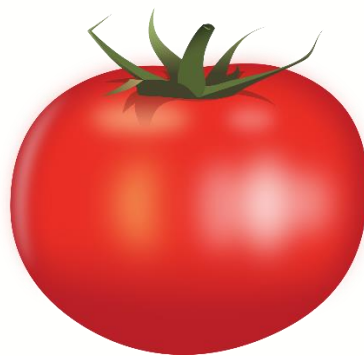




Tomato Fact Sheet



Authors: Alex Kelly, Rosemary Collier
Warwick Crop Centre, School of Life Sciences,
The University of Warwick



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1 Introduction

This document is designed for use by tomato growers and agronomists in Europe to inform them on smart technologies and methodologies available to them for Integrated Pest Management (IPM) solutions in open-field and greenhouse 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: Greenhouse & Open field

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 population during the season.
- **TRL:** 9
- **Pest target:** Silver Y moth (*Autographa gamma*), Cotton bollworm (*Helicoverpa armigera*), Turnip moth (*Agrotis segetum*), Black Cutworm (*Agrotis ipsilon*), Tomato leafminer - *Tuta absoluta*, Cabbage moth - *Mamestra brassicae* (iSCOUT pheromone trap). Brown marmorated stink bug - *Halyomorpha halys* (iSCOUT Bug trap).
- **Technology used:** Automated 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 and analysed and structure with AI technology. Reports are then prepared for your business decisions. One of the largest tomato processing plants uses Trapview to monitor the quality of tomato plant whilst it is still growing.
- **TRL:** 9
- **Pest target:** Cotton boll worm (*Helicoverpa armigera*), Tomato leafminer (*Tuta absoluta*).
- **Technology used:** Automated 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:** Silver Y moth (*Autographa gamma*), Turnip moth (*Agrotis segetu*), Black Cutworm (*Agrotis ipsilon*), Cotton boll worm (*Helicoverpa armigera*), Cabbage moth (*Mamestra brassicae*) – CapTrap Funnel. Tomato leaf miner (*Tuta absoluta*) – CapTrap Vision.
- **Technology used:** Automated image recognition camera system, power source with batteries, solar panel and sticky plate.

2.1.4 Agrocares Scoutbox

- **What is it?** Scoutbox uses image-based insect detection combined with machine learning for monitoring sticky traps. See where harmful insects (Whiteflies, Thrips, Leaf miners) and beneficials (*Nesidiocoris* & *Macrolophus*) are concentrated on an easy-to-read map on your laptop for effective pest control. Scoutbox can read up to 300 trap plates per day for you with the push of a button. Resulted in an 87.4% accuracy compared with hand counting for whiteflies, saving big on labour costs.
- **TRL:** 9
- **Pest target:** Whitefly (studies on tomatoes showing efficacy), Thrips, leaf-miners.
- **Technology used:** Automated image recognition camera system, power source with batteries, solar panel and sticky plate.

2.1.5 Natutec scout (only Greenhouse)

- **What is it?** Natutec Scout can be used to register the exact location of pests and diseases in the greenhouse on the mobile phone. This can be done either manually by the scout or with the Natutec Scout scanner, which automatically identifies and counts thrips and whiteflies on yellow Horiver sticky cards. Further, Natutec Scout can be used to enter plant protection treatments and analyse the effect of treatments on pest and disease development as well as the effect of pesticide treatments on natural enemies.
- **TRL:** 9
- **Pest target:** Thrips and whiteflies (for automatic image scan counts). Any other pests (for manual counting and input).
- **Technology used:** Image recognition and count feature, pest and disease mapping application.

2.1.6 PATS-C (only Greenhouse)

- **What is it?** PATS-C tracks 24/7 flying pest insects in your greenhouse. This saves you time on scouting rounds and facilitates adequate action when pest pressure rises. High frequency monitoring helps to tackle pests in an early stage, preventing the further spreading of offspring. This reduces unnecessary crop losses and the use of costly resources. PATS-C keeps an eye out for you. Today the service focuses mainly on moth pests (*Lepidoptera*) of which the caterpillars can wreak havoc in no time. The system is active in over 20 crops, including tomatoes.

- **TRL:** 9
- **Pest target:** Moths (*Lepidoptera*) – Tomato looper (*Chrysodeixis chalcites*), Tomato leafminer (*Tuta absoluta*), European pepper moth (*Duponchelia fovealis*), Cotton bollworm (*Helicoverpa armigera*).
- **Technology used:** Automatic greenhouse infrared camera monitoring system.

2.1.7 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. The company provides separate devices for either the monitoring of flies or moths.
- **TRL:** 9
- **Pest target:** Flies (*Diptera*) & moths (*Lepidoptera*).
- **Technology used:** Pheromone lure & sticky trap.

2.1.8 AlphaScents traps

- **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:** Lures - Tomato leafminer (*Tuta absoluta*), Turnip moth (*Agrotis segetu*), Black Cutworm (*Agrotis ipsilon*), Cabbage moth (*Mamestra brassicae*), Cotton bollworm (*Helicoverpa armigera*). Cabbage Looper (*Trichoplusia ni*), Beet Armyworm (*Spodoptera exigua*), Brown marmorated stink bug (*Halyomorpha halys*).
- **Technology used:** Pheromone lure & sticky trap or water trap

2.1.9 Ag-bio: Pheromones and traps

- **What is it?** Ag-bio distributes a range of traps and lures for insect pests. These can be used to monitor pest populations in order to make timely decisions or in some cases they can be used as mass traps to keep populations low in crops.
- **TRL:** 9
- **Pest target:** Traps - Turnip moth (*Agrotis segetu*), Black Cutworm (*Agrotis ipsilon*). Brown marmorated stink bug (*Halyomorpha halys*). Lures – Thrips lure, European pepper moth (*Duponchelia fovealis*).
- **Technology used:** Pheromone lure & sticky trap

2.1.10 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:** Example tomato pests Futurcrop can predict listed on the website : White fly (*Bemisia tabaci*), Onion thrips (*Thrips tabaci*), Tobacco thrips (*Frankliniella fusca*), Western flower thrips (*Frankliniella occidentalis*), Beet armyworm (*Spodoptera exigua*), Turnip moth (*Agrotis ipsilon*), Buckthorn aphid (*Aphis nasturtii*), Peach-potato aphid (*Myzus persicae*), Foxglove aphid (*Aulacorthum solani*), Tomato leafminer (*Tuta absoluta*), Nematodes (*Meloidogyne incognita*, *Meloidogyne javanica*), Diamondback moth (*Plutella xylostella*) and many more.
- **Technology used:** Predictive pest modelling based on weather data.

