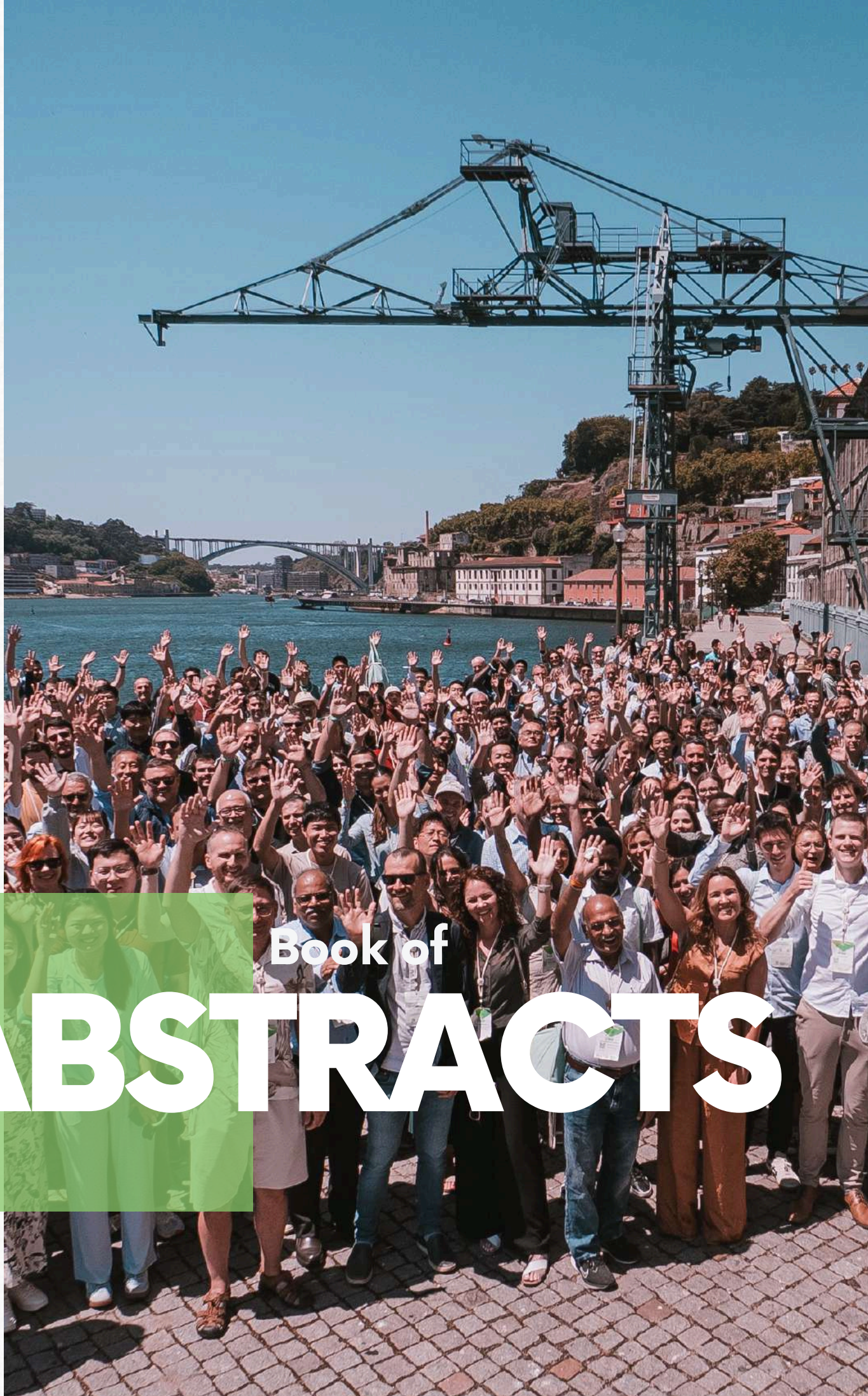




Book of

ABSTRACTS

CONTENTS

1

PAGE 3

WELCOME MESSAGE

2

PAGE 4

ORGANIZING AND SCIENTIFIC COMMITTEE

3

PAGE 5 - 14

PROGRAM

4

PAGE 15 - 41

LECTURES

5

PAGE 42 - 106

ORAL COMMUNICATIONS

6

PAGE 15 - 255

POSTERS

MARTA VASCONCELOS

WELCOME MESSAGE



As President of the International Plant Nutrition Council (IPNC), I had the pleasure of organizing the **XX International Plant Nutrition Colloquium (IPNC) 2025**, themed “Cultivating Resilience: Plant Nutrition for Food, Feed, and Health,” held in Portugal from July 22 to 25, 2025. With the support of the IPNC council members, my local team, SKYROS, and the Universidade Católica Portuguesa, we welcomed over 400 participants from 41 countries, including researchers, agricultural professionals, companies, and students. The colloquium featured plenary sessions with renowned scientists and 12 parallel sessions showcasing the latest research and innovations in plant nutrition. Additionally, we had 298 posters presented, facilitating extensive exchange of ideas among attendees. The event underscored the importance of building resilient and sustainable agricultural systems for global health and food security. I am grateful to all participants, speakers, and sponsors, and I am excited to announce that the next IPNC will be held in Melbourne, Australia, in 2028, and the following one in Nanjing, China, in 2031.

ORGANIZING COMMITTEE

MARTA VASCONCELOS DIANA MOREIRA CARLA SANTOS
MARTA SILVA JOANA MACHADO ELISABETE PINTO

SCIENTIFIC COMMITTEE

ACHIM DOBERMANN CHRISTOGONUS KAYODE DAUDU CIRO A. ROSOLEM
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LEON V. KOCHIAN MARTA VASCONCELOS MARTIN BROADLY
MICHAEL A. GRUSAK NICOLAUS VON WIRÉN PATRICK BROWN
PETER KOPPITKE SØREN HUSTED SYLVESTER OIKEH
TORU FUJIWARA ZED RENGEL



Program

JULY 22

Tuesday

13:00 - 19:00

Registration Opening - 2nd Floor

15:00 - 19:00

Poster Set Up and Rare Food Fair

14:00 - 16:00

Workshop: AI-Supported Market Avenue Generator (MAG) for sustainable agri-food innovations

The MAG development team: Tanja Dergan, Jurij Giacomelli, Bojan Blažica, Vid Podpečan, Marko Debeljak

D. Maria Room

16:30 - 18:00

Workshop: A Deep Dive Into Science Communication: Creating an Engaging Story From Your Research

Sarah Wettstadt, Spain

D. Luis Room

19h30

Welcome Reception

Exhibition Hall

JULY 23

Wednesday

09h00

Opening Session

Marta W. Vasconcelos, Portugal

Arquivo Room

09h20

Opening Plenary Presentation Eating to Extinction: Food, plants and the power of storytelling

Dan Saladino, UK

Arquivo Room

09h20

Coffee Break & Poster Viewing (Theme 1-3)

Exhibition Hall

JULY 23

Wednesday

10h30

Plenary Session Nutrient Uptake, Transport and Homeostasis

Chairperson: Nicolaus von Wiren, Germany

10h40

An Efficient Transport System for Mineral Nutrients in Rice

Jian Feng Ma, Japan

11h20

Optimizing Phosphorus Utilization: Integrating Genetic, Microbial, and Physiological Strategies for Sustainable Crop Production

Yinglong Chen, Australia

11h55

Barriers and Carriers for Plant Nutrient Homeostasis

Dai-Yin Chao, China

12h20

From Sensing to Survival: Deciphering Plant Responses to Iron Starvation

Gianpiero Vigani, Italy

Arquivo Room

12h45

Lunch & Poster Viewing (Theme 1-3)

Exhibition Hall

14h00

Parallel Sessions

Arquivo Room

**Theme 1:
Underutilized
Crops, Crop Wild
Relatives, and
Forgotten Foods for
Better Nutrition
Chairperson:** Geert
Haesaert, Belgium

