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CORDIS Results Pack on

plant health

A thematic collection of innovative EU-funded research results

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Keeping plants healthy while protecting the environment

Research and Innovation

NEW EDITION

Contents

Editorial

Plants are at the centre of life itself. They are a primary source of food for us, as well as for the animals we eat. They help regulate the climate and are a part of the natural environment in which we live. With millions of people regularly employed in the agricultural sector, plants are also a key part of the EU economy. Ensuring plant health is therefore paramount to safeguarding the bloc's economic stability and its citizens' well-being. This new edition of the CORDIS Results Pack on Plant Health showcases 12 EU-funded projects at the forefront of research and innovation activities in this domain.

Plant health is a broad term. It covers protecting plants and crops from deadly pests and disease, mitigating the adverse effects of climate change on plants' ecosystems, and transforming the agricultural sector to feed the world's growing population. In 2016, the United Nations acknowledged plant health as one of the most pressing concerns of our time, declaring 2020 as the International Year of Plant Health.

Importantly, sustainability is at the centre of all efforts to improve plant health: fighting pests and increasing crop yield must be achieved without putting further strain on the environment through the improper use of pesticides. Avoiding hazardous chemicals when addressing pests protects the environment as well as pollinators, natural pest enemies, beneficial organisms, and the people and animals who depend on plants.

Towards sustainable and eco-friendly protection of plants

The European Commission's Farm to Fork Strategy, a fundamental component of the European Green Deal, capitalises on the importance of ensuring sustainability across the food value chain. Taking a holistic approach, the strategy highlights the interconnected nature of food production and aims to keep plants healthy while reducing the impact of food systems on the environment, which goes hand in hand with guaranteeing fair economic returns for farmers and boosting public health and innovation.

With sustainable food production as a key priority, the strategy sets targets to significantly reduce the use and risk of chemical pesticides and fertilisers as well as antimicrobials. It also proposes a revision of the Sustainable Use of Pesticides Directive 2009/128/EC that aims to achieve a sustainable use of plant protection products in the EU, for example by promoting the use of integrated pest management and other non-chemical alternatives to pesticides.

Pioneering EU-funded research leading the way

Following the first edition of the Results Pack on Plant Health, this new edition introduces 9 new projects and 3 updates to projects from the first edition.

Under the XF-ACTORS project, researchers gained significant insights into the European origin of the dangerous plant bacteria, *Xylella fastidiosa* (Xf). Focusing on *Fusarium oxysporum*, another formidable parasite, FOUNDATION studied an ancestral land plant to understand how the parasite has evolved and find novel control strategies.

The Asterix project developed an autonomous robot named AX-1 (formerly Asterix) that reduces the use of pesticides while simultaneously boosting farm profitability. Also taking a technological approach to improving plant health, GREENPATROL developed a new robotic system enabled by the Galileo navigation satellite system to autonomously detect and treat pests in greenhouse crops.

As an alternative to pesticides, the ChemPrime project engaged with agri-tech companies to facilitate the adoption of a crop protection strategy based on chemical plant priming agents. Lipofabrik developed and patented two products that are key to meeting the low toxicity needs of the agricultural sector.

Several projects adopted a crop-specific focus. MUSA developed more sustainable alternatives for protecting banana crops, while TomRes tested and optimised sustainable crop management strategies for tomatoes. The RiZeSisT project investigated alternatives to chemical methods for controlling sheath blight, and NEURICE, also looking at rice, introduced genetic variation in rice crops to address rice sensitivity to salinity and resistance to pest infestation.

Recognising the importance of quick, accurate and reliable detection and identification of plant pests, the VALITEST project strived to enhance the reliability of tests used for these purposes in Europe. INNOSETA established a thematic network on spraying equipment, training and advising to close the gap between the available new high-end crop protection solutions and European farmers.

Fight to protect Europe's agriculture from devastating pest

Historic olive groves and a huge variety of other plants are at risk from a highly destructive invasive pathogen. XF-ACTORS brought together international expertise promoting a fruitful exchange and development of knowledge amongst different experts and disciplines that will help growers to manage the pest and prevent further economic losses in crops.

The plant pathogen *Xylella fastidiosa* (Xf) is believed to have originated in Central America and is now found across the world. The bacterium is transmitted by insects as they feed on the plants' sap and progressively colonises the xylem tissues. These become blocked, robbing the plants of essential water and causing them to die of thirst from the inside.

The pathogen first made its appearance in Europe in 2013 in Puglia, Italy, where the local climate suited the spread of the disease, resulting in the destruction of millions of olive trees, some hundreds of years old. Since its detection in Puglia, different strains of the bacterium have been identified in northern Italy, France, Portugal and Spain. Olives and almond trees are the EU crops under major threat.

The XF-ACTORS project established a multidisciplinary research programme to improve prevention, early detection and control of the pathogen. "XF-ACTORS is the first international research project in Europe entirely devoted to developing a multidisciplinary research programme to fight *Xylella fastidiosa*, one of the most dangerous plant bacteria worldwide. The programme comprises 29 partners from 14 countries, including 4 non-European research centres from the United States, Brazil, Costa Rica and Taiwan," states project coordinator Maria Saponari. The project complements the work of the POnTE project, which has been working to minimise the risk of introduction/impact of emerging pests threatening EU agriculture and forestry.

Know your enemy

Thanks to the wide-scale use of genomic sequencing, researchers can now shed light on the origin of Xf in Europe, which reveals that the pathogen has a longer history in Europe than previously thought. "We now know that strains display a diversity of host ranges and aggressiveness, and so measures to control the impact of the infections should be tailored to the specific scenarios occurring in the different EU outbreaks in Italy, France, Portugal and Spain," says Saponari.

