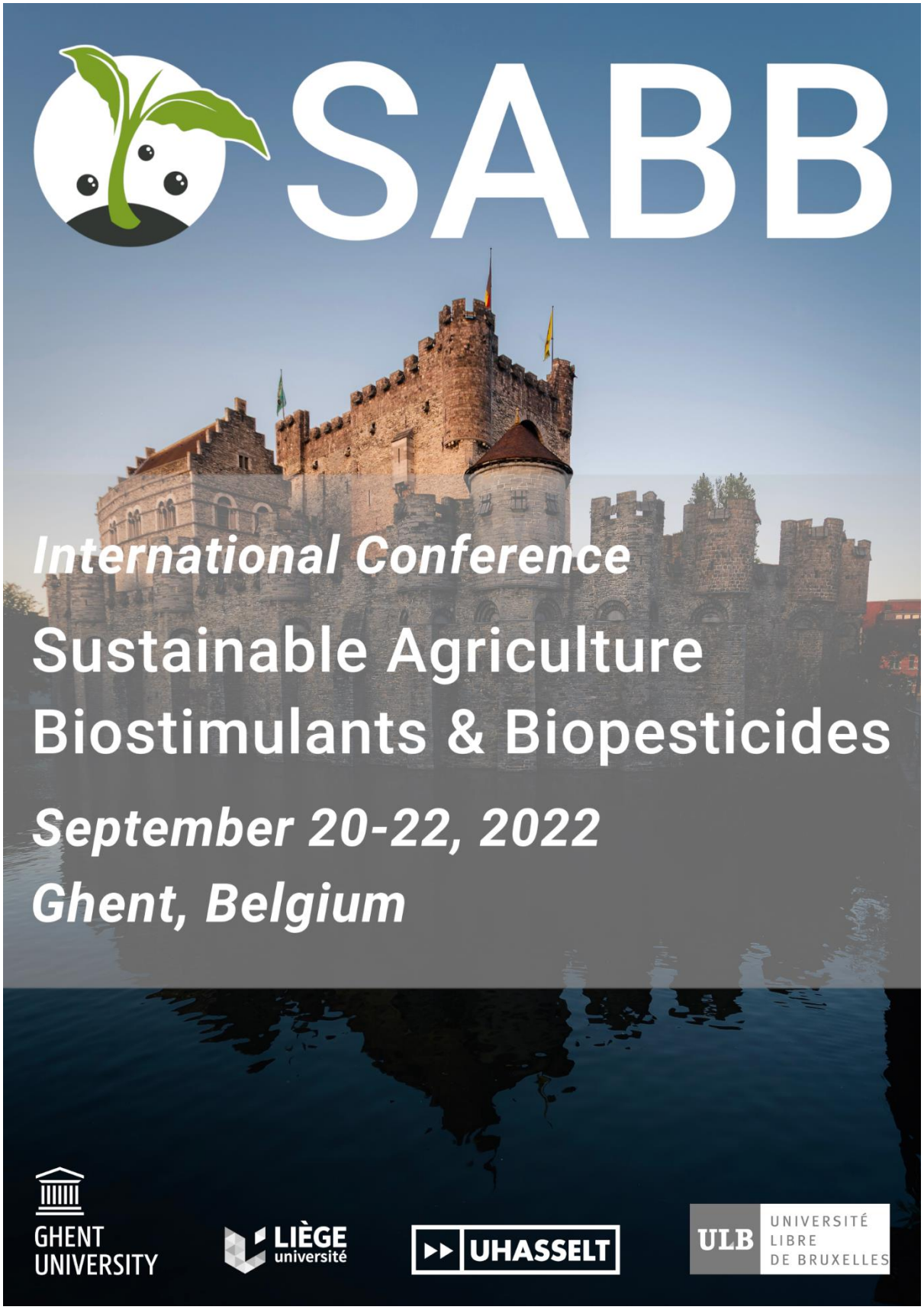
SABB
International Conference
Sustainable Agriculture
Biostimulants & Biopesticides
September 20-22, 2022
Ghent, Belgium
GHENT UNIVERSITY
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Foreword

Dear SABB2022 participant,

You are looking at the abstract book of the first Sustainable Agriculture Biostimulants and Biopesticide international congress. Pretty daring to see it global right from the start. As a science community we have all the reasons to see it that way. Yes, we want a shift toward more ecofriendly agriculture practices; yes, we want to safeguard food production under changing climate conditions, and yes, we want to see economically viable yields for farmers using fewer mineral fertilizers. We want this in every country, not only in our backyard. It does not make sense to cause ecological damage at one side of the globe or for that matter anywhere. Studying and developing biostimulants and biopesticides is meant to be beneficial for all countries and for everybody. It is therefore a real pleasure to see that so many nationalities have responded to the call and join us to share our passion and knowledge on plant biostimulants and biopesticides.

With such philanthropic potential, do you also wonder why it has taken so long to start investigating the many natural products used for decades as biostimulant and biopesticides? Is it that we like the instant effect of the synthetic agrochemicals, many of which are now banned? If bugs die while spraying them, it must be a very potent product, right? It is time to advance beyond the quick and dirty and bring on board new methods that are in better harmony with the natural environment and that are as simple in their use as they are effective. To achieve this on a wide scale of products and crop systems, it will take much more research efforts than we are currently allocating. Money is spent only once. Hence, I would argue for shifting more research project funds toward the study of biostimulants and biopesticides. The trend to move into this direction is gaining in momentum. Belgium is particularly active in this regard and hosts a proportionally large number of research units and agrobusinesses focusing on biostimulants and biopesticides, many of which you will meet here at the congress.

Here, at the SABB2022 congress, you are at the place to be. We ‘re expecting talks presenting novelties and testimonies of biostimulant and biopesticide applications. An exciting mix of industry and academic participants exchange insights, bottlenecks, risks, problems, progress, and discoveries.

Let me close with a few words of gratitude. On behalf of the Organizing Committee, I want to thank our sponsors, Ghent university, the “Fonds Wetenschappelijk Onderzoek” (FWO) and the “Fonds de la Recherche Scientifique” (FNRS). There are many nice gents and dames who have made the congress a reality. Their names are printed in this book and include, surprise surprise, also your name. Indeed, thank you for coming! Feel welcome at the meeting and jump on the bandwagon. As with every bandwagon, it has a beginning and an end. We’re at the beginning, so enjoy the ride!

Danny

Contents

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Venue

UGent Campus Coupure, Auditorium Oehoe (E1)
Coupure links 653
9000 Ghent
Belgium

Directions: https://soleway.ugent.be/routes/124

Practical information

Access to symposium
All participants, accompanying persons and exhibitors are kindly requested to wear their badges attached by lanyard during the symposium in order to be admitted to the venue, the food counter and other scheduled activities. Take very good care of your badge and don't lose it. A fixed rate will be charged to receive a replacement badge.

Catering
Coffee breaks and lunches are included in the registration fee. The meals are served near the exhibition hall of Block E of the campus where the auditorium is also located. Drinks will be provided; cooled tap water is available at all times for free. In the evenings there is no food available at the campus. Restaurants and snack bars are found within walking distance. During the poster session on Tuesday, drinks and appetizers will be served.

Computers and Internet
Access to the internet can be made via a guest login account. Make a wireless connection with "UGentGuest". Allow the automatic setting of an IP address (this will be one starting with the numbers 193.190.8x). Now you are connected, but not yet authenticated. Start a web browser and you will be redirected to a logon screen. Enter the username **guestSabb20**, and password **Rp3nZbjp**. After correct authentication you can use the Internet connection. The wireless connection is valid from 19th September until 22nd September. Your connection to this wireless LAN is not encrypted. To protect your personal data, please use encrypted connections like https, imaps, ssh etc. or a VPN client.
You're not allowed to pass the login information to others.

Program
Every endeavor has been made to produce an accurate program. In case your presentation hasn't reached us upon arrival, you can hand over your slide show to our IT manager Christophe Petit at the registration desk. Speakers are requested to respect the allocated time given and should avoid any unnecessary delay of the program.

Poster exhibition, set-up and removal
Posters are displayed at the exhibition hall of Block E. Adhesive material to attach the posters will be available. Your poster will have a number that can be found in this abstract book. Mount your poster together with the number at the poster board. Posters must be removed at the end of the Symposium, on Thursday by 11:00.

Language
English is the official language for the Symposium.

Certificate of attendance
You can receive a certificate of attendance upon request at the Registration Desk.

Banking, currency and exchange
The official currency in Belgium is the Euro. Banking hours are Monday to Friday 09:00 - 16:00. Weekends closed. Automated cash dispensers are located outside every bank and other areas and cash can be withdrawn 24 hours a day. Foreign currency may be changed at banks, hotels, and airports and in exchange offices. All major credit cards are accepted in most hotels, restaurants and shops.

Keep your belongings safely with you

The venue does not have locker facilities. Coats etc. can be hung at the corridor near the auditorium entrance at own risk. There is normally no passage other than participants.

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The organizers are not liable for any injury or damage involving persons and property during the symposium. Participants are advised to take out their own personal travel and health insurance for their trip.

Mobile phones
Delegates are asked to switch off their mobile phones when attending sessions.

Public transportation in the city
Transport in the city is mainly by bus or tram. Most important sites are within walking distance. You can use tram 4 to shuttle between the campus and the city. There is a stop across the canal close to the blue colored footbridge. Buy a ticket at the automatic vending machines before you step on the tram. Also check http://www.delijn.be/en/index.htm for details on bus and tram time schedules and the cheapest rates.

Smoking
Smoking is not permitted in any of the University buildings.

Weather
Ghent has a mild climate in September and daytime temperatures range between 15°C-22°C. Rainfall is possible. For daily information, we refer to the website of the Belgian meteorological institute: http://www.meteo.be.

Important and useful phone numbers
Emergency: 112
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Other information
An information desk will be open at all times during the symposium activities.

Code of Conduct

The SABB Organizing Committee is committed to providing a safe and productive meeting environment that fosters open dialogue and the exchange of scientific ideas, promotes equal opportunities and treatment for all participants, and is free of harassment and discrimination. All participants are expected to uphold standards of scientific integrity and professional ethics, treat others with respect and consideration, follow venue rules, and alert members of the Organizing Team of any dangerous situations or anyone in distress. The Organizing Team prohibits any form of discrimination or harassment, sexual or otherwise. These should be reported immediately to any member of the Organizing Team. All complaints will be treated seriously and responded to promptly.

To maintain and foster an environment at the meeting where colleagues feel comfortable and are encouraged to share unpublished data, recording, photographing, or sharing on social media of all data, results, hypotheses, conclusions, or any other aspects of a talk or poster are not permitted without the expressed consent of the authors. Also, please refrain from citing abstracts in bibliographies. The information in this abstract book shall be treated as personal communication and shall be cited only with expressed consent of the authors.

The abstract booklet contains the names of all participants. Email addresses or other personal information is not included to comply with the European general data protection regulation (GDPR).

The policies herein apply to all attendees, speakers, exhibitors, staff, contractors, volunteers, and guests at the 1st International Conference on Sustainable Agriculture, Biostimulants and Biopesticides.

Sponsors

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Keynote speakers

Patrick Brown, UC Davis, USA

Dr. Patrick Brown is the Professor of Plant Nutrition at the University of California, Davis – USA. He received his B.Sc. in 1984 from Adelaide University, Australia and Ph.D. from Cornell University, USA in 1988. Dr. Brown has authored more than 220 scientific journal articles and numerous books and is among the highest cited experts in plant nutrition, biostimulants, boron, foliar fertilizers and horticulture. Dr. Brown is recognized globally as a leader in both basic and applied plant nutrition research with notable contributions to the function, transport and management of nickel and boron, and significant contributions to research on potassium, nitrogen, zinc, foliar fertilization, salinity and biostimulants.

Uwe Conrath, Aachen University, Germany

I'm committed to understanding how plants withstand disease. My major focus is on 'defense priming'. The term describes the enhanced capacity of immunized plants to mobilize defense resulting in earlier, faster, and/or more robust activation of defense which often leads to immunity. I also address AgBiotech and bioeconomy aspects for translating concepts discovered in model systems to agriculture. They include defense pathway engineering and leaf-sticking gels and capsules for the slow release of active ingredients.

Vassilis Fotopoulos, Cyprus University of Technology, Cyprus

Vasileios Fotopoulos is Associate Professor in Structural and Functional Plant Biology and head of the CUT Plant Stress Physiology Group established in 2008. His main scientific research focuses on the study of nitro-oxidative signaling cascades involved in the plant's response to stress factors, while emphasis is being given in the development of chemical and biological priming technologies towards the amelioration of abiotic stress factors and promotion of plant growth. Relevant research has resulted in the publication of a patent and the provisional filing of a second one. In addition, he is involved in research studying plant secondary metabolism and antioxidant responses in fruit crops during ripening.

Giuseppe Colla, University of Tuscia, Italy

Full Professor in Horticulture at the Department of Agriculture and Forest Sciences, University of Tuscia, Viterbo (Italy). Research activities of Prof. Colla are focused on the development of new plant biostimulants from natural substances and the evaluation of the biostimulant activity of products on horticultural crops under variable environmental conditions. The interaction of biostimulant products with other agricultural inputs is also evaluated. The biostimulant activity is studied using plant phenotyping platform and other omics technologies such as metabolomics and transcriptomics.