14h00

What are the optimal legume species, genotypes, and fertilization strategies for plant-based foods?
Wole Fatunbi, Ghana

14h15

Improving the Nutritional Profile of Pasta Using Grass Pea
Gabriela Ines Najarro Saavedra, Peru

D.Maria Room

**Theme 2:
Breeding and
Genetics for
Nutrition and
Quality
Chairperson:** Alex
Johnson, Australia

14h00

Iron and zinc biofortification of Japanese Akitakomachi rice by genome editing of metal transporters, OsVIT1 and OsYSL9
Hiroshi Masuda, Japan

14h15

Production of iron-rich rice by mutation of iron-sensing HRZ ubiquitin ligases
Takanori Kobayashi, Japan

D.Luis Room

**Theme 3:
Nutrient Uptake,
Transport and
Homeostasis
Chairperson:** Jian
Feng Ma, Japan

14h00

Boron transport by BOR1 and BOR4 in anthers supports pollen grain development in Arabidopsis
Junpei Takano, Osaka Metropolitan University

14h15

Role of NUDIX hydrolases in Phosphate Signaling and Plant Defense
Gabriel Schaaf, Germany

JULY 23

Wednesday

14h30

Integrating Legume-Based Rotations and Large-Scale Environmental Assessment for Sustainable Crop Production
Pietro Iannetta, UK

14h45

The policy paradox of underutilised crops
Orsolya Lazányi, Hungary

15h00

Using landraces of barley to identify micro-nutrient efficiencies for improved tolerance of marginal soils.
Timothy George, UK

15h15

Unlocking the Potential of Grass Pea: Improving Nutritional Traits Through Investigation of Natural Diversity
Jasmine Staples, UK

14h30

From Toxicity to Tolerance: Rethinking Tipburn Through Elemental Clues and Hydathode Dysfunction to pave a Path towards Breeding Resilient Lettuce
Alan Pauls, Netherlands

14h45

Fine mapping quantitative trait loci controlling boron efficiency in Brassicaceae by combining genetic and phenotypic information from natural and generated populations
Thomas D Alcock, Germany

15h00

Genetic variation for mineral uptake and partitioning in wheat
Malcolm J Hawkesford, UK

15h15

Identifying genetic variation for phosphorus use efficiency in *Lactuca serriola*, a wild progenitor of lettuce
Chris Dijkstra, Netherlands

14h30

Effects of contrasting phosphorus-impooverished habitats in southwest Australia on species-dependent phosphorus-acquisition strategies in Proteaceae, Fabaceae, Myrtaceae and Ericaceae
Ling-ling Chen, Australia

14h45

Navigating plant nutrition in acid soil by aluminum activated malate transporters (ALMTs) as anion channels
Min Yu, China

15h00

When a droplet lands in a microscopic leaf landscape and decides to stay: What happens next?
Malcolm J Hawkesford, UK

15h15

Upregulation of specific "Methyltransferase-type-II-domain-containing-Proteins" protects boron-demanding dicotyledonous plants against growth defects under boron deficiency
Patrick Bienert, Germany

15h30

Role of root endodermal Casparian strip in mineral element uptake in rice
Toshiki FUJII, Japan

15h45

Coffee Break & Poster Viewing(Theme 1-3)

16h30 - 18h00

Marschner Session: The Role of Young Scientists in the Future of Plant Nutrition

Chairperson: Zed Rengel, Australia

Award Ceremony

Exhibition Hall

JULY 24

Thursday

08h30

Plenary Session Underground Nutrition - The Role of Microbiome, Soil and Rhizosphere

Chairperson: Fang-Jie Zhao, China

08h30

Optimizing Nutrient Cycling in Tropical Cropping Systems for Sustainable Agriculture

Ciro Rosolem, Brazil

09h10

Root senescence and its implications for plant nutrition

Nicolaus von Wiren, Germany

09h50

Understanding the availability of nutrients from fertilisers: Changing the paradigm

Peter Kopittke, Australia

10h15

Crop is not growing alone –the role of microbiome in growth and resilience

Peng Yu, Germany

Arquivo Room

10h40

Coffee Break & Poster Viewing(Theme 4-9)

Exhibition Hall

11h10

Parallel Sessions

Arquivo Room

Theme 4:
Plant Nutrition Challenges in the Mediterranean Climates - Australia, Europe, and others
Chairperson: Deli Chen, Australia

11h10

SMARTROOT: Root architecture and plasticity traits for N-efficient barley varieties
Zhenfei Chao, Germany

D.Maria Room

Theme 5:
Beneficial Elements (A Tribute to Epstein)
Chairperson: Patrick Brown, USA

Sponsored by:



11h10

Episodes with Prof. Emanuel Epstein: His Contribution to Si Research
Jian Feng Ma, Japan>

D.Luis Room

Theme 6:
Plant nutrition challenges towards nutritional sustainability - Africa
Chairperson: Christogonus Daudu, Nigeria

11h10

Quantifying Oil Palm Nutrient Requirements Across Different Yield Potential
Rana Farrasati, Indonesia

11h25

Root carboxylate-exudation phosphorus-mining strategies and trait diversification of eucalypti forests in global biodiversity hotspots in south-western and south-eastern Australia
Li Yan, China

11h40

Water and nitrogen treatments shape grapevine responses across developmental stages
Hirotsuna Yamada, Japan

11h55

Contrasting phosphorus-mining strategies: Biomass investment in compound cluster roots vs. efficiency of simple cluster roots in severely phosphorus-impooverished environments
Hirotsuna Yamada, Japan

12h10

The effect of nitrogen fertilization on the yield and quality of Shelly mango fruit
Jasmine Staples, UK

12h25

Source/sink relations in wheat as affected by heat, drought, and combined stress
Birgit W. Hütsch, Germany

11h25

Iodine as a plant micronutrient
Pierdomenico Perata, Italy

11h40

Silicon: Emanuel Epstein's 'quasi-essential' beneficial element
Martin Hodson, UK

11h55

Selenium Use in Agroecosystems within the Scope of the 4R Nutrient Stewardship
Luiz Guilherme, Brazil

12h10

Iodine: Translating Beneficial Nutrient Theory into Farming Reality
Katja Hora, Netherlands

12h25

Comprehending silicon-mediated drought stress tolerance in barley
Gabriel Ragazzo, Germany

11h25

Low-molecular-weight organic compound research in Fukushima
Marcel Pascal Beier, Japan

11h40

Interactive Effects of Nitrogen, Phosphorus and Sulfur Nutrients on Growth, Nutrient Utilization and Crop Productivity
Baoluo Ma, Canada

11h55

CRF Application in Planting Hole at Inland Hilly Area
Bernard Khoo Huang Chai, Malaysia

12h10

Genetic gains over four decades in maize grain yield and kernel nutrient contents under nitrogen-limited conditions
Tony J. Vyn, United States

12h40

Lunch & Poster Viewing (Theme 4-9)

Exhibition Hall

JULY 24

Thursday

14h00

Plenary Session Plant Nutrition and Climate Change

Marta W. Vasconcelos, Portugal

14h00

Plant Nutrition: Maintaining Food Security in a Changing Climate

Sylvie Brouder, USA

14h40

Chloroplast Phosphorus Balance Modulates Plant Growth Under Changing Environmental Conditions

Hatem Rouached, USA

15h05

Engineering climate-resilient crops with enhanced micronutrient uptake

Alex Johnson, Australia

15h30

Building resilient seed and food systems through participatory research

Julie Dawson, USA

Arquivo Room

15h55

Coffee Break & Poster Viewing (Theme 4-9)

Exhibition Hall

16h30

Parallel Sessions

Arquivo Room

Theme 7: Plant-based Foods for Human Health Chairperson:

Kristian Laursen,
Denmark

16h30

Manipulating root aerenchyma formation via OsRBOHH to reduce arsenic accumulation and methane emission in rice
Xing-Yu Zhao, China

