and existing.
- **TRL:** 9
- **Working speed:** 7km/ h
- **Technology used:** Horizontal boom sprayer with plates that open up the crop

5.1.9 Cropsurfer™ / Släpduk™

- **What is it?** Shielded sprayer system made of a stiff plastic sheet that are intended to be mounted on new or existing sprayer booms. It causes a uniform distribution to be obtained even when the distance is short between the nozzle and target. Demonstrations in an onion crop on a windy morning showed the sprayer to produce very low spray drift.
- **Benefits/ information:** They are possible to operate with low water rates and small droplets with reduced drift and increased coverage.
- **TRL:** 9
- **Working speed:** 7km/ h
- **Technology used:** Horizontal boom sprayer with plates that open up the crop

5.1.10 Dubex Wave sprayers

- **What is it?** Dubex sprayers with WAVE methodology, are sprayers that open the crop and spray the spraying liquid exactly where it is needed. Nozzles are positioned at a 25cm distance from each other.

- **Benefits/ information:** WAVE system can achieve a drift reduction of 99%. Produces less drift, very fine droplet size and with less water used.
- **TRL:** 9
- **Working speed:** 7km/ h
- **Technology used:** Horizontal boom sprayer with plates that open up the crop

5.2 Sprayer drones

5.2.1 DJI Drone Agras series

- **What is it?** Advanced automated drone systems that provide precise aerial spraying platform. They work by 1) Data capture: scout and or map crops to find areas that need to be sprayed, 2) Planning: Import your data and use it to plan where to spray and input your spray height and rates. Or use the RTK controller to walk and mark areas for spraying. 3) Application: The T20 will automatically fly to and spray the areas. It uses radar to fly at the set height above the crop and adjusts its flow rate based on speed.
- **TRL:** 9
- **Availability:** Drone applications are not currently available in certain EU countries due to the flying restrictions. T16 model has been used in German vineyards.
- **Spray speed:** Agras T10 – 6ha/h
- **Flight time:** Agras T10 - 17 minutes (16kg), 9 minutes (24.8kg).

5.2.2 DroneVolt Hercules series

- **What is it?** Drone Volt is a French company that offers two types of spraying drones. Two models Hercules 10 v.1.7 and Hercules 20 can work with a tank of 6 litres of product to spray. The Lidar technology associated with drones makes it possible to observe plant growth in order to plan and optimize crop management and help limit the use of fertilizers and pesticides.
- **TRL:** 9
- **Availability:** Available in France for large scale field vegetable production.
- **Spray speed:** Hercules 10 (3 L/minute). Hercules 20 (6-10L/ hectare).
- **Flight time:** Hercules 10 (up to 35 minutes). Hercules 20 (up to 40 minutes).

5.2.3 Drone4Agro

- **What is it?** Tailor-made agricultural drones for spraying and fertilizing crops. Drone4Agro offer 4 basic types of drones with spans from 3 to 9 metres. Each is delivered with a standard battery pack and charger, ex service and maintenance. They can reduce production costs by 30-50% and labour hours by 95%.
- **TRL:** 9

- **Availability:** Available in Netherlands and EU countries. Current usage only in the Netherlands.
- **Spray speed:** 5 ha/hour
- **Flight time :** 20 minutes

5.2.4 M8A pro spraying drone

- **What is it?** Large capacity sprayer drone, suitable for larger fields and higher application rates. Standard features include terrain sensors, a flow meter and full automation of the spray pump. The drone is equipped with a large spray tank with a capacity of 20 L. Use of the drone can save 90% water and 30-40% pesticide usage.
- **TRL:** 9
- **Availability:** Available for purchase in Greece through IONIS: https://ionos-uav.com/products/m8a-pro-20lt/
- **Spray speed:** 11-15 ha/hour.
- **Flight time:** 25-35 minutes, (12-15 min payload).