Kris Audenaert, Ghent University, Belgium

Kris Audenaert is associate Professor at the Dept. of Plants and Crops, Fac. of Bioscience Engineering, Ghent University. He is head of the Laboratory of Applied Mycology and Phenomics. Biologically, his research group focuses on abiotic and biotic stress in crops and explores how new biostimulants and/or biocontrol agents help to grow healthy plants. For biotic stresses, wheat is the core crop and biocontrol agents such as *Serendipita* spp. and *Streptomyces* spp. are being explored as biocontrol

agents against major fungal pathogens such as *Fusarium graminearum, Zymoseptoria tritici, Blumeria graminis* and *Magnaporthe oryzae*. For abiotic stresses traits such as nitrogen-, phosphorus- and micronutrient deficiencies are investigated using maize, wheat and grapevine as target crops. Technologically, the research group has ample expertise in non-destructive plant monitoring using multi-, hyperspectral and fluorescence-based imaging techniques as a tool to visualize the phenotype of plants in their interaction with plant pathogenic- or plant beneficial fungi and bacteria. Kris Audenaert is a member of the IOF valorisation consortium CropFit on Biostimulants, the assoication research platform MYTOX, the Belgian Plant Phenotyping Network and the international training network MytoxSouth.

Pierre Van Cutsem, Université de Namur, Belgium

Pierre Van Cutsem holds an engineering degree in Agronomy (UCL-LLN) and a Ph.D. in Sciences and has been full professor at the Biology department of the University of Namur (Belgium) until last year; he is now emeritus. He has worked in plant physiology for over forty years and his favourite subject has always been structural (cell wall) and storage (polyfructan) polysaccharides. He published, among others, the genomic sequences of the two enzymes (SST and FFT) that synthesize inulin, the storage polyfructan extracted industrially from the chicory root. He worked a lot with the industry on many aspects of chicory physiology, including molecular markers (SSR, SNP) and marker-assisted breeding. Concerning plant cell walls, he published many papers on physicho-chemical properties of pectin and pectin signaling in plants. In 2006 he filed a patent on an oligochitosan-oligopectin complex (COS-OGA) with signaling properties that induces plants to fend off pathogens when contaminated, a mechanism based on preventive stimulation of the plant innate immunity. In 2009 he created FytoFend, a private company that produces, registers and commercializes biopesticides based on the COS-OGA complex. The company is thriving at a time when people and authorities are more and more reluctant to use chemicals alone to protect crops.

Corina Vlot-Schuster, University of Bayreuth, Germany

My laboratory investigates immune responses in plants; in particular, we focus on systemic acquired resistance, an induced defense response, which protects the systemic, healthy tissues of plants undergoing a local infection. We aim to understand the molecular components of this response and how these might be exploited to improve crop protection. Our recent findings highlight a role of volatile organic compounds as airborne signals propagating immune responses within and between plants.

Federica Locci, MPI for Plant Breeding and Research, Germany

Plants deploy cell-surface and intracellular immune receptors to detect pathogens. Receptor kinases and receptor proteins at the plasma membrane recognize microorganism-derived molecules to elicit pattern-triggered immunity (PTI), whereas intracellular nucleotide-binding LRR proteins detect microbial effectors to confer effector-triggered immunity (ETI). Although PTI and ETI are initiated in different host cell compartments, they rely on the transcriptional activation of similar sets of genes, suggesting pathway convergence upstream of nuclear events. My work in Jane Parker´s lab aims to dissect the underlying mechanisms of immune receptor signalling in both Brassicaceae (*Arabidopsis thaliana*) and Solanaceae (*Nicotiana benthamiana*). Our recent work led to the identification of an intracellular signalling branch that works as a convergence point between surface and intracellular receptor- triggered immunity.

Tuesday September 20th, 2022

				abstract #
SABB2022_day 1_biostimulants			**Chair: Danny Geelen**	
8:00 AM	registration			
9:15 AM	welcome			
9:30 AM	KN	Patrick Brown	Biostimulant and nutrient use efficiency	01
10:15 AM	speaker	Caroline De Tender	Chitin-induced growth promotion: an alternative for mineral fertilizers and an inducer of the rhizosphere microbiome in soilless cultivation	02
10:25 AM	speaker	Lara Van Dijck	Assessing the role of root-exuded coumarins in shaping host - microbiome interactions	03
BREAK (25 min)			**Chair: Maaike Perneel**	
11:10 AM	IS	Cinzia M. Bertea	Plant biostimulants as a sustainable approach to improve fruit development and quality under abiotic stress conditions	04
11:30 AM	speaker	Caroline Van Beirs	The auxin transport inhibitor cis-cinnamic acid is a natural plant growth-promoting compound	05
11:40 AM	speaker	Salomé Lengrand	Are endophytic bacteria involved in increasing plant drought tolerance provided by humic and fulvic acids application?	06
11:50 AM	speaker	Seppe Top	Seaweed biostimulants affect sap flow and stem diameter variation in tomato (Solanum lycopersicum)	07
LUNCHBREAK (+- 90 min)				
SABB2022_day 1_biopesticides			**Chair: Tina Kyndt / Ann Cuypers**	
1:30 PM	KN	Vassilis Fotopoulos	Plant and seed priming as 'green' tools for sustainable agriculture under a changing climate	08
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2:30 PM	IS	Catherine Michaux	A human-safe insecticide strategy based on pest trehalase inhibition	10
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BREAK (30 min)			**Chair: Kris Audenaert / Geert Haesaert**	
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5:06 PM	pitch	Jing Li	BioSUNmulant – From sunflower stems to fibre, biostimulant and bioprotectant	20
5:09 PM	pitch	Noémie De Zutter	Automated phenotyping platforms are an indispensable tool to evaluate the effects of biostimulants and biocontrol products	21
5:12 PM	pitch	Yinwei Zeng	Stimulation of adventitious rooting in hypocotyls with a highly selective synthetic auxin like molecule	22
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Wednesday September 21st, 2022

SABB2022_day 2_biostimulants

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10:10 AM	speaker	Paulien De Clercq	Effect of seaweed-based biostimulants on growth and development of Hydrangea paniculata under drought stress	30

BREAK (25 min)

Chair: David Cannella

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LUNCHBREAK (+- 90 min)

SABB2022_day 2_biostimulants/biopesticides

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BREAK (25 min)

SABB2022_day 2_workshop

Chair: Maaike Perneel

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Thursday September 22nd, 2022

SABB2022_day 3_workshop

Chair: Danny Geelen

8:30 AM	workshop	EBIC	Celine Durieu
9:00 AM	workshop	ILVO	Hilde Muylle and Jasmine Versyck
9:30 AM	workshop	Arche Consulting	An Vandenbosch
10:00 AM	workshop	EMCI Register & EFCI Register	Giel Tettelaar

SABB2022_day 3_technical tour

10:30 AM	technical tour	(return +/- 6:30 PM)

Abstracts

01 - Patrick Brown – Biostimulants and Nutrient Use Efficiency

In recently enacted EU legislation and in proposed US legislation, the definition of a biostimulant includes a specification that biostimulants act to stimulate plant nutrition processes and thus enhance nutrient use efficiency (NUE). The mechanisms by which biostimulants may act to enhance plant nutrition processes are diverse ranging from changes in root growth and architecture, enhanced soil microbial activity, altered plant metabolism, abiotic stress mitigation and other processes. While the term 'NUE'is a widely used it has diverse meaning depending upon the context in which it is used and the intention of the user. Thus, NUE may refer to the return on investments achieved from the addition of a fertilizer or biostimulant or the minimization of nutrient loss to the non-farm environment or the amount of yield that is produced per unit of nutrient acquired by the plant (Brown et al., 2020). This presentation will review available literature and agronomic principles to highlight how biostimulants influence may act to influence plant nutrition processes and affect NUE.

02 - Caroline De Tender – Chitin-induced growth promotion: an alternative for mineral fertilizers and an inducer of the rhizosphere microbiome in soilless cultivation

Chitin is the second most abundant biopolymer on Earth, present in fungal cell walls and the exoskeletons of arthropods such as crabs and shrimps. The latter comprise 12%ofa global production that amounts to1.5 million ton yearly. The search for useful applications of this waste stream is spurred by a changing fertilizer legislation as it is known that chitin is an interesting biostimulant in agriculture. We recently showed that the application of chitin derived from crab shells in soilless growing systems is promising. The use of chitin in small amounts (2 g/L growing medium) resulted in plant growth promotions of strawberry and lettuce, with biomass increases up to 2-fold. This increase in crop fresh weight can be explained on one hand by the increase in plant-available nitrogen (N) in the growing medium, which is gradually released during plant development. We showed that the released N (appr.90 mg N/L) is actively taken up by the plant, indicating chitin as a potential environmental-friendly alternative for mineral fertilizers. On the other hand, plants grown in growing media containing an excessive amount of nutrients still showed an additional growth promotion by chitin application, suggesting other mechanisms to be involved. The plant growth promotion of chitin was associated with a change in the rhizosphere microbial community. Remarkably, increases of 2 up to 18-fold of the fungal order Mortierellales were noted, indicating an important role for members of this orde rin the chitin-derived growth promotion. *Mortierella* strains were isolated from the lettuce roots. Whereas no active chitin degradation by the strains could be shown on selective media, the growth of both the foliar and root compartment of *Arabidopsis thaliana* in vitro was increased after seed inoculation with the isolated strains. Adding chitin to the growing medium of *Arabidopsis* increased this effect. Therefore, we can conclude that chitin-induced growth promotion in soilless cultivation works at least two-fold: first by the increase of Nin the growing medium and active N uptake by the plant, and second by changing the microbial community towards higher abundances of plant growth promoting fungi.

03 - Lara Van Dijck - Assessing the role of root-exuded coumarins in shaping host -microbiota interactions

Plants shape their root microbiome with the help of various root exuded compounds. One class of these molecules are the coumarins. In aboveground parts of the plant these secondary metabolites are important players in battling pathogen infections. At the roots they play a key role in the mobilisation and uptake of iron from the soil environment. For several coumarins, such as Scopoletin, it has been found that they possess a selective antimicrobial activity. More specifically they are able to inhibit the growth of different root associated fungi. In the Endo-and Rhizosphere coumarins could therefore be functioning in microbial selection. To study the effect of coumarins in a community context, we are performing tripartite interaction experiments between *Arabidopsis thaliana*, diverse fungal endophytes, and rhizobacteria applying an axenic peat-based FlowPotsystem. We are using *Serendipita indica* as a model growth promoting endophytic fungus from the order Sebacinales. In collaboration with Stephan Hacquard's group, we are testing diverse root-associated fungal endophytes isolated from natural *A. thaliana* populations. These fungi range from beneficial to deleterious and show differential coumarin-sensitivity in a culture-based system. As coumarin biosynthesis and exudation is driven by iron starvation, we are growing plants under iron-limiting conditions. A secondary stimulation is provided by a coumarin inducing *Pseudomonas simiae* strain (WCS417r), which promotes coumarin biosynthesis/exudation via upregulation of the *A. thaliana* bHLH transcription factor MYB725. Throughout these assays we are utilising *A. thaliana* mutants with deletions in key coumarin biosynthesis/exudation enzymes to assess the in planta relevance of the coumarins in steering plant-fungal interactions. To this end, we are looking for differential effects of fungal inoculation between wild-type and coumarin mutants. Additionally, we are examining the expression of the core transcription factor that drives coumarin biosynthesis/exudation MYB72, and key enzymes involved in coumarin biosynthesis/exudation (F6'H1and BGLU42)6. To screen for changes in the coumarin profile of *A. thaliana* during fungal endophyte colonisation, we will utilise Mass Spectrometry to examine the coumarin profiles of roots and root exudates. All together these experiments will give us more insight in the in planta function of coumarins during root-associated microbial interactions.

04 - Cinzia Bertea - Plant biostimulants as a sustainable approach to improve fruit development and quality under abiotic stress conditions

The application of plant biostimulants as agriculture practice represents a sustainable way to decrease the use of fertilizers and other chemicals, and reduce the environmental contamination. This aspect increased the attention not only of farmers but also of consumers, who are more confident in sustainable foods because perceived safer and healthier. Up to date, only a limited number of studies were addressed to test the quality of fruits produced by plants treated with biostimulants and often the experiments were focused on the evaluation of few pomological parameters, such as size, weight, yield, and color of the produced fruits. Consequently, the biostimulant effects on nutritional and nutraceutical parameters are still quite unexplored. In this work, the effects of different types of biostimulants were evaluated for their ability to improve fruit quality parameters in plant grown both in controlled and stress conditions. Experimental results obtained on tomatoes (Solanum lycopersicum L.) grown in climatic chamber and/or greenhouse and on two peach (Prunus persica L.)varieties cultivated in field will be presented. In general, the application of the different biostimulants influenced several agronomic traits and modulated the level of nutraceuticals, such as polyphenols and carotenoids, in both tomato and peach fruits. The bioactive compound changes were correlated to a stronger antioxidant activity of the hydroalcoholic extracts derived from treated-fruits. The findings of this study could be relevant due to the fact that biostimulants are considered innovative products that can contribute to make agriculture more sustainable and at the same time meet the increasing demand of consumers for healthier foods with high nutraceutical values.