Advances have also been made in deciphering the mechanisms and the components of the host immune systems responding to Xf infection, opening new routes for future breeding programmes and long-term sustainable management approaches. Project partners also developed the largest data set of genome sequences, offering a unique tool for answering biological and epidemiological questions based on analyses of phylogenetic relationships and population structures.

Studies in laboratories and under field conditions revealed which plant species the EU insect vectors prefer to feed on, their feeding behaviours and during which stage in their life cycle they became effective carriers of the bacterium. Greater knowledge about the insect vectors means more targeted interventions to reduce their population and their capability of transmitting Xf.

Researchers also created risk maps to predict the pathogen spread, enabling the most vulnerable sites to be identified and surveillance prioritised. "The biological data have been used to fine-tune the parameters of the epidemiological models, to ensure they represent as close as possible the real disease scenarios," Saponari comments.

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Knowledge is power

Finding a definitive solution for therapy against Xf is a long-term and ambitious objective. Thanks to XF-ACTORS, we now know several aspects of the outbreak in Europe. Knowledge generated by XF-ACTORS research will help growers to manage the pest and prevent further economic losses in crops. "This includes tools to mitigate the impact of the disease, such as reducing the vector populations or improving the plants' resilience to infection. It will also enhance the capacity and competence of plant health authorities to strengthen the EU plant health regime and improve prevention measures like legislation, technical procedures, means of disease control and so on," points out Saponari.

PROJECT

Xylella Fastidiosa Active Containment Through a multidisciplinary-Oriented Research Strategy

COORDINATED BY

The National Research Council in Italy

FUNDED UNDER

H2020

CORDIS FACTSHEET

cordis.europa.eu/project/id/727987

Parasitic fungus causing wilt and plant death targets different crops to wreak havoc

Fusarium oxysporum is a formidable parasite; attracted by chemicals released from plant roots, it systemically invades its host, causing massive collapse and death. By studying its molecular dialogue with plants, EU researchers with the FOUNDATION project are looking for new control strategies.

More than 120 forms of *Fusarium oxysporum* (Fo), each adapted to a specific crop, cause gigantic economic losses worldwide. "A recently emerged strain, Tropical Race 4, currently threatens to eradicate global banana production," says Antonio Di Pietro, project coordinator and Professor of Genetics at the University of Cordoba.

Parasite molecules 'talk' to the host plant

The research group studied the interaction of Fo in four different plant species: tomato, banana, the model plant Arabidopsis, and the ancestral land plant *Marchantia polymorpha*. "This enables us to identify the conserved mechanisms underlying biotrophic, or live cell, infection stages of Fo wilt disease during interaction with a broad host range," outlines Di Pietro. This research was undertaken with the support of the Marie Skłodowska-Curie Actions programme.

Some time ago, the research team discovered a chemotropic sensing mechanism by which this fungus locates plants in the soil and grows towards chemoattractants released by the roots. The invader then grows silently in the root and colonises the vascular tissue, often leading to plant death.

A second type of crosstalk occurs when the fungus grows between the cells of the root cortex, the apoplast. Di Pietro explains: "By using discovery proteomics, we are looking for key signalling molecules from both parties that likely shape the biotrophic molecular dialogue."

Evasion of the plant immune system is key to successful infection

FOUNDATION has provided unprecedented glimpses of the early infection stages and the molecular dialogue with the multiple plant hosts. For example, the research group has identified the pathogenicity molecules (effectors) that mediate compatibility between fungus and plant.

Releasing these effectors helps the pathogen to become more virulent, so the scientists turned to look at *M. polymorpha*, a newly developed model infection system. Amey Redkar, the Marie Skłodowska-Curie fellow, says: "We aim to determine the function of the identified virulence proteins in this ancient, early, non-vascular land plant to understand how pathogen effector proteins have evolved."

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Applications for pathogen resistance in other crops

Evidence under the FOUNDATION belt suggests that monogenic resistance against Fo is based on molecular recognition of fungal molecules by specific host plant receptors. This then kick-starts the plant immune response.

However, pathogens can change their molecules or target the plant's defence system with specific effector proteins to suppress the immune response. Detailed knowledge of the 'arms race' between Fo and its hosts should reveal new resistance strategies.

FOUNDATION research has generated new, large-scale data sets, a valuable resource for the scientific community. "Moreover," Di Pietro continues, "we can now mine the apoplastic root proteome during Fo infection." An activity-based protein profiling (ABPP) approach has rarely been achieved so far in fungal root interactions and can be used to find missing parts of the molecular cascades for development of sustainable resistance.

A methodological constraint prompted a multi-model approach

Obtaining sufficient fungal biomass for digging out these biotrophic fungal signals has been a challenge. Hence, the FOUNDATION multi-model host system has been crucial. Tomato-Fusarium, for example, is a well characterised system that provides abundant root biomass for biochemical analysis.

"We also performed ABPP in the Banana-Fusarium pathosystem, another rare achievement," Redkar points out. Simultaneously, this provided opportunities to cross validate results from different crop plants.

Application of fungicides to the soil is now banned in most agricultural settings so improving plant resistance is the most efficient way to manage these devastating, difficult-to-control diseases. Di Pietro sums up: "FOUNDATION has provided key insights into the molecular biology of vascular wilt disease and opened up new avenues for crop resistance breeding."

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PROJECT
Fusarium oxysporum mediated underpinning of cell type-specific modulation in multiple host interaction

COORDINATED BY
The University of Cordoba in Spain

FUNDED UNDER
H2020

CORDIS FACTSHEET
cordis.europa.eu/project/id/750669

AX-1 the farmer robot conquers weeds selectively and sustainably

Global population growth and climate change are threatening the world's food supply. An EU-funded biopesticide-spraying robot with an eye for weeds is boosting crop yield sustainably.

The widespread use of pesticides increases the potential health effects on the people who farm and consume products exposed to pesticides. It also has serious effects on natural pollinators critical to our food supply.