2.2 Crop Monitoring: Open field

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 EOSDA Crop Monitoring

- **What is it?** Easy to use satellite field monitoring helping farmers manage multiple fields, cut costs on resources and take reliable decisions. Vegetation index satellite imagery allows problem areas to be identified and scouting missions to be sent. The field leader board ranks field areas according to amount of vegetation change, therefore allowing these areas to be scouted in order of importance. This platform has been used successfully on a tomato farm of 4000 ha, saving them time on scouting, detecting tomato health issues in near real time and cutting operational costs.
- **TRL:** 9
- **Function & targets:** Monitoring imagery for plant health insights & identifying problem areas
- **Technology used:** Satellite imagery (NDVI).

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

2.2.5 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. Available in a number of languages.
- **TRL:** 9
- **Function & targets:** Monitoring imagery for plant health insights & identifying problem areas, Ai image recognition (for more detailed information see Agrio in

Mobile disorder detection techniques), Treatment intervention, Alerts, Warning notifications, pest life-cycle tracking.

- **Technology used:** Satellite imagery (NDVI, leaf chlorophyll content), Weather data, Mobile imagery, Collaboration + advisory tool, Scouting reports, Workgroups, Pest life-cycle tracking.

2.2.6 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

2.2.7 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).

2.2.8 Prospera

- **What is it?** Pinpoint pests, disease and weeds using data from automatic cameras mounted on pivots, drones, in-field machinery or greenhouse ceilings. Their technology analyses tens of thousands of images in order to locate problems. It can even tell you the extent and spread percentage of an infestation – meaning you're able to act earlier, and with greater precision. The technology enables you to view the distribution of the issue at hand and to detect any infestation hotspots. This allows for more accurate, cost-effective and targeted treatments - whether it be along field borders, for only a specific area of the field, or an entire greenhouse.

- **TRL:** 9
- **Function & targets:** Pests, disease and weeds (e.g., late blight – *Phytophthora infestans* in tomato crops).
- **Technology used:** Autonomous 24/7 camera devices with AI image recognition of crop issues.

2.2.9 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 high 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)).

2.2.10 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. 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.

2.2.11 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 Crop monitoring: Greenhouse

2.3.1 Oko Digital: Ecoation

- **What is it?** 1. Drive the OKO in row 2. Recieve live alert. 3. Verify and assign task. The location-aware OKO platform knows where it is in the greenhouse at any given time, making it possible to precisely record issues and mark the location for follow up treatment. While driving in the crop rows, LCD Live Alerts bring the operator's attention to the areas with high risk of pest or disease infestation and prompts for verification and task assignment. OKO Immersive has the same benefits plus added features to monitor and protect plant health. Immersive provides a 360 view of the greenhouse where growers, and consultants can take a virtual walk inside and see what is happening in near real-time. The OKO immersion+ adds the addition of an Ecoation professional to help get the job done.
- **TRL:** 9
- **Function & targets:** Pests and disease risks
- **Technology used:** Digital imagery and sensor system. Drives on pipe rails.

2.3.2 GreenPatrol robot

- **What is it?** GreenPatrol is a European precision farming project aimed at developing a robotic solution for Integrated Pest Management in greenhouses. The robot can operate autonomously to detect several pests. It can generate and follow routes, avoiding obstacles. The robot is trained on the main pest and diseases of tomato and pepper and is being tested in northern Spain. Growers can access an online application to see the robot's status and a map of healthy and infected zones, with recommended actions. The robot can identify where pests are located and treat them in a second phase. The robot has the ability to spray the plant with pesticide.
- **TRL:** 6
- **Function & targets:** Identifying, mapping and treatment for the main pests and diseases of tomato and pepper.
- **Technology used:** Autonomous navigation robot using satellite (no pipe rails), IPM strategy algorithms, pest and disease image recognition, greenhouse scanning and mapping.

2.3.3 Gearsense

- **What is it?** GearSense is a tool that analyses the growing environment with smart cameras and sensors. It is possible to monitor a product, such as tomato, cucumber, bell pepper, throughout its production cycle. On the screen you can see the growth and the behaviour of the plant in response to the changing environmental factors, such as the climate in the greenhouse and the circumstances surrounding the plant. By linking the measurement data to your own analysis tools or to map your growth model, you can continuously optimize the development of the plant.

- **TRL:** 9
- **Function & targets:** Crop performance optimisation
- **Technology used:** Camera with image analysis and AI, sensors with data analysis of all environmental factors of the plant.

2.3.4 Planticus

- **What is it?** Small, wearable detection devices can be deployed in greenhouses or open fields on vehicles or workers, effectively turning each one into a professional scouter. Pictures are taken and uploaded to the Planticus cloud. The detection algorithm processes every image and detects any anomalies. The technology is trained to detect pests and diseases early enough so that treatment is still possible. Their real-time notifications allow to act fast and accordingly, avoiding complete loses of harvest and exuberant sanitation costs.
- **TRL:** 9
- **Function & targets:** Plant and disease identification in tomato crop.
- **Technology used:** small wearable/ mountable camera device, AI pest and disease image recognition.