05 - Caroline Van Beirs - The auxin transport inhibitor cis-cinnamic acidis a natural plant growth-promoting compound

Agrochemicals provide vast potential to improve plant productivity, because they are easy to implement at low cost while not being restricted by species barriers as compared with breeding strategies. Despite the general interest, only a few compounds with growth-promoting activity have been described so far. Recently, we have added cis-cinnamic acid (c-CA) to the small portfolio of existing plant growth stimulators. When applied at low micromolar concentrations to *Arabidopsis* roots, c-CA stimulates both cell division and cell expansion in leaves. Our data support a model explaining the increase in shoot biomass as the consequence of a larger root system, which allows the plant to explore larger areas for resources. The requirement of the cis-configuration for the growth-promoting activity of CA was validated by implementing stable structural analogs of both cis-and trans-CA in this study. In a complementary approach, we used specific light conditions to prevent cis/trans-isomerization of CA during the experiment. In both cases, the cis-form stimulated plant growth, whereas the trans-form was inactive. Based on these data, we conclude that c-CA is an appealing lead compound representing a novel class of growth-promoting agrochemicals. Unraveling the underlying molecular mechanism could lead to the development of innovative strategies for boosting plant biomass.

06 - Salomé Lengrand - Are endophytic bacteria involved in increasing plant drought tolerance provided by humic and fulvic acids application?

Positive effects of humic and fulvic acids (HA)-based biostimulants on plant tolerance to drought stress are reported in the literature. Little is known on the mechanisms of action of HA but the regulation of hormonal and redox metabolisms within plants is involved. Based on a plant study model under controlled conditions, the effect of HA in increasing drought stress resistance is assessed and the potential role of bacterial endophytic community in this process is analyzed. Positive impacts of HA on tomato plants grown in hydroponics under osmotic stress were observed on morphological and physiological parameters with an increase of fresh, dry and water weight of aerial and roots parts, plant length and leaf area, as well as a raise of stomatal conductance and total chlorophyll content. The reduction of the malondialdehyde concentration in aerial parts of plants treated with HA reflects a reduction of oxidative stress. The interaction between HA and endophytic bacteria associated to tomato seeds was studied in a second bioassay. Seeds are known to be a major vehicle for PGP bacteria through generations and to maintain a stable community in plants. For this purpose, a sterile culture system in hydroponics was developed. The positive effects of HA were confirmed and the culture in sterile conditions enabled to isolate seed endophytic bacteria, offering new opportunities in studying seed endophytic bacteria–HA interactions.

07 - Seppe Top - Seaweed biostimulants affect sap flow and stem diameter variation in tomato (*Solanum lycopersicum*)

Drought has become an increasing problem in agriculture in recent years with fresh water becoming a scarce resource. One of the solutions to potentially alleviate detrimental effects of drought is using commercial seaweed-based biostimulants. We aim at getting a better understanding of their effects. Tomato plants (*Solanum lycopersicum* L.) were grown in soil under drought stress conditions with a 40% reduction in irrigation compared to control plants in 2020, and a 67% reduction in 2021. Plant responses to (i) drought stress, and (ii) a combination of drought stress and different seaweed biostimulants were continuously measured with sap flow and stem diameter variation sensors and compared to well-watered plants. No differences were observed in overall yield and fruit size between treatments, indicating a potential water saving of at least 40% as confirmed by the sap flow measurements. Although no differences were observed in yield, some of the tested biostimulants did impact plant functioning. An *Ascophyllum nodosum* based biostimulant resulted in water uptake during drought comparable to well-watered control plants, while a *Saccharina latissimi* based biostimulant resulted in significantly lower water uptake than stressed control plants but with comparable yield as well-watered plants, increasing plant water use efficiency. We recommend using plant sensors for future objective quantification of water management and subtle effects of biostimulants on plant performance, and even as part of more elaborated set-ups to unravel modes of action of biostimulants in crops.

08 - Vasileios Fotopoulos - Plant and seed priming as 'green' tools for sustainable agriculture under a changing climate

Increased frequency of extreme environmental events resulting from global climatic changes remarkably influences plant growth and development. Close examination of plant-to-plant communication in nature has revealed the development of unique strategies from plants for responding to abiotic stress, with one of the most interesting being through priming for improved defense responses. The process of priming involves prior exposure to a biotic or abiotic stress factor making a plant more tolerant to future exposure. Priming can also be achieved by applying natural or synthetic compounds which act as signaling transducers, 'activating' the plant's defense system. The development of sustainable, 'green' technologies is therefore becoming of utmost important, also due to the need for reduced agrochemical use. The current presentation gives an up-to-date description of main research activities carried out at the Cyprus University of Technology with the employment of chemical compounds, microorganisms and advanced nanomaterials and polymers applied as priming agents for stress protection and improved growth at plant and seed level. This technology offers an attractive alternative to established approaches such as conventional breeding and genetic modification with key advantages, representing a characteristic example of integrative plant physiology where multiple disciplines such as materials science, agriculture and analytical chemistry join forces to develop exciting new tools in modern agriculture.

09 - Corina Vlot-Schuster - Airborne defense cues drive plant-microbe interactions to promote plant health

Plants are constantly under attack by a multitude of biotic stressors, including pathogens. In return, plants are equipped with several different molecular defense pathways, which can be turned on, off, or combined, depending on the situation. We have recently found that the volatile emissions of plants change upon the execution of defense responses against pathogens. Given the vast number of different volatile organic compounds (VOCs), which can be emitted by plants, this provides significant potential to finetune defense responses. I will present data to show that pinenes, which are VOCs belonging to the class of monoterpenes, are an integral part of the innate immune response systemic acquired resistance in the model plant Arabidopsis thaliana. Upon emission of these molecules into the air, neighboring plants respond to the same molecules with enhanced resistance to pathogens, while propagating the signal, which is emitted and again recognized by farther-away neighbors. We hypothesize that this might lead to a self-sustaining wave of defense cues, which can move through dense plant populations, including agricultural fields. To support this, we could recently show that the cereal crop plant barley emits VOCs, which are recognized as defense cues by neighboring plants of the same and of other species. Consequences for crop protection strategies will be discussed.

10 - Cathérine Michaux - A human-safe insecticide strategy based on pest trehalase inhibition

Aphids are major pests damaging forests, cereals, vegetables and fruit crops not only by their direct action on the plants, but also because they act as vectors of many phytopathogenic viruses. Aphid infestations are generally contained with insecticides such as carbamates, neonicotinoids or pyrethrinoids which are neurotoxins and/or endocrine-disrupting compounds. As a consequence, they have been found to be harmful to fish and mammals. In Belgium several crops such as sugar beet have temporary authorizations to continue to be protected with neonicotinoids to control aphids but it will be ended soon without any sound alternative. Even the very recent sulfoximine-based insecticides were demonstrated to have a serious impact, in particular on pollinator insects, which led many countries to progressively ban their use. Hence, scientists are urged to find new solutions, alone or in combination with existing strategies, that would effectively control aphids' populations. As potential safer insecticides, inhibitors reducing the availability of energy for the insect are promising alternative, and since trehalose is a major energetic reserve in insects, the inhibition of its catalysis is an effective control strategy. The degradation of trehalose can be achieved by several routes including its hydrolysis by the trehalase enzyme (Treh) to produce glucose. Acyrthosiphon pisum is a model organism for biological studies as its genome has been sequenced and annotated. So far, there has been minimal researches on the Treh of A. pisum. Characterizing its activity and properties is therefore essential to allow designing selective A. pisum Treh inhibitors.

11 - Willem Desmedt - Transient phenylpropanoid pathway perturbation triggers an induced resistance response in plants

Induced resistance (IR) refers to a phenotypic state that is characterized by enhanced resistance to pests and/or pathogens and which is induced by an external stimulus. We have discovered that transient chemical inhibition of CINNAMIC ACID-4-HYDROXYLASE (C4H), the second enzyme in the phenylpropanoid pathway, induces a broad-spectrum IR phenotype in both a model monocot(rice)and a model dicot (tomato) against a range of bacterial, fungal and nematode pathogens as well as several arthropod pests. PA-IR was not associated with phytotoxicity or yield loss. By combining a multi-omics and mutant analysis approach, we show that the model chemical C4H inhibitor piperonylic acid (PA) induces profound reprograming of (glycosylated) phenylpropanoid and flavonoid metabolism and that PA-IR is independent of canonical defense hormone pathways. Our findings fit within an emerging body of literature indicating that the phenylpropanoid pathway is not just a source of antimicrobial and cell wall-reinforcing compounds, but also plays a key regulatory role in plant immunity. In rice, we further show that PA –as well as more well-known IR stimuli such as beta-aminobutyric acid and acibenzolar-S-methyl –alter the composition of rice root exudates, and that this in turn strongly but transiently alters the composition of rhizosphere nematode communities. Further highlighting the important but hitherto underappreciated role of root exudates in IR, we show that the efficacy of PA-IR against root-knot nematodes in rice is partially dependent on exuded diterpenoid phytoalexins, and that genetic impairment in the production of these phytoalexins leads to dramatically altered rhizosphere nematode communities. In addition to these more fundamental results, we also conducted small-scale field trials which show that PA treatment is effective at managing root-knot nematodes in tomato and thus may hold promise as a component of an IPM program for nematode management in intensive greenhouse horticulture. Taken together, our results show that transient chemical phenylpropanoid pathway inhibition is an effective way to induce an IR phenotype in plants, with possible applications both in sustainable crop protection and in fundamental research into the role of the phenylpropanoid pathway in plant immunity.

12 - Junli Wang - A link between glutamate receptor like proteins and host cell death in plant immunity.

Animal and plant immune systems utilize NLR proteins to detect pathogens and translate recognition into host cell death and transcriptional reprogramming for defence. Coiled-coil NLRs (CNLs) are proposed to execute cell death autonomously as plasma membrane oligomeric pore/ion channel while Toll-like/Interleukin 1 receptor (TIR) type NLRs (TNLs)form a signalling network with 'helper' NLRs containing a HELO domain cell death module found also in fungi and animals. How plant HELO-NLRs confer cell death and induce transcriptional defences is unclear. I am studying this using *Arabidopsis* and tobacco where TNLs signal via HELO-NLR N required 1 (NRG1). Preparatory work shows that NRG1 interacts with glutamate receptor like (GLR) proteins which can function as gated ion channels. I hypothesize that plant TNL activated HELO-NLRs recruit GLRs to increase Ca2+ion fluxes at host membranes, which reprograms cells for resistance and cell death. An alternative hypothesis is that TNL-activated HELO-NLRs function in the nucleus to transcriptionally induce the expression of GLRs and other immune response genes. I will describe recent experiments testing these two HELO-NLR properties and outcomes. The date will advance understanding of how plants controlCa2+ion fluxes, and whether this is fundamentally different to CNLs which might be autonomous cell death executioners in plants.

13 - Eva Degroote - Cold water extract of Cucurbitaceae as basis for future nematode control agents

Plant pathogenic nematodes are responsible for annual agricultural losses worth an estimated 100 billion dollar. Worldwide, nematicides are used to control nematodes, but the regulation concerning these agrochemicals is becoming more strict every year. That is why the need for new and more sustainable products is increasing constantly. In this research, cold water extracts of Cucurbitaceae peelings were evaluated as a control strategy against root-knot nematodes. Since rice, a staple crop, and tomato, a cash crop, both suffer a great deal from damage due to root-knot nematodes, *Meloidogyne graminicola* and *Meloidogyne incognita* respectively, the focus of this research was directed to these two pathosystems. Cold peelings extracts (COPE) from different members of the Cucurbitaceae family, e.g. melon, pumpkin and zucchini, were tested for their resistance inducing capacities. Results showed that the number of galls in rice as well as tomato formed by root-knot nematodes was significantly reduced upon foliar application of melon, pumpkin and zucchini COPE (mCOPE, pCOPE and zCOPE respectively). Further research was focused on mCOPE. It was revealed that mCOPE not only induces plant resistance against nematodes, but also has a direct nematicidal effect on *M. graminicola* as well as on *M. incognita*. Via RNA-sequencing in rice, our data indicate that the induced resistance might be regulated by ethylene, a hormone known to play a crucial role in the immune system of plants. This result was confirmed by hormone measurement using GC-MS analysis. In tomato RNA-seq data suggested that jasmonic acid, an important hormone in plant defence against nematodes, is a crucial player in the observed induced resistance against *M. incognita*. In conclusion, our results show that cold water extracts of Cucurbitaceae peelings can protect rice and tomato via induced resistance against root-knot nematode infection. Next to that, we revealed that mCOPE has a direct nematicidal effect on these root-knot nematodes. Lastly, in rice as well as in tomato, we have demonstrated that plant hormones play an important role in establishing induced resistance.