Precision agriculture can increase the effectiveness of inputs to enhance farm profitability, natural resource management, and environmental and human well-being. The EU-funded Asterix project has embodied these benefits in an autonomous robot named AX-1 (formerly Asterix) that applies eco-friendly biopesticides sparingly.

AX-1 uses a bioherbicide and our innovative spraying technique ensures selectivity. A patented, vision-based, ultrahigh-precision nozzle system is integrated with machine learning algorithms trained to differentiate between crops and their weeds.

Bigger is better and hits just the spot

Conventional herbicides are applied by blanket spraying a mist over the whole field, killing weeds but also harming the crop. Further, wind can carry the tiny droplets over significant distances where they can settle on water resources, adjacent vegetation, farm workers, and neighbouring homes and people.

Project coordinator Anders Brevik of Kilter AS, the newly formed sister company of coordinator Adigo AS, explains: "AX-1 uses a bioherbicide and our innovative spraying technique ensures selectivity. A patented, vision-based, ultrahigh-precision nozzle system is integrated with machine learning algorithms trained to differentiate between crops and their weeds." AX-1 sprays relatively large individual droplets of bioherbicide only on the weed leaves. The larger drops minimise drift to non-targets.

© Anders Brevik

Focus on farmers, benefits for all

The result of more than 10 years of development and field testing, AX-1 can work around the clock, weeding most vegetables and herbs at a rate of approximately 1 hectare per hour. It reduces the amount of weed killer used by up to 95 % – its 50 litres of herbicide are equivalent to the 1 000 litres in a conventional sprayer. Weighing about 10 % less than a tractor and sprayer, AX-1 can also drive in the field shortly after rain to increase productivity.

Importantly, AX-1 significantly augments yield. "We know from experience that herbicide use slows down crop development. We thought we might increase yield by about 5 %, but early data in parsley root suggest that we get approximately 45 % higher yield with AX-1," adds Brevik. The technology can be used in both organic and conventional agriculture. It can nearly eliminate pesticide use in traditional farming and enhance the efficiency of production while significantly lowering the cost of organic farming techniques. In short, it enables farmers to produce food that is good for consumers, the environment and the climate at an economically viable price.

Sowing the seeds of change

Asterix addressed the European Commission's 2030 target to reduce the use and risk of chemical and more hazardous pesticides by 50 %. Market penetration will become easier and the technology more widespread as European Commission regulations change to reflect and support these goals. The first units are scheduled for delivery April 2021, and the team forecasts 10 or more additional sales within Germany and Norway in 2021 before moving into the rest of Europe.

Brevik concludes: "We are out of balance with Mother Nature. By radically reducing the area we use for farming with diets that are largely plant based, we can make space for the wilderness to return. Our products and solutions increase agricultural yields while at the same time using fewer pesticides, less fertiliser and emitting less carbon." AX-1 is on its mission to conquer new lands and do its part to save the planet in the process.

PROJECT
Weeding robot for precision farming reducing herbicide usage by 95%

COORDINATED BY
Kilter AS in Norway

FUNDED UNDER
H2020

CORDIS FACTSHEET
cordis.europa.eu/project/id/829983

Pest control with help from space

A new robotic system enabled by the Galileo navigation satellite system autonomously detects and treats pests in greenhouse crops, paving the way for higher yields and lower use of pesticides.

Farmland has been on the decline in Europe for years, due to growing urbanisation. The move to protect and increase forest areas has also had an impact, making greenhouse farming more relevant than ever. While greenhouses enable farmers to produce more with less, their warm and moist conditions also allow for infestations to spread rapidly: pests and diseases cause around 15 % of losses for an average greenhouse in the EU.

The EU-funded GREENPATROL project has designed a solution that could help farmers tackle this issue while minimising the use of chemical insecticides. It uses Galileo, Europe's Global Navigation Satellite System (GNSS), to guide a robot inside the greenhouse which can autonomously detect pests, apply treatments and monitor infestations.

Eye in the sky

"The solution is a tool for precision farming, where GNSS technology is a key enabler. Using the satellite system's precise positioning algorithms and combining this data with information from on-board sensors, GREENPATROL is able to position itself inside the greenhouse with an accuracy of within 20 cm," explains Raúl Arnau Prieto, project manager at the Technological Centre CTC and GREENPATROL project coordinator.

Precision farming aims to increase productivity while reducing waste and hazards by observing and monitoring crops and collecting data on plant health with the help of satellite navigation.

"Greenhouse structures can make satellite signals difficult to track. The Galileo wideband signal offers significant advantages in this type of environment, greatly improving the performance inside the greenhouse," says Michael Pattinson, engineering manager and project manager for GREENPATROL at GMV NSL.

Smart decision-making

The robot is equipped with artificial intelligence to carry out a broad range of tasks without human intervention. "GREENPATROL is capable of scouting the greenhouse looking for pests. It detects them and identifies the most harmful species using a deep learning vision system. The system then maintains a model of what has been detected and the evolution of the impact of the pest in the crop field," Arnau Prieto explains.

GREENPATROL is capable of scouting the greenhouse looking for pests. It detects them and identifies the most harmful species using a deep learning vision system.

In addition to its automated features, the solution could be instrumental in supporting decision-making for integrated pest management strategies, which combine a number of techniques to minimise risks to people and the environment: "The system provides detailed information to human operators on which regions to inspect and which pesticides to apply where."

Strategic value

GREENPATROL could play a strategic role in reducing the burden of pest control. "Such an interconnected system could ultimately map all diseases affecting crops in a particular region and thus enable us to fight pests more effectively while significantly reducing the amount of pesticides used," notes Dalibor Húska, leading researcher for Integrated Pest Management Strategy at Mendel University, in Brno.