16h45

Efficacy of lactic acid fermentation to improve Zn, Fe and Ca bioaccessibility from plant-based foodstuffs
Paula Pongrac,
Slovenia

D.Maria Room

Theme 8: Abiotic & Biotic Stresses and Plant Nutrition Chairperson:

Diego Rubiales, Spain

16h30

Early, Sensitive Detection of Biotic and Abiotic Stresses via Functional Phenotyping of Plant Water Balance
Menachem Moshelion, Israel

16h45

Nutritional immunity in plants: the role of micronutrients in host-pathogen interactions
Marta Nunes da Silva, Portugal

D.Luis Room

Theme 9: Nanonutrition & nano-fertilizers Chairperson:

Soren Husted, Denmark

16h30

Nanofertilization: What's All the Hype About?
Soren Husted, Denmark

16h45

Plant biostimulants: revisiting plant nutrition
Patrick du Jardin, Belgium

JULY 24

Thursday

17h00

Strategies for enhancing the nutritional value of peas for human consumption – fertilization versus genotype effects
Jens Axel Knuhtsen, Denmark

17h15

Health-promoting properties of high amylose novel durum wheat materials and derived foods
Angelo Santino, Italy

17h30

A quantitative analysis of the sufficiency and diversity of nutrient supply from plant-based foods in China
Wen-Feng Cong, China

17h45

Hollow Stem Formation in Broccoli: Impact of Level and Timing of Nitrogen Top-Dressing
Alexander Frieman, Germany

18h00

Effects of contrasting phenolic pea genotypes on gut function: insights from human in vitro gastrointestinal models
Rafael D. C. Duarte, Portugal

17h00

Boron Supply Alleviates Aluminum Toxicity-Restrained Polar Auxin Transport and Pectin Trafficking in Root Transition Zone
Lin Tao, China

17h15

ZFP36-CCaMK module mediated arbuscular mycorrhizal symbiosis in rice
Liping Huang, China

17h30

The role of mineral nutrients (magnesium, iron, sulfur) in symbiotic nitrogen fixation
Zhi-Chang Chen, China

17h45

Omics based approaches to decipher the role of iron in plant nutrition & immunity upon ToBRFV infection in Solanum lycopersicum L.
Aditi Padmakar Thakare

18h00

Plant nutrient elements defined from plant's and farmer's perspective
Jóska Gerendás

18h15

Challenges and prospects for next-generation enhanced efficiency fertilizers
Deli Chen, Australia

17h00

Integrating advances in precision agriculture and data science to scale, measure, and model optimum nitrogen fertilizer management across thousands of farmer fields
Mitch Baum, United States

17h15

Legumes' detrimental effects on successive maize and its linkage to P mobilization
Michelle Natalie Herrmann, Germany

17h30

Exploring interactions between soil, roots and hydroxyapatite nanoparticles
Pauline Møs, Denmark

17h45

Foliar Application of Polymeric Manganese Oxide Nanoparticles: Mechanisms of Uptake and Metabolic Responses in Manganese Deficient Barley
Andrea Pinna, Denmark

18h00

Biostimulants for sustainable plant nutrition? State of the Art
Klara Bradacova, Germany

18h15

Optimizing Plant Nutrition and Climate Resilience: The Role of Soil Biodiversity, Rhizosphere Processes, and Crop Management
Markus Weinmann, Germany

18h30

Poster Viewing (Theme 4-9)

20h00

IPNC Farewell Dinner

JULY 25

Friday

08h30

Plenary Session – The Importance of Potassium for Food Security, Resilience and Sustainable Agriculture

Chairperson: Patricia Imas, Israel

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INTERNATIONAL FERTILIZER ASSOCIATION
Helping to feed the world sustainably

08h30

Introduction: Potassium and food security

Patricia Imas, Israel

08h40

Potassium in plants – still a hot topic

Ingo Dreyer, Chile

09h10

A new role of potassium in drought stress mitigation

Ismail Cakmak, Turkey

09h40

Assessing global potassium limitations to crop yields

Patricio Grassini, USA

10h00

Discussion

Arquivo Room

10h10

Coffee Break & Poster Viewing (Theme 10-12)

Exhibition Hall

10h45

Parallel Sessions

Arquivo Room

**Theme 10:
Advances in
Potassium Research
and Management
Chairperson:
Patricio Grassini,
USA**

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D.Maria Room

**Theme 11:
Plant Mineral
Nutrition, from the
Genes to the
Harvest (A tribute
to Phillip White)
Chairperson:
Martin Broadley,
UK, Konrad
Neugebauer,
Germany, Paula
Pongrac, Slovenia**

D.Luis Room

**Theme 12:
Novel Technologies
Chairperson: Peter
Kopittke, Australia**

10h45

Comparison of potassium internal efficiency, requirement, and removal within and across crop species
Walter Carciochi, USA

11h00

Potassium management in greenhouses and intensive agriculture
Patricia Imas, Israel

11h15

Modeling soil-plant K dynamics
Tom Schut, Netherlands

11h30

Potassium Dynamics and Sustainability of Soil Health and Crop Productivity in Long-Term Fertilizer Experiments in India
Surinder Kumar Bansal, India

11h45

Potassium Availability in Highly Concentrated Fertiliser Bands: Influence of Soil Properties and Fertiliser Types
Yili Zang, Australia

12h00

Understanding and Characterizing Potassium Soil Variability in the Almond System to Improve Potassium Management
Margherita A Germani, United States

General Discussion

10h45

A tribute to Phillip White
Chairpersons

11h00

The enhanced activity of glutamine synthetase by increasing BnaA02.GLN1;2 expression promotes nitrate uptake and nitrogen use efficiency in Brassica napus
Guangda Ding, China

11h15

Elucidation and reconstitution of the precursor biosynthesis of aluminum-detoxifying hydrolyzable tannins identified in Eucalyptus camaldulensis
Chihiro Oda-Yamamizo, Japan

11h30

Various hydrolyzable tannins contribute to aluminum detoxification in a highly aluminum-resistant tree, Eucalyptus camaldulensis
Ko Tahara, Japan

11h45

Comprehensive understanding of the mechanisms of nutrient uptake regulation: starting from ribosomal sensing of cytosolic nutrients leading to translational and transcriptional regulation
Toru Fujiwara, Japan

12h00

Transporters of sugar and amino acids dominant nitrogen-controlled yield formation in rice
Guohua XU, China

10h45

High-Throughput Plant Functional Screening: Novel Biostimulants Testing Method and Platform under Multi-Environmental Stresses
Keren Moshelion, Israel
Sponsored by:



11h00

Relevance of Nitrogen Fertilizer Management and Nitrogen Use Efficiency for Low-carbon Crop Production
Luís Torres, Germany
Sponsored by:



11h15

High nitrogen enhanced PS I cyclic electron transport to induce proton motive force $\Delta\Psi$ for higher CO₂ assimilation rate
Hayato Satoh, Japan

11h30

High-throughput analysis of plant nutrients by laser induced breakdown spectroscopy
Frederikke Neergaard Mikkelsen, Denmark

11h45

Smart B100 Advanced Research Center (CCD-SB100): a novel approach for nutrient management in the field supported by generative AI
Mattos Jr. D., Brazil

12h00

High-throughput screening of acid-tolerant and high-yield rapeseed varieties based on multi-temporal UAV RGB and multispectral images
Guangda Ding, China