2.3.5 CropScanner app

- **What is it?** This app provides fast and direct entry of scouting-data with a smartphone or tablet; real-time overview of your greenhouse at any time; structured view of the scouting data via pc or web; visualisation of pest pressure and population build-up of beneficials; extensive data-analysis; direct contact with a Biobest advisor for personalised IPM advice. Advice can be personalised from a distance to fit the exact situation in the greenhouse. The app significantly improves the remote provision of tailored IPM advice.
- **TRL:** 9
- **Function & targets:** Scouting observations used for Pest and disease heatmaps, graphs, pest pressure and population build up visualisation.
- **Technology used:** Greenhouse mapping application

2.3.6 IPM Scoutek

- **What is it?** Multi-lingual greenhouse IPM software designed to make scouting operations and IPM strategies more efficient. Scouts can easily record observations on pests, traps and beneficials which are then marked and stored on the greenhouse map. This IPM data on the app replaces excel spreadsheets with detailed views of pressures, trends, action threshold alerts, scouting activity, applications, heatmaps and more. The software tracks your applications so that you can see how well they are working.
- **TRL:** 9

- **Function & targets:** Scouting observations app for pest and disease monitoring and application efficacy tracking.
- **Technology used:** Greenhouse mapping application.

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- **What is it?** Pinpoint pests, disease and weeds using data from automatic cameras mounted on pivots, drones, in-field machinery or greenhouse ceilings. Their technology analyses tens of thousands of images in order to locate problems. It can even tell you the extent and spread percentage of an infestation – meaning you're able to act earlier, and with greater precision. The technology enables you to view the distribution of the issue at hand and to detect any infestation hotspots. This allows for more accurate, cost-effective and targeted treatments - whether it be along field borders, for only a specific area of the field, or an entire greenhouse.
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- **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))

2.3.9 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. Available in a number of languages. The satellite monitoring feature can only be used in open field and the mobile imagery application can be used in any system.

- **TRL:** 9
- **Function & targets:** The Ai image recognition can detect: Virus (Cucumber mosaic virus – CMV, Tomato spotted wilt virus – TSWV). Bacteria (Bacterial canker of tomato -*Clavibacter michiganensis*). Fungi (Botrytis blight - *Botrytis cinerea*, Anthracnose, Early blight - *Alternaria solani*, powdery mildew of tomato - *Leveillula taurica* & *Oidium neolycopersici*, Downy mildew, Root rot - *Rhizoctonia*, White mould - *Sclerotinia sclerotium*, *Verticillium* wilt). Pests (Tomato leafminer – *Tuta absoluta*, Fall armyworm - *Spodoptera frugiperda*, Leafminer, Fuir fly - *Ceratitis capitata*, Red Mites - *Tetranychus urticae* etc., Brown marmorated stink bug - *Halyomorpha halys*, Western Flower Thrips - *Frankliniella 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

2.4 Other monitoring

2.4.1 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.

2.4.2 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: Open field & Greenhouse

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 (Cucumber mosaic virus – CMV, Tomato Mosaic Virus - ToMV, Tomato spotted wilt virus – TSWV, Tomato ringspot virus - ToRSV, Tomato yellow leaf curl virus - TYLCV, Tomato yellow ring virus – TYRV, POTY group test, Potato Y virus). Fungi (*Botrytis cinerea*). Bacteria (*Clavibacter michiganensis pv. michiganensis* – Cmm, *Ralstonia solanacearum* – Rs).
- **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 (Tomato Spotted Wilt Virus – TSWV, POTY group test, Pepino mosaic virus - PMV, Poty group test, Potato virus Y -PYV, Tobacco mosaic virus - TMV, Tobacco necrosis virus - TNV, Tobacco ringspot virus - TRSV, Tobacco streak virus - TSV, Tomato apex necrosis virus - ToANV, Tomato black ring virus – TBRV, Tomato brown rugose fruit virus - ToBRFV, Tomato bushy stunt virus - TBSV, Tomato chlorotic spot virus - TCSV, Tomato mosaic virus - ToMV, Tomato mottle virus - ToMMV, Tomato ringspot virus - ToRSV, Tomato ringspot virus-Ch*, Tomato yellow leaf curl virus - TYLCV, Tospovirus broad-spectrum). Bacteria (*Ralstonia solanacearum*). Fungi (*Verticillium spp.*).
- **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 (Eggplant Mottled Dwarf Nucleorhabdovirus- EMDV, Lettuce Necrotic Stunt Tombusvirus - LNSV, Pelargonium Leafcurl Tombusvirus - PLCV, Pepino Mosaic Potexvirus - PepMV, Petunia Asteroid Mosaic Tombusvirus - PeAMV, , Tobacco Mild Green Mosaic Tobamovirus - TMGMV, Tobacco Necrosis Necrovirus A type - TNV A, Tomato Aspermy Cucumovirus - TAV, Tomato Blackring Nepovirus - TBRV, Tomato Brown Rugose Fruit Tobamovirus - ToBRFV, Tomato Bushy Stunt Tombusvirus - TBSV, Tomato Chlorosis Crinivirus - ToCV, Tomato Chlorotic Spot Tospovirus - TCSV, Tomato Mosaic Tobamovirus Dahlemense - ToMV, Tomato Ringspot Nepovirus pelargonium isolate - ToRSV, Tomato Spotted Wilt Virus Tospovirus - TSWV, Tomato Yellow Leaf Curl Bigeminivirus – TYLCV). Bacteria (*Clavibacter michiganensis subsp. Michiganensis*, *Dickeya chrysanthemi Saintpaulia* isolate, *Pseudomonas syringae pv. tomato*, *Ralstonia solanacearum*, *Xanthomonas campestris pv. vesicatoria*).
- **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 (Tobacco etch virus - TEV, Tobacco mosaic virus - TMV, Tobacco ringspot virus - TRSV, Tobacco streak virus - TSV, Tomato mosaic virus - ToMV, Tomato ringspot virus - ToRSV, Tomato spotted wilt virus - TSWV, Potato virus Y - PVY, Potato virus X - PVX, Potyvirus group - POTY, Impatiens necrotic spot virus - INSV, Alfalfa mosaic virus - AMV, Cucumber mosaic virus - CMV. Bacteria (*Ralstonia solanacearum*).
- **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, Tomato mosaic virus - ToMV, Tobacco mosaic virus -TMV, Tomato spotted wilt virus - TSWV, Potato virus Y – PVY) Bacteria (*Ralstonia solanacearum*, Pepino mosaic virus - PepMV, Impatiens necrotic spot virus - INSV).
- **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 (Pepino mosaic virus - PepMV, Tomato brown rugose fruit virus - ToBRFV, Tobacco mosaic virus - TMV, Tobacco ringspot virus - ToRSV, Tobacco streak virus - TSV, Tomato aspermy virus - TAV, Tomato leaf curl New Delhi virus - ToLCNDV). Bacteria (*Clavibacter michiganensis subsp. michiganensis* - Cmm, *Ralstonia solanacearum* - Rs, *Xanthomonas* genus level - Xan). Fungi (*Rhizoctonia solani* - Rhiz).
- **Technology used:** Lateral flow kit