Having delivered a fully functional prototype, the project team is currently working to bring their product to the market. The exploitation plan demonstrates that the robot's industrial production could deliver profits within 3 years.

© GREENPATROL

While the system has been initially focused on tomato plants as a high value vegetable for the EU, the solution can easily be adapted to other types of crops.

To further extend and improve the robot's capabilities, the team has submitted a new project proposal that aims to make the system fit for the next generation of insecticides using nanoparticles.

PROJECT

Galileo Enhanced Solution for Pest Detection and Control in Greenhouse Fields with Autonomous Service Robots

COORDINATED BY

The Components Technological Centre Foundation in Spain

FUNDED UNDER

H2020

CORDIS FACTSHEET

cordis.europa.eu/project/id/776324

New technology prepares crops' immune system against attack

Consumers in Europe and beyond are showing increasing concern about the presence of pesticides in agricultural food products and the environment. Hence, there is an urgent need for effective crop protection strategies that will minimise, and ultimately eliminate, reliance on pesticides, while being economically viable for farmers.

A large proportion of global harvests are lost each year to plant diseases. Although pesticides help to reduce these losses, there are worries about pesticide resistance and their impacts on health and the environment. One alternative is the treatment of plants with chemical priming agents that increase their resistance to pests and disease. This long-lasting protection is based on a form of immunological memory, which enables plants to mount a faster and stronger immune response against future attack.

The EU-funded ChemPrime project addressed this challenge by facilitating the adoption of chemical plant priming agents as a crop protection strategy. "The initiative aimed at obtaining specific knowledge to facilitate the translation of our basic research on chemically induced plant immune memory into crop protection strategies," states project coordinator Jurriaan Ton.

Important insights

The project engaged with agri-tech companies to identify possible obstacles to the adoption of priming chemicals as a crop protection technology and map out commercialisation routes. Researchers also increased the synthesis efficiency of priming chemicals to reduce the costs of production and make the agents more affordable and attractive for agricultural exploitation.

Prior research identified mechanisms by which selected β-amino acid chemicals can induce broad-spectrum resistance with minimal side effects on plant growth. "A previous European Research Council project called PRIME-A-PLANT revealed key insights into how plants perceive and respond to priming-inducing chemicals. ChemPrime developed these discoveries into a crop protection strategy through working with commercial stakeholders," explains Ton.

A new technology

Initial project work involved translational research to make the concept more attractive to commercial stakeholders. "We have identified genetic targets to improve the effectiveness of the priming response to selected β-amino acids. We have also examined the effectiveness of these priming chemicals against a range of economically relevant crop diseases, the occurrence of chemical residues in crop products, and the importance of chemical formulation for applications in different production systems," notes Ton.

In a second phase the project mapped out pathways for the commercialisation and application of priming chemicals as a new crop protection technology. This research has identified the need for genetic (and potentially epigenetic) selection of crop varieties that respond optimally to priming chemicals as a means to tailor the technology to specific crop products.

In addition, it found that hydroponic production systems, such as greenhouses and vertical urban farms, are the most viable and obstacle-free route to application, while exploitation of priming chemicals in soil-based production systems requires crop-specific optimisation of slow-release seed coating technology. Importantly, this research also identified the need for cost-efficient synthesis pipelines of priming chemicals to increase potential demand in the crop protection industry.

Commercial engagement

ChemPrime generated results that are of both scientific and translational value. "We uncovered new regulatory genes in the perception, signalling and trade-offs of chemical immune priming in plants," Ton says. "These can be used by crop breeding companies to select for crop varieties that respond well to these resistance-inducing chemicals. Our findings also provided new clues about the mechanisms by which primed plants retain epigenetic immune memory."

We uncovered new regulatory genes in the perception, signalling and trade-offs of chemical immune priming in plants.

Engagement with the agri-tech sector provided a better understanding of the exploitation potential of chemical priming agents, as well as stakeholder demands and expectations of new crop protection strategies. "This has led to a new research partnership with a seed company that aims at exploiting epigenetic variation in lettuce to optimise immune priming against downy mildew diseases. In addition, ChemPrime is exploring funding opportunities to create a spin-off company for the biochemical production of bioactive β-amino acids," concludes Ton.

PROJECT
A new crop protection strategy by chemical priming of the plant immune system

COORDINATED BY
The University of Sheffield in the United Kingdom

FUNDED UNDER
H2020

CORDIS FACTSHEET
cordis.europa.eu/project/id/824985

Meet the biosolutions set to revolutionise the agriculture sector

The use of chemical products for plant protection and growth may be a thing of the past as an EU-funded project gears up to take their biopesticide and biostimulant products to market.

The world population continues to grow and is projected to reach near 10 billion people by 2050. Rising alongside this is the demand for food, with many turning to intensive farming practices to grow high-yield crops to meet it. Such methods, however, can lead to the overuse of, amongst others, fertilisers, synthetic plant protection products and fossil fuels and ultimately affect biological diversity and climate change. This has heightened the need for more sustainable agricultural practices and a growing demand from the EU for bio-based products.

Meeting this demand head on, the EU-funded Lipofabrik project aimed to provide the agricultural market with effective and environmentally friendly alternatives to current chemical products used to safeguard plants and increase crop yield. "The cutting-edge research team at Lipofabrik, a start-up from the University of Lille, has developed and patented two products from *Bacillus subtilis*: PlantBoost® and LipoMyco®," explains Arnaud Delecroix, project coordinator. "They are protected by three patents and are extremely important for meeting the need in the agriculture sector for new, green and low-toxicity products."

A closer look at PlantBoost® and LipoMyco®

Biostimulants are known for their benefits to crop health and performance. They can improve plant growth by enhancing nutrient uptake, crop quality and nutrient efficiency, and tolerance to abiotic stress. PlantBoost® is a biostimulant product that can help boost the growth of plants such as tomatoes, lettuce, cucumber and other vegetables. It can also be applied to fruit plants such as grapes, apples and citrus fruits. Delecroix highlights: "The results from the tests we performed using this product showed a growth increase in tested plants by more than 50 % when compared to the non-treated plants. We have seen its efficacy."