JULY 25

Friday

12h15 - 13h00

Closing session

Marta W. Vasconcelos, Portugal

Closing remarks

Presentation of poster prizes

Introduction to the 21st IPNC 2028

Farewell

Arquivo Room

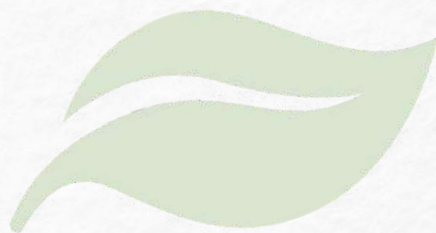




4

CHAPTER

TALKS



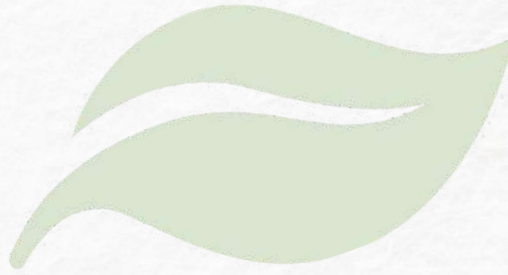
PLENARY SESSION **AN EFFICIENT TRANSPORT SYSTEM FOR MINERAL NUTRIENTS IN RICE**

Jian Feng Ma (Japan)¹; Sheng Huang (Japan)¹; Naoki Yamaji (Japan)¹; Noriyuki Konishi (Japan)¹; NAMIKI MITANI (Japan)¹

¹ - Institute of Plant Science and Resources, Okayama University

The transport of mineral nutrients from soil to various organs, tissues, and cells in plants relies on a diverse array of transporters. Rice, in particular, has evolved an efficient transport system for mineral nutrients, facilitated by the unique structural features of its roots and nodes. In rice roots, the presence of two Casparian strips—located at both the exodermis and endodermis—and the formation of aerenchyma, where most cortex cells between these two layers are destroyed, create a specialized pathway for nutrient movement. This structural arrangement necessitates the involvement of both influx and efflux transporters at the exodermis and endodermis to facilitate nutrient transport from the soil solution to the stele. Key transporters identified in rice include OsLsi1 and OsLsi2 for silicon (Si) uptake, OsNramp5 and OsMTP9 for manganese (Mn) uptake, and OsLsi1 and OsBOR1 for boron (B) uptake. OsLsi1 and OsNramp5 function as influx transporters, polarly localized on the distal side of the exodermis and endodermis, while OsLsi2, OsMTP9, and OsBOR1 act as efflux transporters, localized on the proximal side of the same cell layers. These coordinated localization enables efficient uptake of these nutrients. Recent studies have revealed that the regulation of these transporters in response to nutrient availability varies by element. For instance, the expression of OsLsi1 and OsLsi2 is downregulated at the transcriptional level by Si supply, a process controlled by a shoot-derived protein signal. In contrast, OsNramp5 and OsMTP9 are not regulated by Mn at either the transcriptional or translational level, while OsBOR1 is rapidly degraded under high B conditions. Additionally, we have identified critical amino acid residues essential for the polar localization of OsLsi1, demonstrating that this polar localization is vital for efficient Si uptake in rice roots. The distribution of mineral elements within rice is mediated by transporters expressed in the nodes, which feature a highly developed vascular system comprising enlarged vascular bundles (EVBs) and diffuse vascular bundles (DVBs). Several transporters involved in intervascular transfer between EVBs and DVBs have been identified. For Si distribution, OsLsi6, OsLsi2, and Lsi3 form an efficient system for preferential Si allocation, while OsNIP3;1 and OsBOR1 play key roles in B distribution. OsNramp3 is implicated in Mn distribution. These transporters are regulated at transcriptional, posttranscriptional levels, depending on the element. Recently, we also identified transporters responsible for the local distribution of Mn and Si between the leaf blade and leaf sheath, which will be discussed in detail at the symposium.





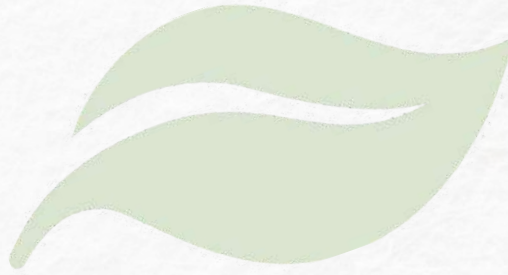
PLENARY SESSION **OPTIMIZING PHOSPHORUS UTILIZATION: INTEGRATING GENETIC, MICROBIAL, AND PHYSIOLOGICAL STRATEGIES FOR SUSTAINABLE CROP PRODUCTION**

Yinglong Chen (Australia)¹; Zed Rengel (Australia)²

1 - The University of Western Australia, Perth, WA, Australia; 2 - The University of Western Australia, Perth, Australia

Phosphorus (P) deficiency is a major limitation to crop productivity worldwide. This study integrates multiple research efforts to explore plant responses, genetic regulation, microbial interactions, and adaptive mechanisms under P-deficient conditions, providing insights for improving P-use efficiency in crops. A genotypic evaluation tool was developed to assess P efficiency in maize genotypes. The study identified P-efficient genotypes with adaptive root traits, enabling targeted breeding for low-P environments. A comparative study of maize revealed that long-term P fertilization alters rhizosphere microbial communities, affecting P-starvation-responsive genes and defense pathways. In rice, long-term organic fertilizer application increased root-secreted acid phosphatase (APase) activity regulated by OsPAP10c gene, facilitating organic phosphorus hydrolysis and mobilization, and enhancing rice productivity. Similarly, peanut root-associated phosphate-solubilizing and nitrogen-fixing bacterial communities responded positively to APase application, improving P and nitrogen acquisition under low-P conditions. Soil compaction and P availability also affect rhizosphere microbial dynamics. Peanut rhizosphere studies revealed that P-solubilizing bacteria and nitrogen-fixing bacteria shift in response to soil compaction and P fertilization, with significant implications for nutrient cycling and soil fertility management. Finally, transcriptome and biochemical analyses in wheat identified ethylene signaling as a key regulator of P-deficiency responses. Ethylene modulates P redistribution and root development, offering new targets for breeding P-efficient wheat cultivars. These findings collectively contribute to a deeper understanding of plant adaptive strategies to P limitation, paving the way for sustainable agricultural practices and enhanced crop productivity under P-deficient conditions.





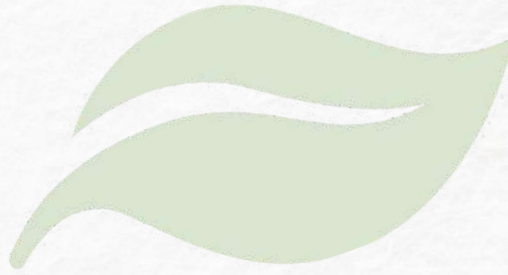
PLENARY SESSION **BARRIERS AND CARRIERS FOR PLANT HOMEOSTASIS**

Dai-Yin Chao (China)¹

¹ - National Key Laboratory of Plant Design, Shanghai Center for Plant Stress Biology, CAS Center for Excellence in Molecular Plant Sciences, Chinese Academy of Sciences, Shanghai 200032, China

Mineral nutrients play critical roles in plant growth, reproduction, and environmental adaptation, as well as in human health. Homeostasis of mineral elements is maintained under the coordination of two systems: diffusion barriers and transporters. Here, we present our recent advances in decoding their molecular mechanisms. We demonstrated that the Casparian strip (CS), a lignin-based structure, forms an apoplastic seal through the interaction between GAPLESS and CASP proteins, which anchor the CS to the plasma membrane to prevent apoplastic diffusion. Further, we identified endodermal dirigent proteins as molecular drivers of CS lignin polymerization. Evolutionary studies revealed that suberin lamellae, a secondary barrier in roots, originated in seed plants and contributed to their success in late Carboniferous Period. We also systematically characterized nutrient transporters and their regulatory components (termed "Carriers"). Genetic and biochemical analyses identified key transporters, including members of the NPF, HMA, MOT and YSL families, which mediate uptake and allocation of Fe, Cu, Co, Ni, Mo and other metals. By integrating these insights, we engineered crops with optimized nutrient-use efficiency, demonstrating the agricultural potential of manipulating barriers and carriers. Our findings provide a mechanistic framework for understanding plant nutrient homeostasis and strategies for sustainable agriculture.