14 – Federica Locci - Sensing the danger: a confluent view of plant innate immunity

In plants, pathogen detection relies on cell-surface and intracellular leucin-rich repeat (LRRs) receptors. LRR-receptor kinases (RLKs) and LRR-receptor proteins (RLPs) at the plasma membrane recognize microorganism-derived molecules to elicit pattern-triggered immunity (PTI), whereas nucleotide-binding/leucine-rich-repeat receptors (NLRs) detect intracellular pathogen effectors to activate effector-triggered immunity (ETI). In *Arabidopsis*, two NLR signalling branches are controlled by EDS1-protein complexes: one via EDS1-SAG101 which leads to host cell death, the other by EDS1-PAD4, inhibiting pathogen growth. EDS1-PAD4 also confer broadly effective “basal immunity” to virulent pathogens. In our recent work, we propose that EDS1-PAD4 branch is a convergence point for defence signaling activated by both surface-resident and intracellular LRRs receptors (Pruitt N., Locci F. et al., 2021). Furthermore, we recently identified in vivo protein interactors of Arabidopsis EDS1-PAD4, including a truncated and canonical NLR (i.e., TN-HC1 and TNL-HC2), which both appear to be Brassicaceae specific following a large-scale phylogenetic analysis. By using a reverse genetic approach as well as protein-protein interaction studies, we show that TN-HC1 and TNL-HC2 contribute to basal defence triggered by surface-localized RLP, but not to ETI. Our study is aiming to shed light on mechanisms of signal convergence between surface and intracellular receptors in plant immunity.

15 - Ali Siah - Biocontrol of the wheat pathogen Zymoseptoria tritici: current status and future challenges

Septoria tritici blotch, caused by the fungal hemibiotrophic pathogen *Zymoseptoria tritici,* is one of the most economically damaging diseases on wheat crops worldwide. In the European Union where the climate is suitable for disease epidemics, about 70 % of marketed fungicides target *Z. tritici*. However, such chemical inputs are increasingly controversial because of their potential negative impacts on both the environment and human health. Hence, looking for eco-friendly disease management alternatives, such as the use of biocontrol compounds, including bio-fungicides and resistance inducers, is strongly encouraged to promote sustainable agriculture and safer food. Plant resistance inducers, also referred to as elicitors or priming agents, are compounds that confer improved protection to pathogen or pest attacks by activating the plant immune system. The mode of action of resistance inducers differs from that of bio-fungicides because they do not target directly the bio-aggressor through antifungal activity, but they inhibit its development indirectly via the induction of a wide range of plant defense reactions. The present review summarizes the investigations undertaken on the efficacy and the modes of action of biocontrol compounds on the wheat-*Z. tritici* pathosystem and provides new insights into the works required for their successful implementation in wheat integrated pest management strategies.

16 - Jaap Wolters – Tetraose glycoalkaloids from potato can provide complete protection against fungi and insects

Chemical pesticides are commonly used to protect crops against pests and diseases, but more sustainable alternatives are needed. Plants with innate resistance can provide a solution. Resistance breeding typically relies on the use of immune receptors or impaired susceptibility genes, but these come with challenges in terms of strength, durability or pleotropic effects. Natural defence compounds from plants are usually not considered in breeding, because knowledge of how these compounds contribute to resistance and how they are produced is limited. In a search for resistance against early blight of potato, we identified wild relatives of potato that provide us with unique insight in the role of glycoalkaloids in plant immunity. We cloned two glycosyltransferase resistance genes that can provide complete resistance to *Alternaria solani* and Colorado potato beetle through the production of tetraose steroidal glycoalkaloids. Moreover, we show that the compounds from wild potato are active against a wide variety of fungi. This research highlights the potential of using natural defence compounds produced by plants to protect them against pests and diseases.

17 - Halimat Ogunsanya - BIO4FOOD: Crop waste-derived biostimulant for nutrient-rich food

Synthetic fertilizers and pesticides used on farmland during current agricultural practices pose a considerable risk to the environment and human health. To reduce the environmental impact of chemical fertilizers and pesticides, while securing crop yield and consumers' safety, several alternative and sustainable products are presently on the market or are being developed. Bio4Foodaims to develop novel biostimulants and biopesticides using crop waste as a source for bioactivity. Waste from crops including thyme, mint, tomato, tannins, and several others were extracted with water and organic solvents. Using dedicated root and shoot assays, extracts were tested for biostimulant and biopesticide activity. The root-knot nematode, *Meloidogyne graminicola* was co-cultured with riceplants pre-treated with crop waste extracts. The fungicidal activity was shown using *Rhizoctonia* spp, *Pythium* spp, and *Fusarium* spp cultures. Alterations in root and shoot growth were observed. These results encourage the investigation of the chemical composition of the extracts and suggest biostimulants and biopesticides can potentially be developed from crop waste products.

18 - Lena Ons - Repurposing of known agrochemicals: 2,4-dichlorophenoxyacetic acid at low non-herbicidal concentrations as a potent inducer of plant resistance

Plant diseases and pests are currently managed through a wide range of chemical pesticides. However, their extensive use faces two main challenges: the emergence of resistant pathogens and residual effects negatively affecting the environment and human health. One way to reduce the need for pesticides is by using activators of the natural defense of plants. In this regard, we evaluated the efficiency of 2,4-dichlorophenoxyacetic acid (2,4-D), a synthetic auxin well-known for its herbicide activity as a selective killer of dicot weeds, for its ability to induce plant resistance at very low non-herbicidal concentrations. Experiments in the model *Arabidopsis thaliana* indicated that root pretreatment with 2,4-D at concentrations 50-100 times lower than needed for herbicidal activity was effective in reducing the disease symptoms caused by the necrotrophic fungus *Botrytis cinerea* on seedlings. A similar protective effect was observed against the biotrophic oomycete *Hyalopernospora arabidopsidis* after leaf treatment, indicating the broad-spectrum potential of 2,4-D-induced resistance. Moreover, leaf pretreatment with2,4-D at such low dose was able to trigger plant resistance in the economically relevant crop, tomato, and thereby protect the plant against grey mold caused by *B. cinerea*. Finally, we investigated the mechanisms leading to 2,4-D-induced resistance by analysis of the effect of 2,4-D in *A. thaliana* mutants of known plant defense pathways such as the jasmonic acid, ethylene and salicylic acid signaling pathways. Our findings demonstrate that such preventive treatments using 2,4-D at concentrations far below those needed for herbicidal activity could improve the management of plant pathogens both economically and environmentally as they could reduce the amount of fungicide used.

19 - Kilian Van Loocke - Biocontrol potential of *Bacillus* and *Pseudomonas* sp. strains towards *Phytophthora* root rot in hydroponic lettuce cultivation

Lettuce production accounts for more than 20 % of the vegetable cultivation under glass in Flanders. However, recent introduction of the soil-borne oomycete *Phytophthora cryptogea* in hydroponic lettuce cultivation has led to economic yield losses up to €50 000 per ha per year. This causal agent of root rot infects plants by releasing biflagellate, asexual zoospores into the recirculation water. We previously showed that concentrations as low as 0.1 zoospores per mL are sufficient to affect entire hydroponic lettuce systems. After infection, lettuce roots show a slimy appearance and decay, eventually leading to an unprofitable lettuce crop. Current control strategies include the use of chemical plant protection products. However, these chemicals can cause adverse effects on humans and the environment reinforcing the need for alternative control strategies. In this study, the biocontrol potential of *Bacillus* and *Pseudomonas* sp. strains was assessed by performing *in vitro* and *in vivo* antimicrobial assays. Firstly, using azoospore germination assay, we showed that all tested bacteria were able to delay the germination of zoospore cysts. Secondly, dual culture assays revealed that 10 out of 12 tested bacteria (*Bacillus velezensis* GA1 and RHF4.1-25 and eight *Pseudomonas* sp. strains) significantly decreased the mycelial growth of *P .cryptogea*. *Bacillus velezensis* RHF4.1-25, *Pseudomonas chlororaphis* CMR5c, *P. aeruginosa* PNA1, *P. mediterranea* EDOX and *P. protegens* Pf-5 reduced mycelial growth by at least 70 %. Finally,an agar overlay assay confirmed that *B. velezensis* GA1 and the above mentioned *Pseudomonas* strains were able to inhibit *P. cryptogea* growth. Preliminary testing of *B. velezensis* GA1-mutants deficient in cyclic lipopeptide (CLP) and/or polyketide production revealed that polyketides might be responsible for the activity against *P. cryptogea.* Currently, we are investigating the biocontrol capacity of several of these strains against P. cryptogea a mini-hydroponic deep floating system. Our findings show the potential of using living organisms as biological control agents in managing *P. cryptogea.*

20 - Jing Li – BioSUNmulant: from sunflower stems to fibre, biostimulant and bioprotectant

Sunflower (*Helianthus annuus*) is an annual crop grown primarily for its seeds, with the leaves and stems being left on the field as organic matter. We developed the harvesting equipment and technology to produce fibre from the sunflower stems by separating the inner stalk (pith) and external bark. Fibre is extracted from the bark using a continuous twin-screw extrusion method. A by-product from bark extrusion is an aqueous extract (sunflower bark extract; SBE) that was shown to harbour components with biostimulant and bioprotectant activity. SBE has a strong antioxidant activity and contains polyphenols, carbohydrates, proteins, and other metabolites. The addition of SBE to *in vitro* cultures of *Arabidopsis* seedlings that are exposed to 100 mM NaCl mitigated salt stress-induced shoot growth inhibition. Floating leaf discs were also protected from damage by pretreatment with SBE. Next to stress alleviation, SBE was shown to induce plant resistance to the pathogenic oomycete *Hyaloperonospora arabidopsidis*. Prompted by consistent biostimulant and bioprotectant activity from SBE over several harvest years, we embarked on several studies to evaluate the potential of SBE as a biostimulant and bioprotectant. To this end, we improved the twin-screw extrusion method and engaged in SBE fractionation to enrich active ingredients and chemical characterization. We also formulated SBE and applied it to maize, rapeseed, and paprika to assess the responses of these crops upon SBE application.

21 - Noémie De Zutter - Automated phenotyping platforms are an indispensable tool to evaluate the effects of biostimulants and biocontrol products

The ecological awareness on the excessive agricultural use of chemical fertilizers and pesticides increases, and restrictions on the use of these agrochemicals are being imposed in Europe. Therefore, the real-time monitoring of crop growth and health status in order to respond appropriately to possible (a)biotic stresses and to avoid the overuse of agrochemicals are the main incentives towards precision agriculture. In the past, plant phenotyping was primarily done by scoring traits by the naked eye. As this approach is time consuming, has a low resolution and is prone to human bias, plant phenotyping has evolved towards a new scientific discipline: phenomics, which refers to the characterization of plant phenotypes through the acquisition and analysis of high-dimensional phenotypic data. Phenomics is especially interesting when investigating the effect of potential biostimulant and/or biocontrol products (BBP), as their impact is often small and/or transient. Within our research group, research and industry work tightly together towards a more sustainable future through the screening of potential BBP in close association with the host plant. By incorporating a high-resolution multispectral imaging technique, the effect of novel BBP can be monitored on seeds, seedlings and plants in their natural environment, or under extreme conditions. Due to the highly automated sensor-to-plant principle, the spread of a disease or the effect of an agrochemical or stressor can be traced throughout the plant in time. Using a combination of RGB, chlorophyll fluorescence, anthocyanin, NIR and GFP/RFP imaging, the impact of these BBP can be visualized in multiple ways. Recently, our research group expanded its equipment with a hyperspectral camera designed for trait discovery. Moreover, researchers with both biological and image processing expertise can be consulted to compute scientifically relevant measures from these images, thus reaching beyond the mere visualization of phenomena.

22 - Yinwei Zeng - Stimulation of adventitious rooting in hypocotyls with a highly selective synthetic auxin like molecule

Adventitious roots (AR) are an important evolutionarily adaptive feature helping plants to restore root loss and abiotic stress. Adventitious roots are distinct from lateral roots, not only by their position on the shoot part of the plant, but primarily by different environmental cues that induce de novo formation of these roots. To unravel molecular processes specifically involved in adventitious rooting, a chemical library was screened for strong AR inducers. A novel auxin like molecule was identified, dubbed hysparin (HYS), that selectively enhanced adventitious root formation on the hypocotyls of etiolated *Arabidopsis thaliana* seedlings. HYS does not induce lateral root formation, suggesting that its actions are different from the canonical auxin like molecules. In addition, HYS promotes hypocotyl elongation in non-etiolated *Arabidopsis* seedlings. To illuminate the HYS model of action, we characterized HYS-induced AR formation using histological clearings and expression analyses of reporter lines revealing auxin signaling (DR5: GUS) and cell division (proCYCB1;1::GUS). To determine the chemical structure bioactivity relationship, analogs were synthesized and tested for root and hypocotyl elongation phenotypes. Combining the phenotypical analyses, we propose a model for the mode of action of hypocotyl-specific AR-induction by hysparin.