The cutting-edge research team at Lipofabrik, a start-up from the University of Lille, has developed and patented two products from Bacillus subtilis: PlantBoost® and LipoMyco®.

The LipoMyco® product, on the other hand, is an antifungal active ingredient. The first part of the name, Lipo, stands for lipopeptide. Lipopeptides are molecules obtained through a fermentation process of the *B. subtilis* strain. Myco refers to mycosubtilin, a vital and strong antifungal lipopeptide. Delecroix reports: "LipoMyco® is as efficient as a chemical product currently used to protect plants against fungi and moisture. It can be used on wheat, vineyards, potatoes and more. I am convinced that we have in our hands the most powerful biological antifungal active ingredient in the market."

Bringing the products to market

"This project helped us prepare PlantBoost® for the market and our next step is to start selling it by the end of the first semester 2021," confirms Delecroix. As for the LipoMyco® product, it will require a further six months to complete. "We are still developing a formulation for it so that it can be used by our partners. We are in a very good position to succeed in this." LipoMyco® is also being prepared for its registration in Europe and in the United States – a required step for new products in agriculture that can take three to five years. The required tests for this process are currently being performed.

"What we are doing at Lipofabrik is unique and made possible thanks to our extraordinary teams. It is through their hard work that we can transform the market and provide farmers with green, biological and biodegradable products that will replace toxic chemicals," concludes Delecroix.

PROJECT
A ground-breaking biomolecular production platform for safer, more efficient and sustainable pest control and crop health management

COORDINATED BY
Lipofabrik in France

FUNDED UNDER
H2020

CORDIS FACTSHEET
cordis.europa.eu/project/id/849713

Banana plant, soil and root ecology reveals sustainable routes to pest and disease control

All living organisms have enemies. EU-funded research has harnessed the enemies of banana plants' enemies for a natural battle in which banana plants, people and the environment are all winners.

Population growth and global climate change are putting tremendous pressure on our agricultural food chain, making it even more imperative to protect precious crops from pests and diseases. Banana crops are particularly susceptible, and their protection currently relies on chemical pesticides and fungicides. The EU-funded MUSA project set out to develop more sustainable approaches for banana crops by taking advantage of the microorganisms and insects that act as plant caretakers.

According to MUSA coordinator Aurelio Ciancio of the Institute for Sustainable Plant Protection, National Research Council of Italy: "Any organism noxious to plants has a number of natural enemies that we can use against it. These biocontrol agents include microorganisms like fungi, bacteria or even viruses as well as beneficial insects or mites that are antagonistic towards one or more pests. Some of these, usually fungi and bacteria, live inside a plant's roots or leaves – so-called endophytes." Identifying and utilising the ones beneficial to banana plants was the goal of MUSA.

© Aurelio Ciancio

The incredible plant microbiome

MUSA scientists embarked on an exhaustive investigation into banana plant soil and root ecology in search of natural nemeses of the most important threats to banana plants in sub-Saharan Africa, the Canary Islands and the Caribbean. These include nematodes, the banana weevil and the fungus responsible for lethal Fusarium wilt. The team collected thousands of promising bacterial and fungal biocontrol agents and endophytes from collections in partner countries and discovered and sequenced new isolates. Controlled testing revealed numerous opportunities for biological control of pests and disease.

For example, some fungi of the genus *Trichoderma* were highly effective in managing parasitic nematodes or insects

Prior to MUSA, there were few biological alternatives to the chemicals used on banana crops. We have enhanced knowledge of the banana plants' microbiome leading to an arsenal of biological tools to control pests and diseases, ultimately proving that a more sustainable approach is possible.

and opened a new door to weevil biocontrol. Isolates of the fungus *Pochonia* and the bacteria *Pseudomonas* successfully countered the spread of nematodes, weevils and *Fusarium*. Unexpectedly, scientists discovered that the endophytic fungus *Pochonia* in banana roots also induced a defence gene activation in leaves.

No study on agriculture would be complete without a look at the impact of our changing climate. MUSA has published outcomes showing the exacerbating effects of climate change on fungal infection causing devastating leaf diseases such as Black Sigatoka.

Guiding nature to do its thing in ways that help us too

Field trials in Cuba demonstrated the promise of pitting nature against nature for our world's food supply and global economies. Conventionally, banana propagation relies on transplanting small 'daughter' plants obtained from 'mother' plants growing in the field, risking the propagation of diseased plants. MUSA's Cuban in vitro labs introduced beneficial *Trichoderma* endophytes into plants during production of plants for farmers. Losses due to pathogenic fungi dropped, benefiting more than 100 farmers who have seen their revenue increased by about EUR 4 500, approaching Cuba's 2016 per capita net average income. The Cuban Ministry of Agriculture recommended a national policy to incorporate biological/endophytic agents into banana/plantain plants during their production.

MUSA has significantly advanced opportunities for greener crop management. Ciancio concludes: "Prior to MUSA, there were few biological alternatives to the chemicals used on banana crops. We have enhanced knowledge of the banana plants' microbiome leading to an arsenal of biological tools to control pests and diseases, ultimately proving that a more sustainable approach is possible." That is good news for farmers, our table and the planet.

PROJECT
Microbial Uptakes for Sustainable management of major bananA pests and diseases

COORDINATED BY
The National Research Council in Italy

FUNDED UNDER
H2020

CORDIS FACTSHEET
cordis.europa.eu/project/id/727624

Making tomatoes more tolerant to climate change

Reducing water and fertiliser needs in tomato crops provides a solid foundation for next-generation tomato cultivation that is more environmentally and economically sustainable.