PLENARY SESSION **FROM SENSING TO SURVIVAL: DECIPHERING PLANT RESPONSES TO IRON STARVATION**

Gianpiero Vigani (Italy)¹

¹ - Department of Life Sciences and Systems Biology, University of Turin

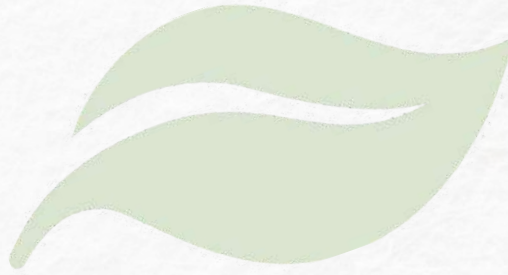
Plants tightly regulate iron levels to sustain growth and development, as iron homeostasis ultimately influences crop production in terms of both quality and quantity. The regulation of iron homeostasis in plants is a complex and vital process that ensures proper iron acquisition, distribution and storage while preventing excessive accumulation that could lead to toxicity.

These regulatory mechanisms operate at multiple levels: (a) perception of external and internal iron status (Fe sensing); (b) amplification of the perceived stimulus through signal transduction mechanisms (Fe signaling); and (c) activation of acclimation responses to Fe deficiency. Significant progress has been made in recent years in identifying key molecular players involved in Fe sensing and signaling. However, a full understanding of the underlying mechanisms needs further scientific efforts. In particular, cytosolic calcium (Ca^{2+}) signaling has been suggested to play a role in regulating iron uptake. Cellular Ca^{2+} dynamics are tightly controlled at the subcellular level; for instance, Ca^{2+} transients in the mitochondrial matrix have been observed in response to various abiotic stresses. However, the contribution of organelles to Ca^{2+} -mediated regulation of iron uptake remains largely unexplored.

At the level of Fe deficiency-induced acclimation, extensive evidence has been gathered across numerous plant species. However, gaining deeper insight into Fe deficiency-dependent metabolic regulation requires considering iron's fundamental role in metabolism. Iron acts as a cofactor for a wide array of metabolic enzymes that drive essential biochemical pathways. Some of these processes are upregulated under low Fe availability, while others are inhibited, indicating that reduced cellular Fe levels differentially impact metabolism. To address this issue, we revisited Fe deficiency-induced metabolic responses in plants by exploring the Fe- O_2 interaction, as Fe chemistry and biochemistry are strongly influenced by oxygen availability. In this context, we investigated the impact of low Fe availability on oxygen-sensing mechanisms and, conversely, the impact of low O_2 availability on Fe deficiency responses in plants.

In this talk, I will present data on the role of mitochondria-dependent Ca^{2+} signaling in regulating Fe uptake and how the Fe- O_2 relationship provides valuable insights into the mechanism of Fe usage in plants.





THEME 1 WHAT ARE THE OPTIMAL LEGUME SPECIES, GENOTYPES, AND FERTILIZATION STRATEGIES FOR PLANT-BASED FOODS?

Kristian Holst Laursen (Denmark)¹; Maria Monrad Rieckmann (Denmark)¹; Jens Axel Knuhtsen (Denmark)¹; Asger Sten Eskildsen (Denmark)¹

¹ - Plant Nutrients and Food Quality Research Group, Plant and Soil Science Section, Department of Plant and Environmental Sciences, Faculty of Science, University of Copenhagen, Thorvaldsensvej 40, 1871 Frederiksberg C, Copenhagen, Denmark.

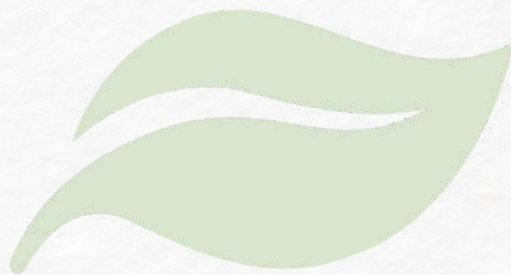
Purposes and aims: The transition towards more sustainable and plant-based diets is steadily increasing the demand for climate-friendly and high-quality crops. Legumes have a great potential as raw materials and ingredients for human consumption, but in Northern Europe, they are underutilized food crops. This is mainly due to a historical focus on legumes for feed and import of soybeans, which are unsuitable for most Northern European climates. The aim of the study was therefore to identify legume species, genotypes and management strategies suitable for production in Denmark. It was hypothesized that especially faba beans (*Vicia faba*) and peas (*Pisum sativum*) are suitable candidates and that fertilization strategies can be optimized to improve their growth, harvest yield and quality.

Methods: Field trial and greenhouse studies were conducted to explore 10 commercially available faba bean and pea genotypes as well as >350 gene bank accessions of peas in the Danish research projects AQRIFood and Peas & Love, respectively. Plants were grown according to organic regulations and their growth, harvest yield and seed quality at maturity were evaluated. For the commercial genotypes, protein concentrates and isolates were also produced and analysed. For selected genotypes and accessions, fertilization trials were conducted to optimize symbiotic nitrogen fixation, legume growth, harvest yield and seed quality.

Results: For the commercially available faba bean and pea genotypes, all showed great agronomic potential and only minor differences in protein and nutrient contents of raw materials, concentrates and isolates. However, significant differences were found for selected anti-nutrients such as vicine and convicine in faba beans. For the gene bank accessions of peas significantly greater variations in protein and nutrient contents were found. However, the harvest yields also varied more than for the commercial genotypes. Finally, it was shown that fertilization with sulphur could improve pea growth, harvest yield and seed quality.

Conclusions: It is concluded that faba beans and peas are highly suitable legume species as raw materials and ingredients for plant-based foods. However, genotypic differences and fertilization strategies must be further explored to increase the utilization of legumes for human consumption in Northern Europe.





THEME 3 **BORON TRANSPORT BY BOR1 AND BOR4 IN ANTHERS SUPPORTS POLLEN GRAIN DEVELOPMENT IN ARABIDOPSIS**

**Junpei Takano (Japan)¹; Zhe Zhang (Japan)¹; Keita Muro (Japan)¹; Akira Yoshinari (Japan)²;
Yu-Ki Tanaka (Japan)³; Yasumitsu Ogra (Japan)³**

¹ - Osaka Metropolitan University; ² - Nagoya University; ³ - Chiba University

Boron is required for plant cell wall integrity by crosslinking the pectic polysaccharide rhamnogalacturonan II. It is widely recognized that reproductive organs require a higher amount of boron for development and growth compared to vegetative organs. However, the mechanism by which plants distribute boron to reproductive organs is not fully understood.

In the roots of *Arabidopsis thaliana*, the borate exporter BOR1 together with the boric acid channel NIP5;1 plays a central role in transporting boron from the roots to the shoots under boron-limited conditions, while the borate exporter BOR4 functions in boron exclusion under boron-excess conditions.

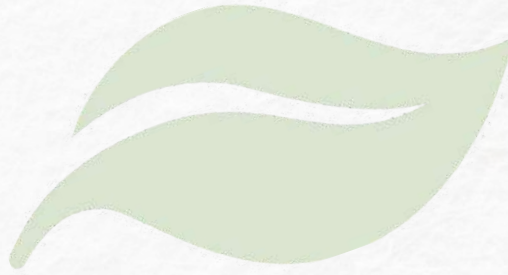
In this study, we utilized GFP imaging and found that BOR1 and subsequently BOR4 are sequentially expressed in the tapetal cells of young anthers. Both BOR1 and BOR4 exhibit polar localization in the plasma membrane toward the locule, where microspore development occurs. Additionally, BOR4 is localized in the plasma membrane of microspores at later stages.

Mutants lacking functional BOR1 (*bor1*) exhibited reduced pollen viability and disrupted pollen structure, leading to reduced fertility under boron conditions that are standard for the wild-type. These phenotypes were rescued by supplementing with higher concentrations of boron. Furthermore, experiments using inflorescence stem grafting and boron measurement in single pollen grains via laser-ablation ICP-MS suggest that BOR1-dependent boron transport in flowers is essential for boron accumulation in pollen, pollen development, and subsequent fertilization under standard boron conditions.