5.3 Mechanical weeders

5.3.1 Robocrop InRow Weeder

- **What is it?** Robocrop InRow uses a digital video camera to capture images of the crop ahead of the toolbar. The information is then utilised for lateral steering of the hoe and individual synchronisation of the InRow weeder discs. The Robocrop computer is constantly adjusting the rotational speed of the discs to suit the variability of plant spacing. Developed for use on transplanted crops such as lettuce, cabbage, celery etc.
- **Benefits/ information:** Accuracy within 8mm of plant stem.
- **TRL:** 9
- **Technology used:** Inter-row and inter-plant mechanical weeder tractor attachment

5.3.2 Dino – Naïo technologies

- **What is it?** Dino navigates your field autonomously with a 2cm precision range thanks to a guidance system that combines the information from RTK GPS and other sensors. Dino detects crops rows and adjusts the tools to weed as close to the plants as possible. Works on onions, carrots, cabbage, lettuce and more.
- **Benefits/ information:** Autonomy for 8 to 10 hours and a work output of up to 10 acres per day.
- **TRL:** 9
- **Technology used:** Autonomous Inter-row and inter-plant mechanical weeding robot

5.3.3 Oz – Naïo technologies

- **What is it?** OZ is an autonomous robot dedicated to farmers with diversified crops with a max surface of 3ha and in each bed another crop. So, market gardeners are a perfect match. Due to the limited ground clearance OZ can assist for seeding and weeding all crops of cause but the in later stages we need to drive between the rows.
- **Benefits/ information:** Autonomy for 8 hours and a work output of up to 1000 m²/hour. Perfect for market gardeners.
- **TRL:** 9
- **Technology used:** Autonomous Inter-row and inter-plant mechanical multipurpose robot

5.4 UV-systems

5.4.1 CleanLight field implements

- **What is it?** These UV-outdoor units can be easily operated and installed on a tractor/ implement. They offer custom solutions for grapes, hemp and any fruits or vegetables grown outside that are vulnerable to disease. Daily application of UV light prevents the development of a variety of fungi, bacteria and viruses whilst not damaging crops
- **Benefits/ information:** By applying CleanLight on a daily basis, growers can control diseases organically and save at least 50% on fungicides.
- **TRL:** 9
- **Application targets:** Disease (Powdery mildew, downy mildew, botrytis and many more).
- **Technology used:** UV light tractor rear mount implement

5.5 Distribution systems for beneficials

5.5.1 Natutec Drive

- **What is it?** Tool with patented technology that enables the application of all beneficials in various carrier materials from a moving vehicle via ventilated air tubes to the crop. It has a box with tubes that distributes predatory mites and other insects in the correct dosage and uniformly over multiple crop rows. It can be used as a customized vehicle or on existing farming equipment, no matter what crop system. It can be attached to a pipe-rail, a trailer or a boom.
- **Benefits/ information:** Keelings farm in Ireland reported a first application accuracy for Thripex (predatory mite) and (Spidex predatory mite) of up to 95% on strawberry crops.
- **TRL:** 9
- **Application targets:** Spidex for control of two-spotted spider mite & many other mites (excluding Red spider mites). Thripex for control of various species of thrips.
- **Technology used:** Trailer or boom attachable airstream release system.

5.5.2 Natutec Drone

- **What is it?** High-tech dispersal drone that transports vulnerable beneficial organisms to disperse them accurately where they are needed. The Natutec Drone can carry loads of up to 13 litres. Koppert's drone pilots are specifically trained to work with the vulnerable beneficials and the unique dispersal system. Currently used for spider mite control on field grown tomatoes in Italy.
- **Benefits/ information:** The drone system disperses beneficial organisms over 8 hectares (20 acres) per hour. That's 20 times faster than manual dispersal.
- **TRL:** 9
- **Application targets:** Spidex for control of two-spotted spider mite & many other mites (excluding Red spider mites). Thripex for control of various species of thrips
- **Technology used:** Drone operated by company pilot.