The tomato is one of the EU's staple crops, cultivated all over Europe in open and protected fields and in greenhouses. Tomato farmers face combined water and nutrient stress in their crops, and solutions are needed to safeguard yields and preserve the environment.

The EU-funded TomRes project tested and optimised sustainable crop management strategies such as legume intercropping, precision fertilisation and irrigation techniques, manipulation of symbiotic microorganisms, and the use of rootstocks more suited to water and nutrient uptake from the soil. Project partners implemented a selection pipeline to identify tomato genotypes most resilient to combined stress (drought and low nutrients). "Starting from about 10 000 available accessions, over 200 were screened in the open field, amongst which 80 were Mediterranean landraces with long shelf life, to select a 43-accession TomRes collection of lines endowed with superior tolerance to combined stress," explains Andrea Schubert, project coordinator.

Making tomatoes more resilient and better performing

TomRes contributed basic science advancements such as more than 20 new alleles (and lines carrying them) that can help steer tomato performance under stress and be used in marker-assisted selection for resilience. The project provided new insights into the role of two pivotal phytohormones, strigolactones and brassinosteroids, in plant resilience, development and environmental memory.

Using advanced technology phenotyping, TomRes discovered new root-associated traits relevant for resilience to combined stress. The new traits are related to root architecture and physiology and are associated with beneficial microbes. "We were able to optimise management practices (variable rate irrigation and fertilisation, resilient rootstocks, biostimulants, green manure and rotations) and select combinations thereof to achieve optimal resilience to combined stress in tomatoes," says Schubert.

We were able to optimise management practices (variable rate irrigation and fertilisation, resilient rootstocks, biostimulants, green manure and rotations) and select combinations thereof to achieve optimal resilience to combined stress in tomatoes.

The selected tomato lines and resilience traits represent an accessible source for tomato breeders interested in providing resilient genotypes to farmers. The optimised management techniques have proven to reach the goal set in the project of reducing water and fertiliser needs. TomRes now provides a solid foundation for next-generation tomato cultivation that is more environmentally and economically sustainable.

Applying project concepts to further research

Project partners provided the required reporting and are now active in animating a research scene where, with the help of EU and national funding, the TomRes concepts may be further improved and implemented, in both tomato and other crops. An example is the PRIMA-funded VEG-ADAPT project, which transfers TomRes concepts to the Mediterranean area and to other crops. Farmers and industry participating in the network are setting the foundations for commercial exploitation of the project results of their interest.

The project profited greatly from a Stakeholder Board, established to provide advice and feedback throughout the project and contributing to TomRes's multi-actor approach. Dissemination to scientists, farmers and the general public proved intense and was not discontinued during the COVID-19 pandemic, during which an online summer school and two workshops were held. Surveys on consumer acceptance of sustainable tomatoes have been successful in spreading the project's concepts and gauging society's interest in novel, more eco-friendly and sustainable cropping systems.

PROJECT

A NOVEL AND INTEGRATED APPROACH TO INCREASE MULTIPLE AND COMBINED STRESS TOLERANCE IN PLANTS USING TOMATO AS A MODEL

COORDINATED BY

The University of Turin in Italy

FUNDED UNDER

H2020

CORDIS FACTSHEET

cordis.europa.eu/project/id/727929

Susceptibility gene tweak could lead to sustainable rice varieties

EU-funded scientists have identified candidate susceptibility genes to sheath blight, a fungal disease that affects cereal grain crops such as rice, causing yield losses of up to 40 %. Experimental tinkering and tailoring of such genes could help control disease spread.

© KeyGene

Oryza sativa, commonly known as Asian rice, has the second largest cereal production after maize. It is the most widely consumed staple food source for over half of the world's population. Sheath blight, caused by the necrotrophic, soil-borne fungal pathogen *Rhizoctonia solani*, is a major rice disease that affects yield and grain quality. The disease is an increasing concern, especially in intensified production systems.

The symptoms usually develop on the leaf sheaths as oblong, water-soaked lesions, which are greenish grey in colour. As the disease progresses, they tend to coalesce, forming larger lesions with greyish white centres surrounded by irregular borders. These lesions interrupt the water and nutrient flow to the leaf tip.

An alternative to chemical methods for sheath blight control

Large-scale deployment of semi-dwarf varieties and heavy use of nitrogen fertilisers have caused a sharp rise in the incidence of sheath blight in rice. Given that there are currently no resistant rice varieties available for cultivation, the main control method for sheath blight at this moment is the use of fungicides. Furthermore, lack of germplasm that offers resistance hampers plant breeding programmes.

"We successfully identified candidate susceptibility genes in rice that could serve as targets to build up strong, durable and broad-spectrum resistance to sheath blight," says Wladimir Tameling, coordinator of the RiZeSisT project that received funding under the Marie Skłodowska-Curie Actions programme. A susceptibility gene describes any plant gene that makes them vulnerable to infection. It does so by hosting compatible interactions with pathogens, enabling them to develop and reproduce. "The ultimate goal is to tweak susceptibility gene function to limit the pathogen's ability to induce disease," notes Marie Curie grantee Johanna Acevedo-Garcia.

Dissecting the molecular mechanisms of susceptibility to *R. solani*

Acevedo-Garcia used detached leaf bioassays to evaluate the plant response to *R. solani*. In particular, she inoculated rice varieties with *R. solani* and used a micro-chamber screening method to quantify resistance. The same method was used to perform RNA sequencing analysis of infected rice, which demonstrated pathogen-induced gene downregulation and upregulation (135 and 1 091 genes, respectively). These results were used to identify a number of candidate susceptibility genes in rice.

Probing susceptibility gene function in rice is opening up new avenues for developing broad-spectrum crop resistance to sheath blight.