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 (Tomato Mosaic Tobamovirus - TMV, Tobamoscreen - ToMV, TMV, ToBRF, Tomato Mosaic Tobamovirus - ToMV, Tospoviruses kit - TSWV, TCSV, Potato Virus Y - PVY). Bacteria (*Clavibacter m. subsp. michiganensis* - Cmm, *Ralstonia solanacearum*). Fungi (*Botrytis cinerea*).
- **Technology used:** Lateral flow kit

3.1.8 LOEWE – Molecular diagnostics RNA PCR

- **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 (Cucumber mosaic virus - CMV, pepino mosaic virus – PMV, Potato Y virus - PMV, Potyvirus - genus level, Tobamovirus Broad Range, Tomato Brown Rugose Fruit Virus - ToBRFV, Tomato Chlorosis Virus – ToCV, Tomato Infectious Chlorosis Virus - TICV, Tomato Mottle Mosaic Virus -TMV, Tomato spotted wilt virus – TSWV,).
- **Technology used:** RNA PCR kit

3.1.9 LOEWE – Molecular diagnostics DNA PCR

- **What is it?** Your sample DNA is subjected to a pre-tested and evaluated PCR system, without the hassle of optimizing reaction- and cycle conditions. Included are PCR reagents, premix, positive and negative controls, DNA-Polymerase and a detailed protocol, thus providing the perfect tool for a successful PCR analysis!
- **Technical requirements:** Complex, requires expert staff and appropriate measures, can be performed in 1 day.
- **TRL:** 9
- **Relevant targets:** Virus (Tomato Leaf Curl New Delhi Virus - ToLCNDV, Tomato Yellow Leafcurl Virus – TYLCV). Bacteria (*Clavibacter michiganensis ssp. michiganensis* – CMM, *Ralstonia solanacearum*)
- **Technology used:** RNA PCR kit

3.1.10 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

3.1.11 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

3.1.12 Veg alert

- **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.
- **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: Open field & Greenhouse

3.2.1 Xarvio scouting

- **What is it?** Simply take a picture of the stress in your field, be it several weeds or an affected leaf. You receive the result within seconds with a reliable internet connection. Find out what disease or pest damage may be affecting your crop. Radar displays information from the community about diseases, pests, weeds and other scouting results. Learn more about the right product for the identified disease or weed. Agronomic advice and product recommendations are provided by our various partners and displayed in the app if available for your SCOUTING result.
- **TRL:** 9
- **Relevant targets:** Disease (Bacterial Spot and Speck, Bacterial wilt, Early blight, Fusarium Wilt, Grey mould, Late blight, Leaf curl of Tomato, Powdery mildew, Sooty

mould, Tobacco Mosaic Virus, Tomato spotted wilt virus, Tomato yellow leaf curl virus. Pest damage (Aphids, Cotton bollworm, Cotton leafworm, Eggplant lace bug, Fruit borer, Leaf-miner flies, Mealybug, Spider mite, Thrips, Tomato Leafminer, Whitefly)

- **Technology used:** Mobile imagery recognition, Community radar alert system. Aphids

3.2.2 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:** Virus (Tomato spotted wilt virus – TSWV, Tomato yellow leaf curl virus – TYLCV, Tobacco mosaic virus -TMV, Cucumber mosaic virus – CMV, Tobacco streak virus – TSV etc.). Bacteria (Bacterial spot and speck of tomato – *Xanthomonas spp.* & *Pseudomonas syringae pv. tomato*, Bacterial canker of tomato – *Clavibacter michiganensis subs. Michiganensis*, Bacterial wilt – *Ralstonia solanacearum*). Fungi (Tomato late blight – *Phytophthora infestans*, Early blight – *Alternaria solani*, Fusarium wilt – *Fusarium oxysporum*, Powdery mildew – *Erysiphaceae*, Leaf mould of tomato – *Mycovellosiella fulva*, Botrytis blight – *Botrytis cinerea*, Verticillium wilt – *Verticillium spp.* etc.). Pest damage (Tomato leaf miner – *Tuta absoluta*, Thrips - *Thysanoptera*, Black cutworm – *Agrotis ipsilon*, Fall armyworm – *Spodoptera frugiperda* etc.).
- **Technology used:** Mobile imagery recognition

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. Available in a number of languages.
- **TRL:** 9
- **Relevant targets:** Virus (Cucumber mosaic virus – CMV, Tomato spotted wilt virus – TSWV). Bacteria (Bacterial canker of tomato -*Clavibacter michiganensis*). Fungi (Botrytis blight - *Botrytis cinerea*, Anthracnose, Early blight - *Alternaria solani*, powdery mildew of tomato - *Leveillula Taurica* & *Oidium neolycopersici*, Downy mildew, Root rot - *Rhizoctonia*, White mould - *Sclerotinia sclerotium*, *Verticillium* wilt). Pests (Tomato leafminer – *Tuta absoluta*, Fall armyworm - *Spodoptera frugiperda*, Leafminer, Mediterranean fruit fly - *Ceratitidis capitata*, Red Mites -

Tetranychus urticae etc., Brown marmorated stink bug - *Halyomorpha halys*, Western Flower Thrips - *Frankliniella occidentalis*).