23 - Johan Yssel - Impact of seaweed extracts on *Vitis vinifera* L. Chardonnay under cool climatic conditions

Plant biostimulants are showing increasing promise to help plants overcome the primary effects of climate change and the associated increase of pest and pathogen pressure. While seaweed extracts (a class of biostimulant) are showing promising effects on *Vitis vinifera* (grapevine) under heat and drought stress conditions (through increasing stomatal conductance, improving water use efficiency, up-regulating stress-response genes etc.), little is known about their effects under more temperate climates. Therefore, the aim of this study was to explore the potential of biostimulants to improve grapevine production quantity and quality in Belgium, an emerging wine producing country in a temperate climate region. Specifically, in a field experiment performed in 2021, five treatments were compared on *V. vinifera* L. Chardonnay in a Belgian vineyard including (i) control (water application); (ii) *Ascophyllum nodosum* extract; (iii) *Ecklonia maxima* extract; (iv) nutrient spray (based on the average nitrogen, phosphorus and potassium content of the seaweed extracts) and (v) a chemical pesticide spray. Treatments were applied starting from EL-14, at five timepoints approximately 2-3 weeks apart, until EL-33. The effects on vine vegetative parameters (chlorophyll content index, leaf photosystem efficiency F_v/F_m and stomatal conductance) were measured across the growing season, as well as reproductive parameters (berry volume, mass and sugar content) at harvest. Results revealed that the application of the *E. maxima* based extract led to a significant increase in the chlorophyll content and performance indices of *V. vinifera* L. Chardonnay over the growing season. Berry volume, mass and sugar content increased slightly, although not significantly at harvest when compared to the mock treatment (i). Altogether, our results suggest that seaweed extracts can have beneficial effects on plant physiological responses even in the absence of heat and drought stress, although the effects on reproductive parameters are less pronounced, which could be a result of heavy rain during the berry ripening stages. Exploitation of these results may better inform the conditions under which biostimulants should be applied leading to a more sustainable crop protection.

24 - Giulia Forghieri - Development of Bio-formulation for Nutrient Uptake Optimization by Crops

Nitrogen (N), phosphor (P) and potassium (K) are necessary elements for plant nutrition and play a pivotal role in agriculture, with N being often a rate-limiting element in plant growth. Today, N, P and K fertilizers global demand is 198.2 Mt, and it is projected to reach 208 Mt in 2026. However, the current fertilizing practices are mostly inefficient, as up to 50% of N can be lost in the environment after the application. In this context, the optimization of nutrient uptake by plants could reduce losses and enable future generations to respond to the increasing fertilizers demand of the incoming year. Many soil bacteria were extensively proven to be able to improve nutrient availability to plants and to directly stimulate plant growth, stress tolerance and to influence crops resistance to pathogens. In this study, bacteria were isolated from a local field and characterized for their ability to fix nitrogen, to solubilise phosphates and to produce phytohormones. The obtained bioformulations were tested on previously selected crops, both in presence and in absence of artificial fertilizers. With the aim to develop effective multifunctional bio-fertilizers, different bacterial consortia were tested and assessed for the ability to boost plant growth and nutrient uptake.

25 - Antoine Grandin-Courbet - Seaweed based-extract improved leaf meristem protection of perennial ryegrass under drought

Climate change has amplified abiotic stresses and especially drought. This stress affects plant growth and development with an impact on grassland sustainability and crop yield. A novel approach to reduce stress-induced limitations is the use of biostimulants. Using a bioassay under controlled conditions, we evaluated the mechanisms involved in the biostimulant effect of an algal extract on perennial ryegrass (*Lolium perenne*) subjected to drought. The objectives of this study were to evaluate the potential of seaweed extract to improve membrane protection by fructans. Fructans are the main non-structural carbohydrates in temperate grasses and in addition to their role as carbon reserve, they also contribute to resistance to abiotic stresses. *Laminaria digitata* extract (EVP6) was sprayed on the leaves at 0.5, 2, 5, 10 15L/ha seven days before the water supply was stopped. This priming period was followed by fourteen days of drought and ten days of recovery which started with rewatering. EVP6 supplied at 2 L/ha allowed a significant stimulation of regrowth during the recovery period. The decrease in leaf relative water content (RWC) during drought was less pronounced in this condition than without seaweed extract (dried control plant), suggesting better osmotic adjustment. Consequently, the water content of leaf meristems was less decreased than in the dried control plant, suggesting an improvement in drought resistance. In addition, the decline in cell membrane stability was less pronounced in plants sprayed with the seaweed extract at 2 L/ha and its recovery was faster, indicating better membrane protection. This could be explained by the higher synthesis of fructans which could then help improve both osmotic adjustment and membrane stability. Understanding the underlying mechanisms by which EVP6 triggers fructan synthesis will be investigated by transcriptomic and enzymatic approaches.

26 – Giuseppe Colla – Biostimulant development: a journey of discovering new protein hydrolysates from lab to field

Protein-hydrolysate based biostimulants can be obtained through enzymatic hydrolysis of proteins from vegetal biomass. Production process and protein sources are crucial for maximizing the yield of bioactive compounds such as peptides and amino acids. Moreover, the development of new biostimulants requires an accurate testing of the product effects on the morpho-physiological traits of plants and plant tissues and a deep understanding of the mechanism of action of selected products. Product screening approaches using omics technologies have been found to be more efficient and cost effective in finding new biostimulants. Bioassays have been used to identify specific hormone-like activity of PHs. Moreover, a protocol based on the use of high-throughput phenotyping platform for screening new vegetal-derived protein hydrolysates (PHs) for biostimulant activity followed by a metabolomic analysis to elucidate the mode of action of PHs has been validated on tomato and lettuce seedlings grown under optimal and stress conditions (N deficiency and salinity). Finally, the best performing products need to be tested in real growing conditions on selected crops to optimize the dose and timing of application.

27 – Jing Li – A meta-analysis of biostimulant yield effectiveness in field trials

Today's agriculture faces many concerns in maintaining crop yield while adapting to climate change and transitioning to more sustainable cultivation practices. The application of plant biostimulants (PBs) is one of the methods that step forward to address these challenges. The advantages of PBs have been reported numerous times. Yet, there is a general lack of quantitative assessment of the overall impact of PBs on crop production. Here we report a comprehensive meta-analysis on biostimulants (focus on non-microbial PBs) of over one thousand pairs of open-field data in a total of 180 qualified studies worldwide. Yield gains in open-field cultivation upon biostimulant application were compared across different parameters: biostimulant category, application method, crop species, climate condition, and soil property. The overall results showed that (1) the add-on yield benefit among all biostimulant categories is on average 17.9% and reached the highest potential via soil treatment; (2) biostimulant applied in arid climates and vegetable cultivation had the highest impact on crop yield; and (3) biostimulants were more efficient in low soil organic matter content, non-neutral, saline, nutrient-insufficient, and sandy soils. This systematic review provides general biostimulant application guidelines and gives consultants and growers insights into achieving an optimal benefit from biostimulant application.

28 - Marco Zarattini - LPMO-oxidized CelloOligosaccharides enhance resistance toward the fungus *B. cinerea* and Heat Stress conditions in *Arabidopsis*.

In plant-pathogen warfare, the efficacy of pathogen-associated cell wall degrading enzymes (CWDEs), on one side, and the ability of the plant host to perceive cell wall damage, on the other side, deeply influence disease outcome. Lytic Polysaccharide Monooxygenases (LPMOs) are a recently discovered class of CWDEs catalyzing an alternative oxidative mechanism of polysaccharides breakdown. Widely conserved across biological kingdoms, nowadays, LPMOs are classified into eight “Auxiliary Activity” (AA) families: AA9-11 till AA13-17. Yet, the AA9 family is deployed by phytopathogens to deconstruct cellulose polymers, thus releasing inside the apoplast a blend of native and oxidized cellooligosaccharides (COS). Here, we show that the perception of AA9-oxidized COS led to damage-triggered immunity in *Arabidopsis* increasing resistance to the necrotrophic fungus *Botrytis cinerea*. Furthermore, we also demonstrated that AA9-derived COS confers thermotolerance by inducing several Heat Shock Factors (HSFs) and Heat Shock Proteins (HSPs) genes, especially HSFA2, along with remarkable priming of ethylene emanation. Our data reveal for the first time that the perception of cellulose-derived oxidized COS positively affects both biotic and abiotic stress resistance.

29 - Stéphanie Vandionant - Woody biochar as biostimulant: Molecular and vegetative benefits in cadmium-contaminated medium

Cadmium is known to cause a range of negative effects in plants, including oxidative stress and decrease in yield. This can trigger endoreplication, an alternative cell cycle in *Arabidopsis thaliana,* resulting in doubling of the nuclear DNA content and eventually endopolyploidy. However, this mechanism works at the expense of an optimal growth and reproduction due to the growth-defence trade-off. In order to alleviate this plant stress, biochar can be added to the environment. This carbonous biostimulant has multiple benefits in environmentally related stress conditions and can immobilize Cd. This material is formed by anaerobic pyrolysis of organic material. In general, woody biochar is a promising sustainable biostimulant, which is able to reduce plant stress and increase plant yield on Cd-contaminated agricultural fields. The aim of this study is to investigate whether *Pinus sylvestris* tree bark (TB) and medium-density fiberboard (MDF) biochars are sustainable biostimulants, capable of reducing Cd's negative effects in seedlings, both at molecular and biometric level. The fresh weight and nuclei concentration data of the seedlings indicate a postponed (MDF) or counteracted (TB) decline with increasing Cd concentrations. Comparison of these two parameters indicates that the addition of woody biochar postpones the Cd-induced growth-to-defence shift in the function of endoreplication. Lastly, gene expression data of oxidative stress markers demonstrate that woody biochar reduces the production of reactive oxygen species (ROS). Three main conclusions can be drawn from this study: Firstly, the decline in vegetative growth with increasing Cd concentrations is postponed by MDF biochar and even counteracted with TB biochar. Secondly, nuclei concentrations measured via flow cytometry indicate that this parameter can be used as a proxy to investigate the effects of stress factors regarding endoreplication in *A. thaliana* seedlings. Lastly, the addition of woody biochar diminishes the biosynthesis of ROS in Cd-exposed *A. thaliana* seedlings and this is probably due to the immobilization of Cd. Overall, woody biochar is a sustainable biostimulant, which makes plants able to cope with the negative effects of Cd contamination. Further research, including metal determinations of seedlings and media, is needed to unravel its mode of action.

30 - Paulien De Clercq - Effect of seaweed-based biostimulants on growth and development of *Hydrangea paniculate*

To maximize growth and quality, the ornamental sector uses large amounts of water. Therefore, commercial nurseries maintain plant available water of their potted ornamentals close to full container capacity. As water is an increasingly scarce resource, solutions that use irrigation water more efficiently while maintaining similar growth and quality will become more important. Biostimulants could offer a sustainable solution as they would increase plant tolerance to abiotic stress. In the 2-Seas Interreg project Bio4safe, we studied the effect of different biostimulants in container production of woody ornamentals under reduced irrigation. The effect of four seaweed extracts and one microbial biostimulant on *Hydrangea paniculata* under continuous (2019) and periodic drought stress (2021) were tested. The seaweed extracts were *Ascophyllum nodosum, Ecklonia maxima, Saccharina latissima* (all brown algae) and *Solieria chordalis* (red alga). One-year-old liners were potted in containers filled with a peat-based substrate. Biostimulants were applied on drought-stressed plants as foliar applications. These plants were compared to drought-stressed treatment without biostimulants and a well-watered control treatment. In a first trial (2019), overhead irrigation was reduced by 20 % compared to a well-watered control irrigation. This reduction in irrigation water resulted in more compact plants with more branches, which is a desired trait for Hydrangea. Application of biostimulants did not affect chlorophyll and polyphenol content (DUALEX) compared to the untreated stressed control. The *A. nodosum* extract slightly increased stomatal conductance (Porometer) and dry weight of the plants compared to the same control, the effect of this biostimulant on the branch length was even significant. In the second trial (2021), plants were

irrigated by drippers following good agricultural practices. Repeated drought stress cycles were applied by turning off the drip irrigation until the plants visually suffered from drought stress. Periodic drought stress also resulted in reduced branch lengths and biomass. Biostimulant effects were again limited. The *A. nodosum* extract seemed to accelerate flowering, as more fully developed flowers were counted compared to all other treatments, but had no effect on branch length or dry weight. The *E. maxima* extract negatively influenced branching.