Mutants lacking BOR4 (*bor4*) exhibited reduced pollen viability and disrupted pollen structure, with significantly lower boron content in pollen, under both boron-limited and boron-excess conditions. The contribution of BOR4 to fertility under low and high boron conditions is currently under investigation.

Our findings suggest a model in which the borate exporters BOR1 and BOR4, together with the previously described boric acid channel NIP7;1, facilitate boron transport in tapetum cells toward the locule, and BOR4 further facilitates boron transport to the cell wall of microspores, to support pollen development in young anthers.





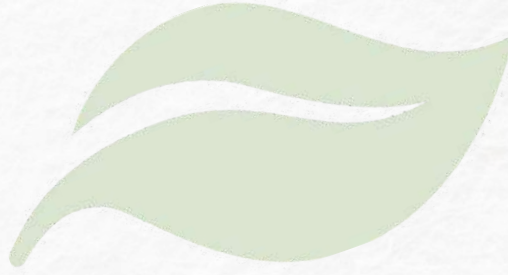
PLENARY SESSION **OPTIMIZING NUTRIENT CYCLING IN TROPICAL CROPPING SYSTEMS FOR SUSTAINABLE AGRICULTURE**

Ciro Antonio Rosolem (Brazil)¹

¹ - Western São Paulo University

The ever-growing demand for food, fiber, and energy presents a significant challenge in agriculture, which is expanding to areas with marginal soils, most of which are under tropical humid climates. Many of the soils in these expanding areas are sandy, often nutrient-poor, low in organic matter, and predominantly acidic. These conditions increase the likelihood of nutrient loss through leaching, atmospheric emissions, erosion, and adsorption into less available forms. As a result, to achieve economic crop yields, soil amendments and fertilizers have been applied at escalating rates. Besides, the higher the fertilizer rate, the lower the efficiency because of the law of diminishing returns, or: as yields approach their biological plateau, more nutrient is required to achieve each additional unit of yield increase. Consequently, global nutrient use efficiency has declined over the past 20 years. With higher nutrient inputs, nutrient losses tend to increase disproportionately, particularly in the soils where agricultural systems are expanding. Several strategies can help mitigate nutrient loss. Among them, the use of crop rotations and cover crops in the system holds significant potential for reducing nutrient loss and enhancing nutrient use efficiency. No-till systems have shown to reduce erosion and nutrient loss. However, cropping systems with the right crop rotations and cover crops can effectively retain nutrients within the agricultural system. For nitrogen, this is achieved through mechanisms such as atmospheric nitrogen fixation, leaching avoidance, reduced ammonia and nitrous oxide specific emissions, and nutrient cycling. Phosphorus adsorption can be reduced, and some crop and cover crop species can solubilize adsorbed phosphorus through modifications in root morphology and organic acids exudation, recycling it back into the system, which could be a tool to recover some of the Legacy P. Potassium leaching may also be prevented in sandy soils, and potassium solubilization from minerals can be facilitated and cycled within the system. It is well demonstrated that no-till systems with crop rotations and cover crops are instrumental in increasing nutrient use efficiency. However, there is a gap in the knowledge of the underlying mechanisms. One of the main challenges lies in synchronizing nutrient release from plant residues with crop demand, which requires a thorough understanding of plant residue mineralization. Additionally, it is essential to assess the extent to which these processes contribute to nutrient cycling and the long-term sustainability of high-yielding cropping systems.





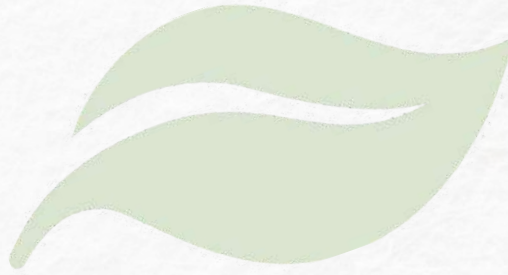
PLENARY SESSION **ROOT SENESCENCE AND ITS IMPLICATIONS FOR PLANT NUTRITION**

Nicolaus von Wirén (Germany)¹; Esin Cevza Tunc (Germany)¹

¹ - Leibniz-Institute of Plant Genetics and Crop Plant Research

Morphological and physiological changes occurring during root aging have remained poorly understood, despite their importance for water uptake and plant nutrition. We have established that root senescence follows a genetically-regulated developmental program that is characterized by changes in root anatomy, metabolism and color, decrease in root activity, increasing levels of stress-related hormones and increasing expression of certain transcription factors or genes involved in oxidative stress defense. In seminal roots of hydroponically-grown barley, we have investigated the hormonal control of senescence progression and its implications for nutrient uptake. This contribution attempts to provide an overview on the current knowledge on root senescence processes and their relevance for plant nutrition. We argue that better understanding of root senescence is of great importance not only to establish a balanced view on whole-plant senescence but also to improve resource efficiency in crops.





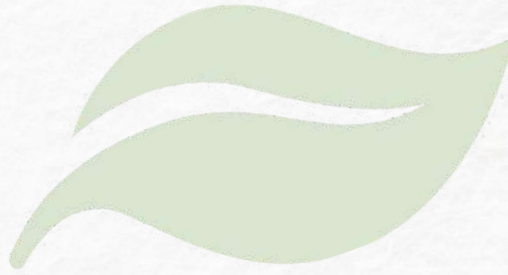
PLENARY SESSION **UNDERSTANDING THE AVAILABILITY OF NUTRIENTS FROM FERTILISERS: CHANGING THE PARADIGM**

Peter M. Kopittke (Australia)¹; Brigid A. McKenna (Australia)¹; Frederik J.T. van der Bom (Denmark)²; Nelly Raymond (Denmark)²; Casey L. Doolette (Australia)³; Enzo Lombi (Australia)³

1 - The University of Queensland; 2 - University of Copenhagen; 3 - University of South Australia

The inefficient use of fertilisers leads to significant environmental damage worldwide as well as associated economic loss. Firstly, we examine how the inefficient use of fertilisers for food production has resulted in the transgressing the biogeochemical planetary boundaries and that excess fertiliser usage is an important contributor to pushing Earth into a less hospitable state. Secondly, addressing this global challenge requires a paradigm shift in research from traditional, 'bulk', and ex situ techniques to spatially resolved, in situ, and minimally destructive approaches – to illustrate the importance of this paradigm shift, we developed synchrotron-based X-ray computed tomography (SRXCT) to allow the in situ visualisation of root distribution in soil cores. In this regard, SRXCT offers potential advantages compared with conventional X-ray sources for the in situ study of plant roots within soil, including producing X-rays that are collimated, monochromatic, tuneable, and of higher intensity; delivering high-resolution data whilst avoiding issues such as beam-hardening and source divergence. Here, using SRXCT to examine roots of wheat in response to placement of P fertilisers, we show the importance of spatially-resolved approaches (c.f. bulk analyses) for better understanding plant responses to nutrients. Thirdly, we then used a range of state-of the-art techniques to identify the characteristic zones of P fertiliser reactions in soils, with this allowing us to relate changes in P behaviour and availability to plant responses. Specifically, we examined how the underlying reactions in critical zones around fertiliser granules are fundamental in driving availability of nutrients from fertilisers. Overall, this work underscores the importance of advanced imaging and analytical methods in optimising fertiliser use for sustainable agricultural practices.