Acevedo-Garcia encountered some problems with certain *R. solani* isolates obtained from public germplasm collections which impacted her analysis. After sequencing genomes, she discovered that they were not *R. solani* but a different microorganism. "Another challenging issue has been to effectively adapt bioassays and yield highly reproducible results. Research in this field is still scant," explains Acevedo-Garcia. "We heavily invested our efforts in this direction and are very proud of having developed robust bioassays in plants and detached leaves to evaluate the response of our plant material to the pathogen."

Tameling concludes: "Probing susceptibility gene function in rice is opening up new avenues for developing broad-spectrum crop resistance to sheath blight. Our research is poised to make a big impact on plant breeding programmes, helping produce improved rice varieties that resist damage by *R. solani* without the side effects of chemical methods."

PROJECT
Discovering susceptibility genes to Rhizoctonia solani in rice as breeding targets for sheath blight disease resistance

COORDINATED BY
Keygene N.V. in the Netherlands

FUNDED UNDER
H2020

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cordis.europa.eu/project/id/791867

Introducing genetic variation in rice crops to protect against climate change and pest infestation

Rice is one of the most important cereal crops in the world. To address rice sensitivity to salinity and resist infestation by pests, European researchers developed novel rice varieties with improved salt tolerance through fast-breeding.

The global temperature rise over the past 50 years has increased salinisation, especially in coastal areas, due to an increase in sea level and water scarcity. Salinity affects rice plant growth and reproduction, negatively affecting cereal productivity. At the same time, seawater treatment has emerged as the most effective strategy for combatting the apple snail species from the genus *Pomacea*, which eats the sown seed and the rice plantlets in paddy rice fields, inducing losses of tens of billions of euro a year.

Introducing genetic variation in rice crops

To overcome the negative impact of apple snail seawater treatment but also mitigate the effects of water salinisation due to climate change, scientists of the EU-funded NEURICE project developed commercial rice varieties. "Our goal was to obtain rice lines tolerant to abiotic (salinity) and biotic (apple snail) stress," explains project coordinator Salvador Nogués Mestres. NEURICE brought together experts from diverse scientific fields such as biotechnology, plant physiology, farming and agriculture development, electrophysiology and cell signalling.

Partners selected a salt-tolerance character called Saltol from a traditional Indian rice variety named Pokkali, known to be one of the most salt-tolerant rice varieties in the world. They then backcrossed it for several rounds with different Spanish, French and Italian elite rice strains while selecting those descendants that kept the salt-tolerance genomic region, a non-GMO strategy known as introgression.

Our goal was to obtain rice lines tolerant to abiotic (salinity) and biotic (apple snail) stress.

The tolerance to salinity of these descendant plants was evaluated in hydroponic tests under controlled greenhouse conditions. At the same time, scientists investigated key mechanisms implicated in salinity tolerance control at the molecular, cellular and whole plant levels and sequenced hundreds of rice varieties to find out new salt tolerance-related genes.

"Introgressing a character in only 2 years is very challenging, and as far as we know we've developed the fastest backcross breeding protocol ever," emphasises Nogués. Scientists analysed over 70 DNA markers in each generation to select those individuals with the highest percentage of European variety genome while keeping the Asian salt-tolerance alleles. In addition, a breakthrough fast-breeding method including in vitro embryo-rescue technique forced immature

rice embryos to germinate one month in advance and achieve three generations a year. This way they successfully introduced a chromosomal region by breeding in the fastest manner, yet avoiding transgenic technologies. Importantly, the new salt-tolerant rice varieties maintained the features required for the regional natural environment. In spring 2021, the first registered Saltol, salt-tolerant European varieties will be commercialised for farmers.

The future of salt-tolerant rice varieties

With Europe producing two thirds of its consumed rice in excess of 3 million tonnes per year, maintaining rice crop health is paramount for agriculture and for food security. Researchers discovered new genes and alleles that can now be exploited to improve the adaptation of European rice varieties to the new conditions imposed by climate change, such as higher salinity, higher temperatures and less water availability.

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According to Nogués: "The most significant achievement of the project was raising awareness among European farmers about the apple snail pest, and how to avoid its spreading to the main European rice production areas." Introduction of these novel salt-tolerant European rice varieties can lead to the eradication of the apple snail throughout Europe through seawater treatment. This will have a positive environmental and socioeconomic impact, avoiding less effective and highly contaminant chemical strategies.

Know-how obtained during NEURICE on how to produce these new salt-tolerant rice varieties, the discovery of new salt-tolerance genes and the new varieties themselves will be fed into the European rice industry and rice farming sector. Coupled with improvement of management practices such as rational water use and implementation of remote salinity monitoring systems, it will significantly advance the agriculture of rice.

PROJECT

New commercial EUropean RICE (Oryza sativa) harbouring salt tolerance alleles to protect the rice sector against climate change and apple snail (Pomacea insularum) invasion

COORDINATED BY

The University of Barcelona in Spain

FUNDED UNDER

H2020

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cordis.europa.eu/project/id/678168

Shaping the future of plant pest diagnostics in the EU

A multidisciplinary consortium is championing the fight against plant pests by enhancing the reliability of tests used for their detection and identification.

Each year, approximately 40 % of global food crops are lost due to pests and diseases. This has a detrimental effect on food security, the sustainability of agriculture and the economy. Quick, accurate and reliable detection and identification of pests are crucial to tackling this issue. However, such tests are mostly validated on an intra-laboratory basis or through limited test performance studies, putting into question their quality and validity as well as highlighting the need for harmonised test validation processes.

Our main objective was to improve the reliability of plant pest diagnostics.

The EU-funded VALITEST project set out to change this. "Our main objective was to improve the reliability of plant pest diagnostics," explains Mathieu Rolland, deputy project coordinator. To achieve this, the project's first goal was to complement existing or produce new validation data for the detection and identification of plant pests that are of interest to various stakeholders. This is alongside the goals of harmonising procedures and encouraging and improving the interactions between stakeholders for better diagnostics.