31 - Kris Audenaert - The elusive *Serendipita* genus and its metabolites: a promising biostimulant

In this work, we introduce a new untapped source of potentially beneficial fungal species belonging to the basidiomycetous order Sebacinales. A collection of 51 Sebacinales isolates was gathered in The Democratic Republic of Congo. Based on morphological data, ISSR fingerprinting profiles, and ITS and TEF1α marker gene sequences, we uncovered that this collection is closely related to *Serendipita williamsii*, which together with *S. indica* has been recently transferred from the genus *Piriformospora* to *Serendipita* within the newly proposed *Serendipitaceae* family. Because of their closer affiliation with *S. williamsii* than with *S. indica*, we provisionally designated the new isolates together with the described reference strain as the *Serendipita* (= *Piriformospora*) *williamsii* species complex. The low success rate of previous studies to isolate endophytic sebacinoids directly from field samples can be linked to the organism's low abundance in natural ecosystems. Indeed, the metagenomics data generated in this work showed that these endophytes sparsely colonized the roots as they accounted for only 0.00% to 3.62% of the total read count per analyzed root sample. However, notwithstanding the low abundances at which they were detected, sebacinoids occurred in as much as 87% of the maize samples gathered at Congolese smallholder farms, implying that they represent a consistent taxon within indigenous fungal populations across smallholder farm sites in the region. Moreover, unlike the total fungal and arbuscular mycorrhizal communities, sebacinoid communities appeared to be quite robust, i.e., less susceptible to environmental and anthropogenic factors (soil characteristics and slash- and-burn management, respectively). Green Deal incentives imposed by the European Commission have spurred research to search for bio-stimulative alternatives for fertilizers. Therefore, we explored our isolates for plant growth-promoting (PGP) traits which proved to exhibit promising PGP capabilities. More specifically, shoot biomass production and root growth of chlamydospore- and mycelium-inoculated *Arabidopsis* seedlings were stimulated in *in vitro* assays. Additionally, we demonstrated that volatile metabolites called VOCs (volatile organic compounds) emitted by *Serendipita* strains are able to enhance the performance of *in vitro* grown *Arabidopsis* seedlings, probably by modifying plant auxin and cytokinin signaling. Across all experimental systems tested, an up to 9.3- and 2.0-fold increase in shoot fresh weight and lateral root density, respectively, was measured in VOC-exposed plants. Furthermore, an altered shoot morphology, augmented starch and anthocyanin levels, and an improved maximum quantum efficiency of photosystem II were recorded in the treated plants. The strongest evidence for the PGP potential of the Congolese isolates was provided by greenhouse experiments in which plants were exposed to different abiotic stress conditions. The results revealed that maize plants could cope better with nutrient limitations and drought stress when treated with *Serendipita* mycelium. Altogether, based on our data, we believe that the Congolese *Serendipita* isolates provide unprecedented opportunities for fundamental as well as translational research on the *Serendipitaceae* and that they might be relevant for applications within a sustainable agricultural context.

32 - Francesco Magro - Plant methods for the characterization of plant biostimulants effects

This study is aimed to present an omics approach for profiling responses to plant biostimulants (PBs) across different growing conditions and using tomato (*Solanum lycopersicum* cv. Micro-Tom) as a model plant. The method was conceptualized by Sipcam-Oxon's Nutritionals R&D team and developed in cooperation with two research groups at the Universities of Padova and Bologna (Italy). This team is comprised of members with multidisciplinary expertise including transcriptome profiling via massive-scale mRNA sequencing, bioinformatics, and phenomics, i.e., the study of the morphological and physiological changes induced by PBs application, across different growing approaches ranging from vertical farming using soil-free techniques to the greenhouse and open-field conditions. Two cases of study are here presented to highlight the effects in tomato of a brown seaweed extract and a novel calcium-enriched PB. Seaweed extract-treated plants showed a transcriptome reprogramming, mainly involving the biological processes of photosynthesis, after the second and the third leaf application, together with greater fruit yield, due to a greater number of flowers and fruit set, with respect to untreated plants. The novel calcium-enriched PB showed to be effective in modulating the expression of genes involved in plant stress response and increasing the treated plant's transpiratory activity and net photosynthesis after three applications carried out during the flowering stage. According to this evidence, the seaweed extract determined the increase of the number of flowers and fruit set, while the novel Calcium-enriched PB mitigated physiological disorders under field conditions. This study provides a detailed and robust method to highlight PB effects in tomato under different growing conditions. Based on our findings, the combination of transcriptomics and phenomics approaches could become a key system for dissecting the plant response to PBs.

33 - Kris Kunnen - Don't waste your waste: how waste of microgreens cultivations becomes a resource for coconut coir-based biochar, possibly increasing substrate and product quality along the way.

Within urban agriculture, microgreens gained immense popularity due to potentially higher nutritional values, specific tastes and ease of cultivation. However, current substrate-based microgreen cultivation systems mainly rely on the use of peat-based growing media. More sustainable growing media, like the industrial waste stream coconut coir (CC), are less used due to inconsistency in their physical, chemical and biological properties, reducing their performance value. The current project focusses on the production of biochar (a carbon-rich by-product of pyrolysis) from the waste of CC-based microgreens cultivation systems. Firstly, this results in a carbon-sequestering resource produced from the CC substrate waste. Secondly, the implementation of this biochar into new CC could stabilize the physicochemical properties (pH, EC, nutrient retention) of the growing medium, as well as improve plant development and quality (e.g. germination, yield). Nevertheless, the physicochemical biochar properties are highly dependent on pyrolysis parameters (e.g. temperature). Therefore, production parameters of biochar were investigated in the current study. Results from a quick phenotypical screening using *Arabidopsis thaliana* germination suggest that pyrolysis temperatures (400, 500, 600 and 700°C) differently affect the biochar and hence root length and fresh weight of *A. thaliana* seedlings. These results are further explored in experiments focusing on the effects of biochar (1) on pH, EC and nutrient leaching/retention, (2) on seedling development, and (3) in its implementation in the CC-based microgreen cultivation system.

34 - Martin Quiévrieux - Testing biostimulants to validate the claims through multi-scale assays and a meta-analysis

Biostimulants are made available on the market according to their intended effects on crop plants. The European law has set a legal definition for “plant biostimulants” based on their effects on crop plants and/or soil, referred to as “claims” (Regulation (EU) 2019/1009). Consequently, standardized procedures will be required to validate the claims of biostimulants. Which protocols will prove sufficient to demonstrate their efficacy still needs to be determined. Although many data are available, from the laboratory to the field, it seems important to generate parallel data sets by using the same biostimulants at the laboratory, greenhouse and field scales. By combining the data sets, the relevance of the different tests and the efficacy of the field and contained use approaches can be best evaluated and compared. In order to set up an evaluation platform for biostimulants in the Walloon Region of Belgium, the project BioStimTest has been launched by a gathering of public and private partners. Organic and mineral (as well as microbial) commercial biostimulants are being tested on winter wheat, maize and potato with field trials. On the other hand, greenhouse and laboratory bioassays are performed using monocotyledonous and dicotyledonous plant models and include seed germination tests and plant cultivation under more or less artificial conditions (*in vitro* assays, hydroponic culture and pot plants in greenhouse). Improvement of nitrogen use efficiency and of drought tolerance are the two biostimulant claims considered by the project. Accordingly, different fertilization regimes and rain supplies limitation by controlled crop coverage are used in the field experiments, under the temperate climate of Belgium, whereas contrasted nitrogen or water supply or polyethylene glycol use are implemented in laboratory and greenhouse bioassays. Data produced by these bioassays and plant performance in field trials are compared with a meta-analysis in order to develop claims-validating protocols at the laboratory and/or greenhouse scale which are most predictive of efficacy under field conditions.

35 - Halimat Ogunsanya - Biostimulant activity in extracts from Belgian endive roots

Belgian endive (*Cichorium intybus* var. *foliosum*) is a popular vegetable in Europe where about 95% of the world’s production is located. The storage roots of Belgian endives are incubated in the dark to force the production of thick etiolated shoots that are consumed. What is left after harvest are the forced roots which still contain some valuable metabolites. Water extracts from this root by-product was found to harbour root and shoot growth stimulating activity. In-vitro grown *Arabidopsis* seedlings show a significant increase in biomass when cultivated on plates containing 0.5g/L of endive root extract. The Belgian endive water extract was fractionated using water and organic solvent partitioning. To characterize the active ingredients, the water-solvent mixtures were centrifuged and separated into three components: the interphase (IT) between the organic phase and the aqueous phase, the water (W) phase, and an insoluble pellet (P). We determined which fraction contains bioactivity by testing separate fractions and their combinations using a root growth assay. Bioactivity was found in the pellet fraction, suggesting that solvent addition to the crude water extract precipitated the bioactive compounds. The pellet fraction likely contains pectin, (hemi)cellulosic polysaccharides, proteins, and phenolic compounds. Oligogalacturonides (OG) derived from the pectin precursor galacturonide (GalA) have been shown to stimulate root growth and trigger defence response in plants by accumulating H_2O_2. We observed H_2O_2 accumulation in *Arabidopsis* treated with Belgian endive extract, suggesting that oligogalacturonides are responsible for the observed biostimulant activity. The findings indicate that Belgian endive roots are a potential source for the development of organic waste-derived biostimulant.

36 – Alejandro Navarro Galiano - Two different biostimulants enhanced *Arabidopsis thaliana*'s tolerance to hypoxia.

Climate change has been altering global rainfall regimes - and thus water availability. Therefore, dealing with the weather's impact on crops is already one of the main challenges to be overcome in the agricultural sciences. Increasingly, frequent flooding episodes limit oxygen availability in plant tissues, leading to hypoxic stress. Priming response was investigated *Arabidopsis thaliana* plants submitted to long-term hypoxia after plants were treated with two different commercial biostimulants – one amino acid and one seaweed-based. Plants were treated with each biostimulant, one week before stress, at a concentration of 4L/ha. They were then kept under stress for 3 weeks and withdrawn to undergo another week of reaeration and recovery. Phenotypical aspects were assessed both on the third week and post reaeration and showed significant positive impacts of both biostimulants on leaf elongation ($p < 0.05$, ANOVA). Leaf tissue was collected after the recovery period for transcriptomic analysis and differential gene expression (DGE). In the presence of stress, the transcriptome was largely impacted by both amino acids and the seaweed biostimulants, with 17.5% and 8.6% of gene dysregulation, respectively. To approach the functionality, all differentially expressed genes were allocated using Gene Ontology biological process terminology and analysed by a hypergeometric function to eliminate the false positive discovery (Q-value < 0.05). The GO analysis showed considerable changes in genes related to stress response and signalling processes led by both biostimulants, allowing a better understanding of the underlying strategies, and signalling pathways of each of them. The same analysis workflow was used to unstressed plants and interestingly, biostimulants not only showed a better growth rate compared to control but also a dysregulation in key genes allocated to biological processes (such as response to ROS, immune system triggering, and signalling), suggesting that chemical priming triggers plant's long-lasting memory even in the absence of stress. A more comprehensive view of phenotypical results differentially expressed genes and gene ontology will be presented at the conference.

37 – Marcin Smiglak - Chlorophyll a fluorescence as a tool to study the influence of two novel biostimulants: ionic derivatives of salicylic and benzo(1.2.3)tiadiazole-7-carboxylic acid- on pepper (*Capsicum annum* L.)

The interest in plant biostimulants has increased worldwide in the last decade. Extensive screening following the development and synthesis of novel biostimulants is a crucial process for understanding the response of plants to these compounds. Screening approaches using molecular techniques have proven to be efficient in searching for new compounds exhibiting biostimulation. However, a screening protocol based on non-destructive physiological measurements has not yet been established. The aim of the present study was to investigate the influence of two new biostimulants: ionic derivatives of salicylic and benzo(1.2.3)tiadiazole-7-carboxylic acids on pepper (*Capsicum annum* L.) plants by non-destructive methods, and to identify the most sensitive photosynthetic parameter indicating biostimulation. To investigate the effects of two novel compounds at three different concentrations, a vegetation chamber experiment was carried out. Biostimulant treatments were administered by a single foliar application after plant establishment (i.e. before flower bud differentiation) and included: control - water (W), three different concentrations of derivative of salicylic acid (A): 100 mg/L (A1), 200 mg/L (A2), 400 mg/L (A3) and derivative of benzo(1.2.3)tiadiazole-7-carboxylic acid (B): 15 mg/L (B1), 30 mg/L (B2) and 60 mg/L (B3). Before and 24 hours after biostimulant application, non-destructive measurements were carried out to assess the chlorophyll a fluorescence derived parameters (OJIP) and the photosynthetic efficiency of the leaves. The results indicated that the tested biostimulants had a significant effect on evaluated non-destructive parameters, and the effect was concentration-dependent. Among studied biostimulants in varying concentrations, a generally positive effect was observed for ionic derivatives of salicylic acid (A3) and benzo(1.2.3)tiadiazole-7-carboxylic acid (B2) on selected OJIP parameters which seems to improve

plant photosynthesis. In general, the F_v/F_m and F_v/F_o ratios indicated that the plants were not under abiotic stress influenced by the new biostimulants.. Furthermore, the selected Chl a fluorescence derived parameters can be used as a reliable and quick tool to study biostimulation process.

38 - Mariluz del Pino-de Elias - Biostimulants for barley: Determining the potential of bio-based products for barley growth and development in field

Over the past century, there has been a dramatic increase in greenhouse gas emissions. The rising population and the demand of food, poses severe challenges to the agricultural sector. The Farm to Fork Strategy aims to reduce dependency on pesticides and fertilisers and increasing organic farming practices. Biostimulants are an alternative to chemical inputs and could enhance food security sustainably. The objective of this research is to determine whether the use of biostimulants enhance nutrition use efficiency, stress tolerance, yield and grain quality in barley. Field trials were conducted at UCD Lyons Farm (Co. Dublin, Ireland). Plots were created to assess the effect of three bio-based products together with a reduction of nitrogen rates in winter barley. There are also plots untreated with fungicides to see the effect of biostimulants against fungal diseases. The treatments are as follows: treated/untreated plots with fungicides; 2 varieties (KWS Cassia and Valerie); reduced nitrogen regime at 50%, and 25%; and 3 biostimulants from different categories (i. seaweed extract; ii. protein hydrolysates; iii. beneficial bacteria) with 4 replicates. To test treatment combinations, the experimental design was created as a Randomise Complete Block Design. The hypothesis is that these treatments, when sprayed with biostimulant, can improve nitrogen uptake efficiency. It could mean that reducing N fertiliser inputs whilst complementing with biostimulant does not compromise yield and grain quality standards when compared to traditional fertilisation programmes. Throughout the season, growth stage of plants is being monitoring along with number of plants/m2, plant height, ears/m2, as well as a record of symptoms of diseases . More data related to yield, and grain quality will be gathered after harvesting. The study will run the field experiment for 3 years. Datasets will be obtained, opening a field of study which will support a global transition to sustainable agri-food systems to reach Net-Zero by 2050.