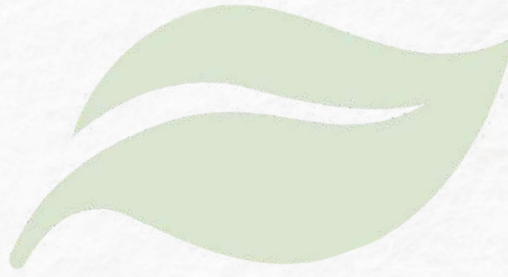
PLENARY SESSION **CROP IS NOT GROWING ALONE** **–THE ROLE OF MICROBIOME IN GROWTH AND RESILIENCE**

Peng Yu (Germany)¹

¹ - Plant Genetics, TUM School of Life Sciences, Freising, Germany

Below the surface, life thrives in the dynamic interface between the soil, plants, and microorganisms, driving essential nutritional functions and ecosystem services on our planet. This talk explores the genetics of plant roots, covering the formation and function of root systems, the crucial role of the rhizosphere, and their biotic and abiotic interactions with microorganisms, or the 'microbiome,' which influence diverse environmental domains. We employ classical plant population and microbial genetics approaches to unravel the mechanisms behind these interactions. Our goal is to translate this understanding into practical applications that enhance agricultural productivity and ecosystem health. Ultimately, we aim to manipulate plant below-ground genetics and engineer the root and rhizosphere 'holobiont' to help secure food production and bolster climate resilience for the future.





THEME 5 **EPISODES WITH PROF. EMANUEL EPSTEIN: HIS CONTRIBUTION TO SI RESEARCH**

Jian Feng Ma (Japan)¹

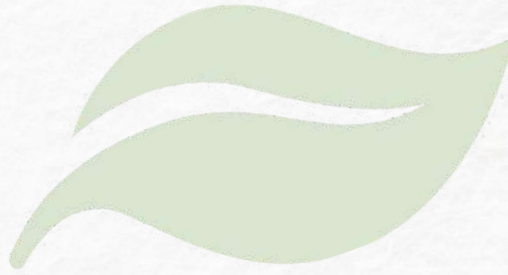
¹ - Institute of Plant Science and Resources, Okayama University

Prof. Emanuel “Manny” Epstein (1916–2022) was a legendary figure in the field of plant nutrition. He pioneered the application of enzyme kinetics to ion transport and was the first to characterize high- and low-affinity nutrient transport mechanisms. In his later years, he developed a keen interest in silicon (Si) in plants, the most abundant element in the Earth's crust. Although Prof. Epstein did not publish extensively on Si, he authored two comprehensive review papers on the subject in PNAS (1994) and Annual Review of Plant Physiology and Plant Molecular Biology (1999). Historically, Si research was predominantly conducted in Japan, with much of the work published in Japanese. Prof. Epstein's review papers in international journals played a pivotal role in stimulating global interest in Si research.

According to the criteria for essential elements established by Arnon and Stout (1939), Si has not been classified as an essential element for plants. However, Prof. Epstein argued that Si should be considered a “quasi-essential element” due to its presence in plants at levels comparable to macronutrients such as calcium, magnesium, and phosphorus. In grasses, Si often occurs at higher concentrations than any other inorganic constituent. Additionally, Si has been shown to confer numerous benefits to plant growth, particularly under biotic and abiotic stress conditions. Prof. Epstein also contended that plants grown in conventional nutrient solutions without added silicon are, in many ways, experimental artifacts, as they do not reflect natural conditions.

I have been researching Si in plants since 1985 and shared Prof. Epstein's fascination with this element. I assisted him by translating Japanese research on Si into English for his review papers and had the privilege of engaging in numerous discussions with him. In this presentation, I will share some memorable episodes from my interactions with Prof. Epstein and highlight some of our recent work on Si transporters.





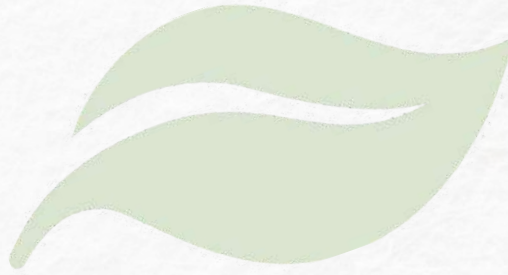
THEME 5 IODINE AS A PLANT MICRONUTRIENT

Pierdomenico Perata (Italy)¹

¹ - PlantLab, Institute of Plant Sciences, Sant'Anna School of Advanced Studies, Pisa, Italy

Very low amounts of iodine (between 0.20 and 10 μM , i.e., in the range of the concentrations required by plants for several micro-nutrients) improve plant growth and development thus promoting both biomass production and early flowering. Furthermore, iodine modulates gene expression in a specific way, activating multiple pathways, mostly involved in defense responses. Interestingly, iodine is required for plant's tolerance to Botrytis, and the wide range of defense-like responses triggered by iodine suggests its potential effectiveness against a broad spectrum of biotic agents. Remarkably, iodine can be a structural component of several different proteins, and conserved iodinated proteins are synthesized in both the roots and shoots of phylogenetically distant species. These three lines of evidence highlight that iodine has a nutritional role in plants. This means that the influence of iodine on plants is not merely the result of an indirect priming effect by a potentially phytotoxic compound. Plant nutrients are chemical elements that are components of biological molecules and/or influence essential metabolic functions: iodine matches this definition.





THEME 5 **SILICON: EMANUEL EPSTEIN'S 'QUASI-ESSENTIAL' BENEFICIAL ELEMENT**

Martin J. Hodson (UK)¹

¹ - Department of Biological and Medical Sciences, Faculty of Health and Life Sciences, Oxford Brookes University

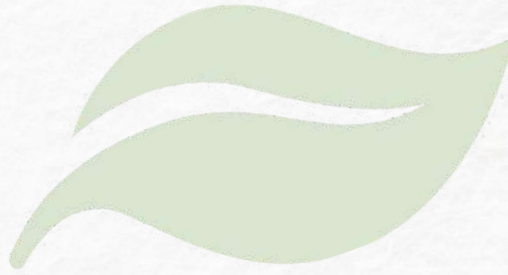
Silicon (Si) is an important component of mineral soils. It is mostly present in crystalline forms that are sparingly soluble, while amorphous silica is somewhat more so. The main soluble form taken up by plant roots is monosilicic acid (H_4SiO_4). Plants vary considerably in the amount of Si that they take up, with grasses and cereals being particularly high Si accumulators. The majority of dicotyledons are much lower. Si is transported in the xylem within the plant, and most of it is deposited in the leaf cell lumina and walls as solid amorphous silica or phytoliths.

Most plant species can complete their life cycles in the almost total absence of Si under laboratory conditions (exceptions include rice and horsetail). However, in the field, Si is involved as a defence against grazing, pests and pathogens. It also has roles in the amelioration of abiotic stresses, including water stress and aluminium, and heavy metal toxicity. In many agricultural situations, plants require Si to thrive, and this led Emanuel Epstein to call it a 'quasi-essential' element. However, most plant scientists do not consider Si to be an essential element, preferring the term 'beneficial element'. There is an active debate around this topic.

In some situations where plant amorphous silica is not returned to the soil after harvest, soil soluble Si availability may become depleted. Si fertilisation is very important for rice, and its use is growing globally for other crops, particularly for those grown in glasshouses. There are moves to have Si included in fertiliser formulations in some countries.

The potential of phytoliths to sequester carbon in soils has been investigated because of the possibility of being able to draw down carbon from the atmosphere and to store it safely for many years underground. There is also interest in adding ground minerals, such as basalt, to arable land in enhanced weathering projects to help combat climate change. It is possible that these approaches could be joined up: ground minerals increase available soil Si; plants benefit from the positive effects of Si, becoming more stress resistant; and increased Si availability leads to greater phytolith production and increased carbon sequestration. This all requires much more research, but if the idea develops into anything like a reality, then plant Si may become more than just 'beneficial' for humanity.