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Transforming diagnostics

Validation data is not available for all the tests used in plant pest diagnostic laboratories. Therefore, to ensure the quality and validity of results, additional validation data is required. Meeting this need, the project organised 2 rounds of test performance studies, whereby the performance of 83 detection tests covering 11 pests and including about 10 000 samples were analysed. "As a result, we have generated validation data for these priority pests, and in the process validation procedures have been enhanced and further harmonised," notes Rolland.

The work of VALITEST has also led to an improved framework, proposing new statistical tools for the analysis of validation data and guidelines, to ensure the reliability of the results obtained with high-throughput sequencing. It will be used to revise relevant European and Mediterranean Plant Protection Organization (EPPO) PM 7/98 and PM 7/122 standards or draft new ones. "We have also developed new guidelines for the production of reference material, which are essential for the reliable validation of tests and for routine diagnostics," adds Rolland.

The future of testing and plant health

Proficiency evaluation, following a horizontal approach, can aid laboratories in managing and demonstrating their competence and proficiency in testing. Optimising this evaluation, the needs and views of laboratories on horizontal proficiency tests were identified through a survey the project sent to laboratories registered in the EPPO database on diagnostic expertise. Discussions with accreditation bodies have started on a possible plant health approach regarding the level and frequency of proficiency testing in laboratories. "Furthermore, online training activities – webinar series and practical sessions – on the concept of validation, the organisation of test performance studies, and the development, validation and routine use of high-throughput sequencing tests have been organised for diagnostic laboratories," confirms Rolland.

VALITEST aims to bring to market tests that are validated according to international standards and produced by the SMEs manufacturing diagnostic kits. An EU Plant Health Diagnostics Charter describing the quality procedures for the production and the validation of commercial tests produced by EU manufacturers is being developed. This Charter will contribute to guaranteeing the quality and the reliability of products. In parallel, "the project and our partners are laying the foundations for an EU Association of the Plant Health Diagnostic Industry Association," concludes Rolland. This will ensure the market sustainability of SMEs.

PROJECT
Validation of diagnostic tests to support plant health

COORDINATED BY
The French Agency for Food, Environmental and Occupational Health & Safety in France

FUNDED UNDER
H2020

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Sustainable crop protection solutions up close

A new multilingual platform aims to boost the technological preparedness of farms across the EU to ensure more sustainable and environmentally friendly practices.

The adoption of new technologies and agriculture digitalisation are priority objectives to meet challenges of the European Green Deal, including the recently launched European Farm to Fork Strategy and the new common agricultural policy. Farmers will require appropriate and effective training to acquire the relevant knowledge and skills to meet these challenges. Today, however, the degree of adoption of new technologies is heterogeneous across EU Member States and between different types of farms.

The EU-funded INNOSETA project established an innovative self-sustainable thematic network on spraying equipment, training and advising (SETA). The aim was to help close the gap between available high-end crop protection solutions and everyday European agricultural practices. For the past two years, INNOSETA has been facilitating the exchange of novel ideas and information amongst the research, industry and farming communities so that existing research and commercial solutions can be widely communicated and innovative ideas from the farming community captured.

Free platform tailored to the needs of the spraying community

Today, the INNOSETA platform, available in seven languages, has become a well-recognised instrument offering stakeholders practical information on best management practices, simple and useful calibration tools, and engaging training material, especially relevant for family farms. It currently boasts about 300 industry solutions, 80 projects, 400 training materials and 190 papers.

INNOSETA helps close the gap between research and farmers. Taking advantage of already existing tools, the project promotes the adoption of new technologies, increases the educational level of stakeholders and facilitates the implementation of EU rules for a more sustainable and safe use of plant protection products.

In addition, the project platform promotes developments and tools from other public and privately financed projects (most of them EU projects), in a logical, easy-to-use format. Combined with all the activities taking place within the project, it contributes to raising awareness about the need to improve the global crop protection scenario.

"INNOSETA helps close the gap between research and farmers," says project coordinator Emilio Gil. "Taking advantage of already existing tools, the project promotes the adoption of new technologies, increases the educational level of stakeholders and facilitates the implementation of EU rules for a more sustainable and safe use of plant protection products." Moreover, the platform can have technical, environmental, social and economic benefits for different stakeholder communities.

Project partners have already developed a free and public database of plant protection product technologies and materials where manufacturers, academia, authorities, advisors and final users (farmers) can upload, store and find practical tools for their daily work.

Gaining global popularity amongst stakeholders

The project's long-term impact is linked with future EU policy developments. Regional and transnational workshops and other activities already conducted have proven to be important for collecting needs, suggestions, problems and proposals from all the stakeholder groups, as well as gathering input on pros and cons, difficulties encountered and suggestions for further improvements.

As INNOSETA comes to a close, the project consortium is working hard to continue updating and expanding the platform content. This includes enlarging as much as possible the list of available SETAs (currently over 1 000 entries) and promoting and disseminating the platform within the EU territory and globally. Partners also aim to establish a practical and feasible solution to guarantee the sustainability of the platform to ensure this investment doesn't become obsolete.

PROJECT

Accelerating Innovative practices for Spraying Equipment, Training and Advising in European agriculture through the mobilization of Agricultural Knowledge and Innovation Systems

COORDINATED BY

The Polytechnic University of Catalonia in Spain

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RESULTS PACK ON SOIL HEALTH

Soil is the foundation of our lives. Soil services are essential for the provision of food through agriculture, energy and raw materials, carbon sequestration, water purification, nutrient regulation, biodiversity preservation and pest control, to name but a few. This CORDIS Results Pack highlights projects working in the field of soil research that promise to make valuable contributions over the coming years.

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