- **Technology used:** Mobile imagery recognition, Collaboration + advisory tool.

3.2.4 CropDiagnosis

- **What is it?** Automated diagnosis of crop condition through a smart questionnaire consisting primarily of pictures. First you describe the crop's details (type, location, soil, history, etc) and the threat's characteristics (type, appearance, progress, etc). Then answer the smart questionnaire which results in the most likely diagnosis. The app then presents a filtered list of matching chemical products that can mitigate the problem. Once application technique has been chosen the app then provides personalised application instructions.
- **TRL:** 9
- **Relevant targets:** Tomato disorders that may be caused by fungi, bacteria, viruses, nematodes, phytoplasmas, pests, insects, weeds and other pathogens.
- **Technology used:** Smart reasoning machine (AI) questionnaire and Agri database loaded with open and coded data.

3.2.5 Cropify

- **What is it?** This is a Plant Disease Identifier. Upload an image of (tomato, potato) plants and identify the disease that affects it. Learn about remedies and there is a practical video explanation to prevent further loss of plants. Using deep learning model to detect the disease of a plant through the smart phone using camera to scan over leaf and guide them with instant remedies.
- **TRL:** 9
- **Relevant targets:** Disease (Tomato leaf curl, Tomato powdery, Tomato stemshot, Tomato late blight, early blight, bacterial leaf spot).
- **Technology used:** AI image disease recognition.

3.2.6 Agrobases

- **What is it?** AgroBase is an app containing information on pests, weeds, diseases and all registered pesticides in a chosen country. 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://agrobasesapp.com/>
- **Technology used:** Knowledge database with images

3.2.7 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

3.2.8 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

3.2.9 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: Open field & Greenhouse

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): Open field

4.1.1 iMETOS stations and disease models

- **What is it?** All Pessi Instruments disease models are based on the latest research work from the best scientists and measured with the highest accurate sensors available. Timely disease alarms mean more efficient fungicide application, less spray and maximum crop yield and quality. IMETOS boast over 80 different disease models for more than 40 crops. <https://metos.at/disease-models-lettuce/>
- **TRL:** 9
- **Extra capabilities:** Part of the FieldClimate platform, a nested approach to IoT agriculture, which contains decision support surrounding irrigation, fertilising, pesticide application, harvesting and more 24/7 all year round.
- **Relevant targets:** Disease (Tomato late blight - *Phytophthora infestans*, early blight – *Alternaria solani*, Powdery mildew of tomato, Grey mould – *Botrytis cinerea*, *Septoria* leaf spot - *Septoria lycopersici*, Anthracnose fruit rot - *Colletotrichum*, Leaf mould - *Fulvia fulva*, *Phytophthora* blight – *Phytophthora capsici*).
- **Technology used:** Predictive disease modelling based on personal weather station and sensor data

4.1.2 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:** Disease (Late blight, Blue/grey mould, *Alternaria*).
- **Technology used:** Predictive disease modelling based on personal weather station data, soil monitor, weather forecast and growth observations.

4.1.3 Wisecrop

- **What is it?** This Plant Health app includes a set of tools to optimize the management of crops with regard to diseases, pests and phytosanitary treatments/spraying. One of the tools available is for disease and pest prediction models. There are a number of models, developed for different types of crops including tomatoes. They mostly rely on weather conditions, after setting up the base parameters of the crop, to indicate the current and future risk of certain diseases/pests and trigger alerts if the risk is High. This is one tool in a larger crop management system.

- **Extra capabilities:** Climate monitoring, irrigation optimisation, nutrition optimisation, field & labour management, cost calculation.
- **TRL:** 9
- **Relevant targets:** Pest and disease modelling (Not specified but it has been developed for tomatoes).
- **Technology used:** Weather sensors (Air temperature; humidity; wet leaf; speed and direction of the wind; Solar radiation, rainfall, among others).

4.1.4 Nematool

- **What is it?** Autonomous soil temperature probe associated with a digital app for nematode management. You will receive accurate alerts about the current generation of nematodes and the appearance of eggs that will give rise to the next generation. They interpret the information for you and offer you the necessary alerts for a correct management of nematodes.
- **TRL:** 9
- **Relevant targets:** Nematodes (*Meloidogyne spp.*)
- **Technology used:** Autonomous soil temperature data probe, predictive pest modelling

4.1.5 EVJA: OPI support system

- **What is it?** OPI collects and analyses agro-climatic data of your crops with advanced wireless sensors for agriculture, so you can focus on the information that matters the most to you and optimize your crop management. Complement your experience with disease predictive models, customized for your crops by artificial intelligence. You can now take action at the right time with notifications of threshold being exceeded, allowing you to optimize the use of agro-chemicals and biologic products for a lower chemical residue. Evja has been focusing on tomato cultivation for years.
- **Extra capabilities:** Climate monitoring, data history, risk management of plant stresses and frost, yield prediction.
- **TRL:** 9
- **Relevant targets:** Predictive models for pest and disease development.
- **Technology used:** Personal weather station & sensors (Air temp, air humidity, leaf wetness etc.). Predictive modelling.

4.1.6 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. This platform is used in tomato production.

- **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).