39 - Uwe Conrath - Priming plants for enhanced defense

When locally infected by pathogens, plants activate a systemic immune response, called systemic acquired resistance (SAR). In this process, distal leaves become primed to activate a more robust defense response upon further infection. Defense priming is associated with an elevated level of microbial pattern receptors (e.g. flagellin-sensing 2), accumulation of dormant signaling enzymes (e.g. mitogen-activated protein kinases 3 and 6), and with modification of chromatin. The latter comprises the covalent modification of histones (e.g. histone H3 and H4 acetylation and/or methylation) and the formation of open chromatin indicative of regulatory DNA with a role in defense priming. Together, these events provide a memory to the initial infection and enable the boosted recall defense response. I will disclose the impact of these fascinating discoveries on sustainable agriculture by introducing smart tools and approaches for identifying and employing priming-inducing chemistry and microbes.

40 – Pierre Van Cutsem - Differential response of dicots vs monocots after elicitation by COS-OGA –how does it fit into plant metabolism?

Plant elicitation is increasingly used in environmentally friendly crop protection. The COS-OGA active substance is a complex of chitosan and pectin oligomers that associate in the presence of calcium ions and monovalent cations. This elicitating complex has been known for more than twelve years, it is registered in Europe and used in both organic and conventional agriculture. The main uses concern the preventive protection of dicotyledonous crops such as grapevines against powdery mildew and downy mildew, but also on many vegetable crops. In this presentation, we will explore the comparative response of a dicot species, tomato, with a monocot, rice, following treatment with a commercial formulation of the COS-OGA elicitor, FytoSave®. Using RNAseq, we will focus on differential gene transcription in these two species to tryto understand their response strategies to the presence of these PAMP-DAMP molecular motifs. In particular, we will examine the impact of elicitation on photosynthetic electron flow in tomato and indirectly on the redox homeostasis of the plant and thus on the host-pathogen interaction. The metabolic changes observed will be discussed with a view on the global fitness of the plant towards its environment.

41 – Ivan Visentin - Strigolactones: phytohormones with a potential for agrochemical manipulation of crop performances

Strigolactones (SL) are a class of plant hormones with various functions in plant development and in the interaction with (micro) organisms in the rhizosphere. As developmental regulators the SLs control above- and below-ground morphology, the inhibition of shoot branching, the modulation of the root morphology and the promotion of the shoot secondary growth. Some of these functions have proved to be very interesting for their potential application in agriculture. However, among all the roles played by the SL in drought acclimation and in the induction of floral transition are undoubtedly the more intriguing. In this context, we developed and optimised a protocol to obtain a SL-enriched plant extract from aeroponic tomato culture. Moreover, within two International projects, we tested its efficacy and analysed its effects on tomato culture under different growth conditions: the preliminary results obtained so far have been encouraging and suggest a potential use of this extract as an ingredient for an innovative biostimulant formulation.

42 – Simona Masiero - CYCLIC: a game changing library for the isolation of cyclic antimicrobial peptides for a sustainable agriculture

Oomycete and fungal plant pathogens are controlled using several active compounds, some of which are predicted to be banned in the near future since they have serious impact on the environment, non-targeted organisms, and human health. To avoid repercussions for food security, alternative biomolecules safe for human health and environment, able to control existing and emerging pathogens must be developed. In this respect, our group has developed a yeast two hybrid library suitable to isolate small (8 amino acids long) cyclic peptides able to bind with high affinity pathogen enzymes necessary for the plant infection. The peptides bind the target proteins inhibiting their activity, and consequently reducing or, in the best scenario, abolishing the pathogen virulence. The group has isolated some peptides able to bind enzymes involved in the construction of the cell wall of oomycetes, such as *P. infestans*, *P. viticola* and *P.ultimum*. These peptides are highly specific and arrest the progression of the oomycete infection, posing the basis of a novel strategy for a more sustainable agriculture.

43 - Satish Namdeo Chavan - Dehydroascorbate: A novel induced resistance-inducing stimulus against root-knot nematode *Meloidogyne graminicola*

Rice is the most important food crop throughout the world. The root-knot nematode (RKN) *Meloidogyne graminicola* is one of the most important plant-parasitic nematodes affecting rice production and is present in most rice-growing areas globally. Induced resistance (IR) is one of the promising approaches in the search for environmentally-friendly crop protection methods. Dehydroascorbate (DHA) the oxidized form of ascorbic acid (vitamin C) was found to activate systemic induced resistance in rice against RKN *M. graminicola*. Detailed transcriptome analysis on roots of rice plants showed an early and robust transcriptional response upon foliar DHA-treatment, with induction of several genes related to plant stress responses, immunity, antioxidant activity, and the salicylic acid pathway. Biochemical and hormone measurements in DHA-treated plants confirmed that the DHA-IR is mediated through the production of reactive oxygen species and activation of the salicylic acid pathway. In addition, DHA was found to be nematicidal to the second-stage juveniles of *M. graminicola* upon direct exposure. DHA caused 100% nematode mortality after 72 h incubation in 20 mM DHA solution. Different methods of DHA applications in rice *viz*., foliar treatment, root drench, root dip, and seed treatment, were evaluated for the effective utilization of DHA. Among these methods, DHA was found effective in reducing nematode infection in rice when applied as a foliar treatment, root drench, or root dip method. The root drench and root dip method caused the maximum reduction in nematode infection. DHA was found to protect the rice plants at least up to fourteen days after its application. Our results collectively revealed that DHA activates systemic induced resistance in rice. The IR-stimulating activity and direct nematicidal effect of DHA can be used to effectively manage *M. graminicola* infection in rice.

44 - Brechtje De Haas - Microbiome of hydroponic lettuce is stable under different light qualities

The rhizosphere microbiome is shaped by the metabolite composition of the root exudate. Controlling root exudation may therefore influence the microbes of the rhizosphere. In an attempt to modify root exudation, we investigated whether light quality affects the rhizosphere microbiome in vertical farming. The effect of light quality on carbohydrate, protein, and phenolic compounds was analyzed in leaves and roots of lettuce as well as its rhizobiome community. *Lactuca sativa* Expertise RZ was grown in a Deep Flow Technique hydroponic system. Lettuce plants were exposed to three light qualities: full-spectrum light, 100% blue light, and 100 % red light at 200 µmol m^{-2} s^{-1}. After four weeks, leaf and root tissue and rhizobiome were sampled. Microbiome was sampled in a 0.9% NaCl and 0.9% NaCl including 0.01% Tween80 solution. Glucose, fructose, and sucrose content of plant tissue was analyzed with HPLC on a CarboPAC20 column. Total phenolic content was spectrophotometrically determined in plant tissues. DNA was extracted from microbiome samples and sequenced. Light treatment caused a significantly ($p < 0.05$) higher soluble sugar content in the leaves grown under red light, compared to blue and white. Total phenolic content in the leaves was significantly ($p < 0.05$) higher in plants treated with 100% blue light than 100% red light. Root tissue showed no significant ($p > 0.05$) differences in physiological parameters. Microbiome community structure was not significantly ($p > 0.05$) altered due to the light treatment. These results indicate that the microbiome of lettuce plants is not profoundly altered under different light qualities.

45 - Xinquan Hu - Tracing back potential PGPRs in the root-associated bacterial communities of growth-promoted hydroponic plants

In the background of the growing world population under increasing climate change threats, a transition to sustainable agriculture is required to reduce our dependency on chemical fertilizers and agrochemicals. Plant growth-promoting rhizobacteria (PGPR) can improve plant growth and thereby reduce the negative impact of crop production on the environment. Various modes of action have been reported which include better nutrient use efficiency, stress alleviation, and stimulation through the release of hormone-like substances. Here, in this study, we are interested in discovering PGPRs that improve crop growth in a hydroponic system. In hydroponics, water and nutrients are amply available, and improved growth by PGPRs is therefore associated with other plant biochemical processes. In previous work, we investigated the effect of bacterial inoculation on the performance of hydroponic lettuce (*Lactuca sativa* L.), which were grown in different substrates, and their root-associated bacterial communities. My goal is to identify the candidate PGPRs that are responsible for the increased lettuce growth observed. In one approach, a screening system will be developed to identify microbes that produce auxin-like molecules using a colorimetric method. Alternative approaches consist of using natural colors of colonies grown from bacteria that were extracted from the rhizosphere. An update on my progress will be presented.

46 - Jasmine De Rop - Incorporation of *Rhizobium leguminosarum* and *Pseudomonas* spp. in seed encrustings for nitrogen fixation and biological control in *Phaseolus vulgaris* L.

In this research, the aspects of seed treatments to optimize nitrogen fixation by *Rhizobium leguminosarum* BR1 and the biological control of *Rhizoctonia solani* by means of *Pseudomonas* bacteria (CMR12a and COR33) in beans are studied. First, the substrate with which the seed encrustings are developed is optimized for the survival of both *Rhizobium* and *Pseudomonas* bacteria. The main component of the different substrates tested is soil substrate. Trehalose has been found in the literature to be an advantageous additive for the survival of various microorganisms, so a number of concentrations of this additive in the substrates were tested. In a next phase, the seed encrustations formed were evaluated for germination capacity. The optimal seed encrustation method is determined for each microorganism by the highest germination rate. In the next part of the research, one type of seed encrusting for inoculation with *Rhizobium* bacteria and one type of seed encrusting for inoculation with *Pseudomonas* bacteria will be selected. First, the nitrogen-fixing capacity of *Phaseolus vulgaris* L. through symbiosis with the *Rhizobium* bacteria and second, the biological control capacity of *Pseudomonas* COR33 and *Pseudomonas* CMR12a against *Rhizoctonia solani* will be evaluated in plant experiments.

47 – Camila Levy - Bringing ultra-efficient biostimulant applications into agricultural practice

Increasingly, people are becoming aware of what arrives to their table, and it is more common to hear about, the concept of sustainable agriculture. But the real challenges that farmers are facing nowadays to reach this goal are the huge number of adverse climatic conditions with the dramatic impact on their yield, quality and profitability as a consequence. In this scenario, there is no doubt that we need to help farmers to achieve in an efficient way their maximum crop's potential and it is there the biostimulants sector is gaining a high importance. Tradecorp has developed a new ultra-efficient biostimulant with state-of-the-art technology, derived from biological fermentation, using a specific bacterial strain and an exclusive and sustainable plant fermentation process. The final product does not contain live bacteria, which guarantees a longer shelf-life and stability. The technology and manufacturing process allows to obtain products with a demonstrated biostimulant effect based on the synergistic action of multiple bioactive substances related both with primary and secondary metabolism of plants with a high efficacy at ultra-low doses (50-200 mL/ha). Those substances, resulting from the digestion of sugar molasses as a substrate, conclude in a unique fingerprint of the product which provide specific functions into the plant development. This biostimulation technology has been validated both in the field and through advanced techniques such as metabolomics and transcriptomics. In addition, it has been observed a regulation in the expression of genes associated with photosynthesis, cell wall organization or carbohydrate metabolism, among others. To complete the full picture of the product's mode of action, Tradecorp established a global strategic development plan including a large program of agronomic trials on strategic crops and key geographies. From the information obtained in these trials, it was determined that the optimal product's positioning is at the fruit swell and development stage, increasing crop quality traits and yield when applied via foliar. Therefore, the ultra-efficiency of this biostimulation technology provides a differentiation and profitability for the grower, contributing to a sustainable and well-balance agriculture.

48 – Robin Ingels - A practical approach in developing Biopesticides & Biostimulants

Globachem is a family-owned company based in Sint-Truiden Belgium. Started in 2000, Globachem helps farmers in optimizing their production. We do so by developing, registering, and internationally marketing a wide range of existing and innovative crop protection products. As a result, Globachem, as an agile and dynamic family-owned business, contributes to the production of sufficient safe food for the growing world population, at all times aiming for the smallest ecological footprint. The presentation will provide an insight in how an agrochemical company expects the market to change into the future and provide a practical approach to developing biostimulants & biopesticides. In 10 years, time, Globachem wants to be an innovative key player in the world crop protection market.