4.1.7 Agronet platform

- **What is it?** Platform where pest and disease prediction models are available for tomatoes that use environmental data (weather station) to model life cycles and plant growing periods to provide recommendations of what treatments to use and when. Insect monitoring (requires smart pheromone trap – they do not provide the pheromones) is also available which combines automated traps and analytics for optimized treatment applications.
- **Extra capabilities:** Irrigation optimisation, Frost prediction, Machinery tracking, Activity book, fertilization monitoring
- **TRL:** 9
- **Relevant targets:** Disease prediction (*Alternaria* spp., *Botrytis* spp). Pest monitoring (Tomato leafminer – *Tuta absoluta*, fall armyworm - *Spodoptera frugiperda*, Cotton bollworm - *Helicoverpa armigera*).
- **Technology used:** Predictive modelling based on personal weather station. Smart pheromone traps with cameras

4.1.8 Spec 9 Pro disease and insect models

- **What is it?** SpecWare uses Tom-Cast, a tomato disease forecasting program designed to predict Early Blight, Septoria Leaf Spot, and Anthracnose. Tom-Cast calculates a disease severity value (DSV) to predict the development of these diseases. The Tom-Cast model requires air temperature and leaf wetness data. Specware also provides insect models for tomatoes.
- **Extra capabilities:** N/A
- **TRL:** 9
- **Relevant targets:** Early Blight, Septoria Leaf Spot, and Anthracnose. Insect models.
- **Technology used:** Predictive disease modelling based on personal leaf wetness and temperature sensors.

4.1.9 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 without personal sensors.

4.2 Decision support (Without sensors): Open field

4.2.1 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:** Example tomato pests as listed on the website : White fly (*Bemisia tabaci*), Onion thrips (*Thrips tabaci*), Tobacco thrips (*Frankliniella fusca*), Western flower thrips (*Frankliniella occidentalis*), Beet armyworm (*Spodoptera exigua*), Turnip moth (*Agrotis ipsilon*), Buckthorn aphid (*Aphis nasturtii*), Peach-potato aphid (*Myzus persicae*), Foxglove aphid (*Aulacorthum solani*), Tomato leafminer (*Tuta absoluta*), Nematodes (*Meloidogyne incognita*, *Meloidogyne javanica*), Diamondback moth (*Plutella xylostella*) and many more.
- **Technology used:** Predictive pest modelling based on weather data.

4.2.2 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

4.2.3 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 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:** Monitoring imagery for plant health insights & identifying problem areas, Ai mobile image pest and disease recognition (for more detailed information on specific pests and diseases see Agrio in Mobile disorder detection techniques), Treatment intervention, Alerts, Warning notifications, pest life-cycle tracking.
- **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.

4.2.4 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. Link: www.effispray.com.

- **Extra capabilities:** N/A
- **TRL:** 9
- **Relevant targets:** Optimal spray timing support
- **Technology used:** Weather data

4.3 Decision support with sensors: Greenhouse

4.3.1 Nematool

- **What is it?** Autonomous soil temperature probe associated with a digital app for nematode management. You will receive accurate alerts about the current generation of nematodes and the appearance of eggs that will give rise to the next generation. They interpret the information for you and offer you the necessary alerts for a correct management of nematodes. Through solarization, you can use solar energy to increase soil temperature and control pests, diseases, and weeds. Nematool monitors ground temperature to indicate the quality of the solarization process.
- **TRL:** 9
- **Relevant targets:** Nematodes (*Meloidogyne* spp.)
- **Technology used:** Autonomous soil temperature data probe, predictive pest modelling

4.3.2 iMETOS stations and disease models

- **What is it?** All Pessl Instruments disease models are based on the latest research work from the best scientists and measured with the highest accurate sensors available. Timely disease alarms mean more efficient fungicide application, less spray and maximum crop yield and quality. iMETOS boast over 80 different disease models for more than 40 crops.
- **TRL:** 9
- **Extra capabilities:** Part of the FieldClimate platform, a nested approach to IoT agriculture, which contains decision support surrounding irrigation, fertilising, pesticide application, harvesting and more 24/7 all year round.
- **Relevant targets:** Disease (Tomato late blight - *Phytophthora infestans*, early blight – *Alternaria solani*, Powdery mildew of tomato, Grey mould – *Botrytis cinerea*, *Septoria* leaf spot - *Septoria lycopersici*, Anthracnose fruit rot - *Colletotrichum*, Leaf mould - *Fulvia fulva*, *Phytophthora* blight – *Phytophthora capsici*).
- **Technology used:** Predictive disease modelling based on personal weather station and sensor data.

4.3.3 EVJA: OPI support system

- **What is it?** OPI collects and analyzes agro-climatic data of your crops with advanced wireless sensors for agriculture, so you can focus on the information that matters the most to you and optimize your crop management. Complement your experience with disease predictive models, customized for your crops by artificial intelligence. You can now take action at the right time with notifications of threshold being exceeded, allowing you to optimize the use of agro-chemicals and biologic products for a lower chemical residue. Evja has been focusing on tomato cultivation for years.
- **Extra capabilities:** Climate monitoring, data history, risk management of plant stresses and frost, yield prediction.
- **TRL:** 9
- **Relevant targets:** Predictive models for pest and disease development.
- **Technology used:** Personal weather station & sensors (Air temp, air humidity, leaf wetness etc.). Predictive modelling.

4.3.4 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. This platform is used in tomato production.
- **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).

4.4 Decision support without sensors: Greenhouse

4.4.1 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. Image monitoring technology only available in open field but the app can be used in the greenhouse for the AI image recognition software. Following identification of the plant problem, the software aids you in the decision making of the next steps for treatment.

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:** Ai mobile image pest and disease recognition (for more detailed information on specific pests and diseases see Agrio in Mobile disorder detection techniques), Treatment intervention, Alerts, Warning notifications, pest life-cycle tracking.
- **Technology used:** Mobile imagery AI pest and disease recognition supported by mobile imagery & collaboration + advisory tool.

4.4.2 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:** Example tomato pests Futurcrop can predict listed on the website : White fly (*Bemisia tabaci*), Onion thrips (*Thrips tabaci*), Tobacco thrips (*Frankliniella fusca*), Western flower thrips (*Frankliniella occidentalis*), Beet armyworm (*Spodoptera exigua*), Turnip moth (*Agrotis ipsilon*), Buckthorn aphid (*Aphis nasturtii*), Peach-potato aphid (*Myzus persicae*), Foxglove aphid (*Aulacorthum solani*), Tomato leafminer (*Tuta absoluta*), Nematodes (*Meloidogyne incognita*, *Meloidogyne javanica*), Diamondback moth (*Plutella xylostella*) and many more.
- **Technology used:** Predictive pest modelling based on weather data.

5 Application

5.1 Sprayers: Open field

5.1.1 Trailed sprayer WHIRLWIND M612 “ALBATROS” (Open field)

- **What is it?** The Whirlwind M612 “Albatros Field Crop” Sprayers are sprayers with special boom configuration for the application of fungicide/insecticide treatments on vegetable crops such as tomatoes. 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:** 10/12 km/hour
- **Technology used:** Electrostatic air assisted boom sprayer

5.1.2 ESS Electrostatic spraying system 350RC & 450RC (Open field)

- **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:** Boom sprayer with electrostatic droplet release

5.1.3 Smartomizer

- **What is it?** The Smartomizer is a pro-active system which automatically adjusts it's spraying according to cover of vegetable crop. It gathers and monitors all important spraying data which directly affects the quality and productivity of the specialty crops.
- **Benefits/ information:** Reduced power consumption by 55%, noise contamination by 15dBA, potential sediment drift by 48% compared with bottom line reference sprayer.
- **Working speed:** 5

- **TRL:** 9
- **Technology used:** Air blast trailed sprayer

5.1.4 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

5.1.5 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:** 7km/ h
- **Technology used:** Dropleg sprayer

5.1.6 Dropleg® Beluga

- **What is it?** Underleaf 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:** 7km/ h
- **Technology used:** Dropleg sprayer

5.1.7 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:** 7km/ h
- **Technology used:** Dropleg sprayer

5.2 Sprayers: Greenhouse

5.2.1 Greenhouse spray robot with vertical booms (s55)

- **What is it?** S55 is a spray robot with batteries made for automatic spraying. It works using a pipe rail system to move through a greenhouse. It is only 30cm wide. The spray robot moves on its own so that the operator does not come into contact with the spray. Easy operation with main switch, emergency switch and 4 push buttons. Adjustable nozzle. S55 works for tomato, cucumber, pepper and aubergine.
- **Benefits/ information:** Non-selective spraying robots such as this one have been found to achieve coverage of about 92%
- **TRL:** 8
- **Technical information:** Speed (20-100m/min), covers up to 3500m²/h.
- **Technology used:** Spraying robot.

5.2.2 Greenhouse sprayer OPRS 202 hybrids

- **What is it?** The robot is for use in greenhouses and moves smoothly through the heating pipes via an electric and internal combustion engine with a capacity of 205cm³ and a power of 6.5 HP. The sprayer goes to the end of the row and from the end begins the procedure going towards the connector, this allows even and fast spraying, which is effective only when it is done immediately after the detection of an outbreak of plant disease. The track width of the wheels is adapted to the individual needs of the customer. The PLC operating the device additionally counts the hours worked and also allows you to save the routes and current configuration.
- **Benefits/ information:** Special nozzle also sprays bottom part of plant leaf
- **TRL:** 9
- **Technical information:** Tank capacity (200L), Maximum yield (40l/min), travel speed (0-85m/min).
- **Technology used:** High precision mounted boom sprayer with smart image recognition targeted spraying

5.3 Sprayer drones: Open field

5.3.1 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).

5.3.2 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).

5.3.3 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

5.3.4 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).

5.4 UV-systems: Open field

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 (Mildew, *botrytis*, etc.).
- **Technology used:** UV light tractor rear mount implement.

5.4.2 Thorvald

- **What is it?** 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 the 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 labour requirement. Commercial solutions for glasshouse-grown crops such as tomatoes and cucumbers are currently under development.
- **Benefits/ information:** Protects your crop every night, efficient autonomous, sustainable and saves on labour compared with conventional fungicide application.
- **TRL:** 9
- **Application targets:** Disease (Powdery mildew, etc.).
- **Technology used:** UV light tractor rear mount implement.

5.5 UV-systems: Greenhouse

5.5.1 CleanLight UV crop protection

- **What is it?** UV light daily treatment that kills diseases on crops before they become visible, make spores and therefore before they damage the crops. Acts as a substitute for chemicals and in some cases a complete replacement. Providing the advantage of being a dry method with no build up for resistance, no re-entry criteria and safe for beneficial insects. Originally started in 2005 to protect tomato plants in a Dutch greenhouse, since then the company has grown.
- **TRL:** 9
- **Disease target:** Mildew, *botrytis*, etc.
- **Technology used:** UV light greenhouse heating rail attachment.

5.5.2 Micothon UVC

- **What is it?** Micothon develops and produces a range of mobile and stationary solutions that can control and kill the fungi on growing plants in greenhouses by UVC light. In order to control fungi, the UVC disinfecting process must be carried out every one or two days as new fungi spores have to be stopped before they can reproduce. The Flora UVC is a tube/ rail robot that is available in semi-automatic or a fully automatic version.
- **TRL:** 9
- **Disease target:** Virus, bacteria, fungi.
- **Technology used:** UV light greenhouse heating rail attachment or attachment to Micothon spraying robot.

5.5.3 Lumion UV-C robot

- **What is it?** Robotic platform outfitted with UV-C lights called Lumion. Lumion helps to manage powdery mildew on strawberries, tomatoes and cucumbers using UV-C light. The fungus specific DNA absorbs the UV-C light, thus avoiding damage to the crop. It is a robot that can move around the crop. The platform can operate on rails or tires.
- **TRL:** 9
- **Disease target:** Powdery Mildew
- **Technology used:** UV-C light, modular autonomous robot.