49 - Jan Geerinck - Evoca, the first biofungicide developed on the ground-breaking Biotalys AGROBODY Foundry platform

Evoca™ is the first biofungicide product of a new generation of protein-based biocontrol solutions built on the groundbreaking Biotalys AGROBODY Foundry™ platform. Evoca™ will help growers effectively control key fungal pathogens in the field, as well as in the food value chain to protect fruits and vegetables post harvest, extending shelf life and reducing decay and food loss. Specific target diseases are Botrytis and powdery mildew, which impact a wide range of fruit and vegetables, including vines, berries and covered crops. The environmentally friendly, innovative biofungicide offers a completely new mode of action to reliably help farmers overcome increasing fungicide resistance with pre- and post-harvest applications. In addition to mitigating threats in the field, Evoca™ adds significant value by extending the shelf life of fruits and vegetables with substantially reduced residue levels – addressing the needs of growers, consumers and retailers, reducing food waste and ensuring global export safety. Using its ground-breaking technology platform to develop crop and food protection agents for pre- and post-harvest applications, its revolutionary protein-based biocontrols (Evoca™ being the first) provide the effectiveness and consistency of chemicals, as well as the clean safety profile of biologicals. The AGROBODY Foundry technology uses the features of camelid antibodies as inspiration of its active ingredients, as has already been proven successful in the development of human therapeutics. Biotalys produces its products through fermentation leading to proteins that have the same protective characteristics of the camelid antibodies. Biotalys is leveraging the flexibility of its technology platform to advance a broad pipeline of products with new modes of action that will safely and reliably address key crop pests and diseases across the food value chain.

50 - Camila Levy - BIOTOOL, innovative tool for the biostimulant's mode of action identification and their behaviour under water use efficiency

High-throughput methodologies have become an important tool in agriculture and significantly contributes to plant breeding and management approaches. Biostimulant functional characterisation can be monitored in high precision and resolution in a specific stage of plant's development to determine the plant's response to environmental conditions. BIOTOOL is an innovative research project developed by Tradecorp International and the Italian research centre Landlab, supported by Eurostars programme. The aims of the project are: i) to evaluate the efficiency of biostimulants during the product development phase; and ii) develop novel highly efficient biostimulants selected and tested to improve tolerance to abiotic stress in crops. To reach these goals, BIOTOOL platform was developed as a tool for studying the Water Use Efficiency (WUE) under experimental conditions and for the real-time evaluation of plant status in suboptimal conditions of water application. For that, Tradecorp investigated new active substances (e.g., seaweed derived and from other vegetal sources) positively impacting the metabolic processes of plants, looking for combinations between seaweed extracts to create a novel range of biostimulants, designed to improve the plant's reaction to stresses and overcome the drought or water reduction, allowing a more efficient use of water, and entailing a lower environmental impact during its application in crops. The high-throughput methodology developed for the BIOTOOL platform allows to study the resilience of several crops and varieties to hydric stress and explore a higher water use efficiency (WUE), while continuously collecting data plants transpiration, water usage over time at greenhouse-scale and contemporary apply back to each single plant water, nutrients and biostimulants in any planned quantity and frequency. Some of the preliminary results obtained with the new biostimulants tested with the platform showed that, when biostimulants were applied as preventive treatments under drought conditions, dry weight on lettuce and average fruit weight on tomato was enhanced, increasing firmness and size, and improving the priming activity of existing formulations. These outcomes of BIOTOOL platform were validated in additional greenhouse trials, obtaining similar tendencies with the prototypes tested.

51 – Christina Sudiro - Investigations on the efficacy and mechanism of action of a candidate phytosanitary product against the grapevine downy mildew agent *Plasmopara viticola*

Downy mildew, caused by *Plasmopara viticola*, represents one of the most important diseases in *Vitis vinifera*. Currently, the control of this oomycete requires the repeated application of chemicals. However, according to the Directive 2009/128/CE on the sustainable use of pesticides, chemical treatments in the field must be limited and alternative approaches are urgently needed. The development of novel natural substances offers innovative and economically viable opportunities for the entire wine system. In the frame of the EU Life project Plants for Plants, Landlab has developed a natural extract, LL017, which showed a significant efficacy in protecting grapevine against downy mildew in field. Indeed, several trials in multiple years in combination with reduced dosages of fungicides have shown LL017 efficacy in decreasing disease symptoms while increasing plants' fitness in different cv. Since a deep knowledge about the mode of action of new natural alternative treatments appears crucial for their sustainable application, this study aims at understanding the mechanisms of grapevine protection by LL017. First, a test on leaf disks was performed to assess LL017 efficacy in controlled conditions and to define application conditions and the best timepoints for transcriptome analysis, further carried out on whole plants. Transcriptome profiling revealed the activation of different pathways directly involved in plant resistance, including phytoalexin production, that likely contribute to the increased protection of grapevine against the infection, confirmed in leaf disk assays. Moreover, meta-transcriptomic analyses suggested that the extract may exert its role through signal transduction cascades involving the E3 ligase ATL156 and the transcription factor Myb15, already shown to be implicated in response to *P. viticola* in resistant grapevine plants. Finally, the application of LL017 extract induced the production of reactive oxygen species, in particular the accumulation of hydrogen peroxide. Interestingly, while photosynthesis appeared downregulated following the treatment of local leaves, as expected when strong defence responses are induced, some pathways involved in primary metabolism are instead upregulated. This effect may "balance" the growth/defence trade-off, thus allowing plant growth and productivity, along with defence activation. The results thus support, at molecular level and in controlled conditions, the observation reported in field experiments.

52 - Sandro Frati - Natamycin, a new natural fungicide for post-harvest: opportunities and challenges

Natamycin is a natural fungicide, firstly isolated in 1955 from a fermentation broth of the bacterium *Streptomyces natalensis* cell culture. Today, Natamycin is commonly used in the food industry and registered as Food Additive in several territories in the world (E 235). Natamycin has the potential to be an effective tool to control post-harvest pathogens of citrus and other fruits. Recently, Janssen PMP registered a novel formulation of Natamycin with EPA in the US as post-harvest natural fungicide. The use of Natamycin-based formulations presents several technical advantages but also some barriers. The current presentation will describe the main challenges natural fungicides have to face for the application in post-harvest, with special focus on Natamycin. The *in vitro* and *in vivo* efficacy of the novel formulation on different post-harvest pathogens, including *Penicillium* strains resistant to synthetic pesticides will be discussed. Also, the compatibility of Natamycin-based formulations in commonly used post-harvest practices will be addressed, as well as the possible degradation of the active substance in low and high pH environments. Finally, the regulatory landscape related to the use of Natamycin at global level will be presented.

53 – Chiara Pituello - A controlled release biostimulant based on hydrolyzed protein: release modulation and preliminary results in vineyard application

Hydrolyzed protein-based biostimulants are largely utilized for foliar or soil application to sustain crop quality and productivity, abiotic stress tolerance and nutrient use efficiency. Being readily soluble they require multiple applications to have long-lasting effects. SICIT GROUP SPA developed a new coating technology able to modulate the release of the hydrolyzed protein biostimulant (CBS) from few days up to 120 days. Meso- and micro-nutrients can be co-formulated for specific plant needs. In the case of wine plants Mg, S, Fe and B are selected as key nutrients. The aim of this work was to study CBS release dynamics in water and soil, to tackle soil's main physical (temperature, pH) and biological (organic C, microbial biomass) properties that control their release, and to test their efficacy in open vineyard field. Release dynamics in water showed that the coating is sensitive to temperature, in particular above 40 °C. A temperature response was found also in soil, but it was more evident in neutral soil than in the acidic one. Soil pH influenced CBS release, with an almost doubled release in the neutral soil. Release patterns were not influenced by the different microbial biomass contents in the soils examined. A blend of short-term, medium-term and long-term release CBS has been tested in two vineyards located in North-east Italy (var. Sauvignon and Glera). Plant growth, yield, plant water status and grape maturation parameters have been monitored throughout the growing cycle, together with the assessment of soil microrespiration and enzymatic activities. The application of biostimulant in the field slightly affected most of the physiological parameters examined, and a better plant water status was maintained through the season in case of Sauvignon that experienced water stress during July and August. The peculiar meteorological trend in 2021 with the high temperatures and VPD during August homogenised the physiological parameters in different trials. The tests will be repeated in 2022 in order to understand the contribution of biostimulants of plant growth and grape quality parameters.

54 – Esther Carrera Bergua - Simultaneous quantification of major phytohormones in crude plant extracts, biotimulants and fertilizers.

BIOSTIMULANTS HORMONAL COMPOSITION can offer commercial advantage over similar products in the market. Plant hormones play a pivotal role in several physiological processes during a plant's life cycle, from germination to senescence, and the determinationof concentrations of hormones is essential to elucidate the role of a particular hormone inanyphysiological process. Due to the presence of hormones at very low concentrations in plant tissues (10 -9 M to 10 -6 M), fertilizers or biostimultants, the development of a high-throughput and comprehensive method for the determination of hormones is challenging. The HORMONE ANALYSIS FACILITIES installed at the IBMCP-CSIC (Valencia- Spain), quantifyplant hormones by UPLC-MS (Ultra Performance Liquid Chromatography-Mass Spectrometry) using a Thermo Scientific™ Q Exactive™ Hybrid Quadrupole-Orbitrap Mass Spectrometer. Our service is capable of analyze more than 24 plant hormones, including Auxins, Cytokinins, Gibberellins (including bioactive GAs, as well as their precursors and inactive products), Abscisic Acid, Jasmonic Acid, and Salicylic Acid, in small samples with very lowhormoneconcentrations (below 0.1 ng /g). Sample preparation-using internal standards, extraction procedures and UPLC-MS/MSconditions have been optimized for the determination of plant hormones in a great diversity of starting materials, from plant tissues to biostimulants and fertilizers. The Plant Hormone Quantification Service is a worldwide recognized service with a qualifiedscientific and technical staff that allows us to offers scientific-technical advice due to a widescientific background in the field of Plant Hormone research. Our service maintains also fruitful scientific collaborations with international and prestigious research groups in the fieldandstate-of-the-art.

55 – Marcin Smiglak - A controlled release biostimulant based on hydrolyzed protein: release modulation and preliminary results in vineyard application

In view of the ever-increasing demand for food and the limitation of the use of toxic pesticides, the search for new agents supporting plant development becomes a necessity. Biostimulants are one of the latest achievements of science in the field of plant cultivation. The European Union, recognizing the potential of biostimulants, introduced a new Regulation on fertilizing products, which also regulates issues related to biostimulants. It expands the definition of fertilising products to include new categories, including biostimulants. The purpose of this regulation is, inter alia, making available on the market products that until now have not been covered by uniform rules. This applies to biostimulants.
According to the definition, a biostimulant is a product that stimulates plant nutrition processes regardless of the nutrient content of the product. It improves at least one of the following characteristics: a) nutrient use efficiency, b) resistance to abiotic stress, c) quality features, d) nutrient availability from forms that are difficult to access in soil or rhizosphere.
In our research project, we studied SAR resistant inducers, meaning substances which activity is related to the activation of the plant's natural defence mechanisms, to show that in the absence of biotic stress, their use will not have a negative impact on plant yield.
It was surprising to discover that when used in a specific way, their action not only did not reduce the yield, but even improved plant's quantitative and qualitative parameters. Thus, it is reasonable to treat such substances as biostimulants, and not only as SAR inducers.
The results show the possibilities of using new and designed chemicals in agriculture, which are derivatives of salicylic and benzothiadiazole acids. Among them is the N-methyl-N-methoxyamide-7-carboxybenzo [1,2,3] thiadiazole (BTHWA) our molecule patented worldwide.
Our research shows that such substances have activity related to biostimulation of plant growth and development and mitigation of the negative effects of drought stress. The influence of these substances on the qualitative and quantitative parameters of the yield was shown on: sugar beet, rapeseed, tomato, cucumber, apple, tulip and lettuce. Additionally, these active substances have been tested for their possible influence on selected environmental aspects.

56 - Mariateresa Cardarelli - Seed treatments with beneficial microorganisms for enhancing seed germination and seedling growth in cucumber

Seedling growth enhancement is a primary objective of the modern cultivation strategies since contribute to successful establishment and crop performance. To affect germination and early developmental stages of plants, beneficial microorganisms can be applied through film coating treatments before sowing to promote germination and induce biostimulating effects on seedlings. The objective of the present study was to investigate the effectiveness of different bacteria and fungi strains on seed germination, rooting development and seedling biomass of cucumber. Cucumis sativus (L.) seeds were externally treated with Bacillus megaterium (strains B24 or B27) (first experiment), and Trichoderma atroviride (strains TaTU, Tat11, Ta117) (second experiment) at the dose of 1×104 spores/seed. B. megaterium strains didn't affect germination percentage while T. atroviride strains Ta117 and Tat11 improved germination compared to control. The root phenotyping revealed thicker roots for seed treatment with B. megaterium strain B24. Both B. megaterium strains (B24 and B27) promoted leaf area but only seedlings inoculated with strain B24 exhibited higher shoot and root biomass (fresh and dry weight) in comparison to untreated control. Under Trichoderma inoculation, the strain TaTU proved to be the most efficient by leading to an increase in germination, root development (length and volume), shoot length, leaf area and seedling biomass. The strain Ta117 also enhanced germination, root density and seedling growth compared to the control. Our results underline the value of seed treatment with microorganisms to promote the development of more

vigorous seedlings with a larger root system, and thus higher ability to capture resources and cope with different agronomic and environmental conditions.

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