5.5.4 Thorvald

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- **Benefits/ information:** Protects your crop every night, efficient autonomous, sustainable and saves on labour compared with conventional fungicide application.
- **TRL:** 8
- **Application targets:** Disease (Powdery mildew, etc.).
- **Technology used:** UV light tractor rear mount implement.

5.6 Distribution systems for beneficials: Open field

5.6.1 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. Only compatible with Koppert products.
- **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:** *Chrysopa* (Lacewing) for the control of aphids. Thripex for control of various species of thrips and many more.
- **Technology used:** Trailer or boom attachable airstream release system.

5.6.2 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:** *Chrysopa* (Lacewing) for the control aphids. Thripex for control of various species of thrips. Spidex for control of two-spotted spider mite & many other mites (Excluding red mite)
- **Technology used:** Drone operated by company pilot.

5.7 Distribution systems for beneficials: Greenhouse

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- **TRL:** 9
- **Application targets:** *Chrysopa* (Lacewing) for the control of aphids. Thripex for control of various species of thrips and many more.
- **Technology used:** Trailer or boom attachable airstream release system.

5.7.2 Koppert's Airbug range

- **What is it?** The Airbug and Airobug blowers distribute predatory mites quickly and evenly. This uniform distribution leads to effective biological pest control because the mites reach the pest faster. Several kinds of predatory mites can be released during a single session. Airobug for large surfaces and full-field distribution - high-tech cultivations with mono-rail or pipe-rail. Airbug hand-held blower - full-field distribution - low and mid-tech cultivations without mono-rail or pipe-rail. Mini-Airbug hand-held blower for hotspot application.
- **Benefits/ information:** Ranging from 2-3 metre dispersal range with the Mini-Airbug to up to 10-12 metres with the Airobug.
- **TRL:** 9
- **Application targets:** Range of predatory mites for control of thrips and whiteflies. The devices can also theoretically work with other Koppert biological control products such as *Chrysopa* (Lacewing) for the control of aphids.
- **Technology used:** Automatic pipe-rail or mono-rail blower. Two different handheld blowers.

5.7.3 Agrobio: Bio spreader

- **What is it?** This hand blower is very suitable for blowing especially predatory mites (*montdorensis/swirskii/cucumeris*) but can also be used for other insects. It has a range of four metres. The Biospreader is mainly used for quick manual application of biocontrol agents, particularly mites, when the greenhouse is not suitable for an automated system.
- **Benefits/ information:** Portable, ideal for smaller greenhouses and sold through royal brinkman which offers personal advice from their specialists.

- **TRL:** 9
- **Application targets:** Predatory mites for the control of whiteflies and thrips but could be used for the dispersal of a range of beneficials from Agrobio and others.
- **Technology used:** Handheld blower.

5.8 Other

5.8.1 Pats-X indoor drone solutions

- **What is it?** Pats design drones that eradicate flying pest insects. Their bio-inspired solution proactively controls harmful insect populations. The bat-like drones work autonomously and keep infestations in check. By selectively eliminating harmful insects the ecological balance in a greenhouse ecosystem is sustained.
- **Benefits/ information:** Autonomous insect control with zero pesticides.
- **TRL:** 9
- **Application targets:** Tomato looper (*Chrysodeixis chalcites*), European pepper moth (*Duponchelia fovealis*), Tomato leafminer (*Tuta absoluta*).
- **Technology used:** Autonomous image recognition, automatic pest targeting drone.

5.8.2 Biocaptur S50

- **What is it?** BIOCAPTUR S50 is an innovative, ecological solution for pest control in intensive agriculture. It is high-performance equipment based on the emission of electromagnetic radiation and uses LED technology as emitters of this radiation. The equipment is designed to operate at night, activating its operation through photoelectric sensors that can be combined with hourly timers. BIOCAPTUR S50 works with specific LED technology to attract pests, suck them out and finally catch them.
- **Benefits/ information:** Autonomous insect control with zero pesticides.
- **TRL:** 9
- **Application targets:** Primarily *Tuta absoluta* from first stages to adulthood (in trials the Biocaptur has also caught beet armyworm and cotton bollworm)
- **Technology used:** LED lights, spiral turbine, housing chamber.

5.8.3 Tutatec

- **What is it?** TUTATEC is a dispenser comprising the blend of two compounds (E,Z,Z)-(3,8,11)-tetradecatrienyl acetate and (E,Z)-(3,8)-tetradecadienyl acetate. These compounds are described as components of the sex pheromone of *Tuta absoluta*. The use of these cause sexual confusion (mating disruption) to control the moth *Tuta absoluta* in tomato. If there is no encounter between the sexes, there is no reproduction and the females do not lay the fertile eggs.
- **Benefits/ information:** Highly efficient in low or moderate pest infestations.

- **TRL:** 9
- **Application targets:** *Tuta absoluta*.
- **Technology used:** Sex pheromone mating disruptor.

5.8.4 Optinet

- **What is it?** Anti-insect mesh net range which blocks the entry of pests and insects into the crop environment and therefore helps to significantly reduce the use of pesticides. A study using Optinet 40 and 50 mesh products on tomatoes, cucumbers and chives found thrip infections to be 3 to 4 folds lower than under a standard 50 mesh screen.
- **Benefits/ information:** A study using Optinet 40 and 50 mesh products on tomatoes, cucumbers and chives found thrip infections to be 3 to 4 folds lower than under a standard 50 mesh screen.
- **TRL:** 9
- **Application targets:** Mediterranean fruit flies, whiteflies, aphids leafminers, thrips (dependent on the net that is used).
- **Technology used:** Non-toxic additives that blind and repel the insects before they reach the net.