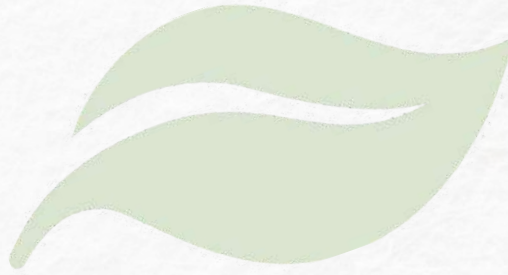
THEME 5 **SELENIUM USE IN AGROECOSYSTEMS WITHIN THE SCOPE OF THE 4R NUTRIENT STEWARDSHIP**

Luiz Roberto Guimaraes Guilherme (Morocco)¹; Leonardus Vergütz (Morocco)³

1 - Head of Science at OCP Nutricrops; 2 - Professor at Federal University of Lavras (on leave); 3 - Chief Science Officer at OCP Nutricrops

Selenium (Se) is an essential micronutrient for both animals and humans, and it has recently been recognized as beneficial for plants as well. For people, selenium offers various health benefits, including antioxidant, anti-inflammatory, anti-cancer, antiviral, and anti-aging properties. It is estimated that 1 in 7 people worldwide, along with approximately 14% of the world's soils, are deficient in selenium. Ensuring the effective use of selenium in agriculture – whether for biofortification or as a beneficial element that enhances plant growth and tolerance to biotic and abiotic stresses – poses challenges, as it requires consideration of soil and plant characteristics. Being chemically similar to sulfur, selenium is absorbed by plants through sulfur transporters in their roots. In soils, selenium predominantly exists as selenate or selenite, which, as anions, react with positively charged soil colloids. This is particularly relevant in tropical agroecosystems, which are the world's frontier for food, feed, and fiber production. The 4R Nutrient Stewardship concept emphasizes applying the right nutrient sources at the right rates, timing, and locations. However, implementing this concept is knowledge-intensive and site-specific. This talk will explore the challenges associated with selenium use in plant and human/animal nutrition, highlighting selected studies that present sustainable approaches to its application in agricultural systems. Our ultimate goal is to optimize the use of the world's limited selenium resources while considering the economic, social, and environmental dimensions of nutrient management to promote better soil, plant, and human health.





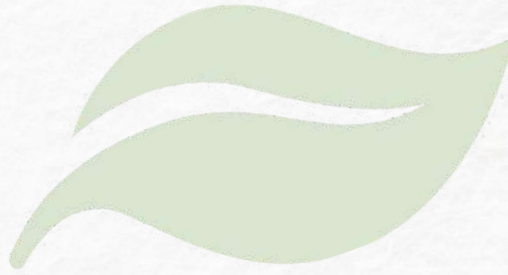
PLENARY SESSION **PLANT NUTRITION: MAINTAINING FOOD SECURITY IN A CHANGING CLIMATE**

Sylvie M. Brouder (United States)¹; Mandana Mirbakhsh (United States)¹; Bruce A. Craig (United States)¹; Jeffrey J Volenec (United States)¹

¹ - Purdue University

Plant nutrition can play a role in either mitigation or exacerbation of global climate change (GCC) when plants drive increased C sequestration in plant-soil systems or cause a net release of greenhouse gases. Staple crop response to GCC is a complex question that is foundational to projections of future food and nutritional security, especially in regions where instability in agricultural productivity already drives hunger and undernutrition. Elevated CO₂ (eCO₂) is expected to enhance yields of C₃ crops, provided other factors do not restrict productivity; maize, a C₄ plant, is expected to have no yield advantage under eCO₂. Results from free air CO₂ enrichment (FACE) studies implemented across the globe have suggested that nitrogen (N) and phosphorus (P) will constrain eCO₂ responses of global plant biomass generally and C₃ crops specifically. However, in croplands, N and P fertilizers are a known source of direct and indirect emissions with 20% or more attributed directly to N fertilizer applications. What cannot be disambiguated from existing FACE studies and reviews is the specific quantities of fertilizer needed to achieve higher yields under eCO₂ and whether nutrient use efficiency (NUE) is maintained, improved or degraded. Further, some primary studies and narrative/conceptual reviews suggest N protein levels may be lower with eCO₂ even when N does not restrict yield, but rigorous, comprehensive review of the literature is lacking. To address this gap, we conducted a systematic review of the FACE literature and quantitatively synthesized yield, grain protein and NUE impacts of eCO₂ as compared to ambient conditions using an array of meta-analytical approaches. We extracted data from >180 primary studies of 7 staple crops. In general, individual FACE studies are space-limited and have not accommodated multiple fertilizer rate treatments and network or mixed treatment comparison meta-analysis is particularly useful when synthesizing across studies that have a limited number of common treatments but lack identical treatment arrays. Overall, our analyses indicate yields may increase without commitment increases in fertilizer applications, but more fertilizer may be required to maximize yields and maintain grain protein; at these higher rates NUE may be lower than it is today. Thus, surpluses of overall field-scale N balances (input – removal) may increase. Greater soil surpluses of reactive N increase risk for greater environmental losses creating direct, positive GCC feedback. We will present these results in the context of an overall discussion on the nutrient cycling mechanisms and processes influenced by GCC.





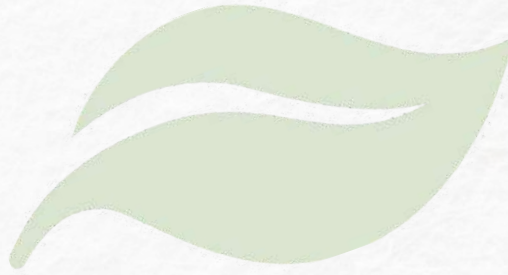
PLENARY SESSION **ENGINEERING CLIMATE-RESILIENT CROPS WITH ENHANCED MICRONUTRIENT UPTAKE**

Alexander A. T. Johnson (Australia)¹

¹ - School of BioSciences, The University of Melbourne

Elevated atmospheric carbon dioxide concentrations are associated with significant decreases in grain iron (Fe) and zinc (Zn) concentrations in C₃ grasses and legumes. New breeding techniques may be required to maintain crop nutrition and food security under future climates. We have employed multiple genetic strategies to increase Fe and Zn uptake in rice (*Oryza sativa* L.) and bread wheat (*Triticum aestivum* L.), including genetic engineering to overexpress individual genes and gene editing to mutate coding sequences involved in micronutrient uptake, transport and translocation. Much of our research has centred on overexpression of nicotianamine synthase (NAS) genes in rice and bread wheat. We are also focused on mutagenesis of upstream Open Reading Frames (uORFs) that are located within the 5' leader sequence of many eukaryotic genes as a means of increasing translation. In particular, we have identified a translationally repressive uORF in the iron-deficiency-responsive element binding factor 2 (IDEF2) transcription factor, which is a positive regulator of the Fe-deficiency response in monocots, and are using gene editing to mutate the IDEF2 uORF in cereal crops. This presentation will describe several aspects of our research and highlight results relevant to Fe and Zn biofortification as well as improved plant tolerance to Fe deficiency.





PLENARY SESSION **BUILDING RESILIENT SEED AND FOOD SYSTEMS THROUGH PARTICIPATORY RESEARCH**

Julie Dawson (United States)¹

¹ - Department of Plant and Agroecosystem Sciences University of Wisconsin-Madison

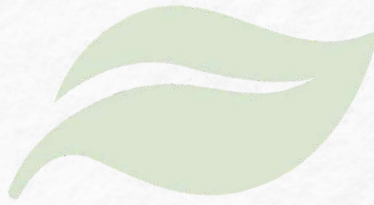
Many farmers are seeing increased volatility of their environmental conditions and are concerned about the continued performance and availability of varieties they use. Increasing regional self-reliance for seed systems and the resilience of regional food systems is important to ensure that farmers have access to varieties that perform well for their cropping systems and provide food for regional communities. In the Great Lakes region of the US, there are many smaller scale and organic farmers serving regional markets.

While larger-scale breeding programs have been highly successful at developing productive and disease resistant varieties, their target region is often not the Northern U.S., and their varieties may not be adapted to northern climates. These varieties also often do not have the quality characteristics needed by farmers serving local food systems, who use a diverse range of marketing and production strategies. This diversity means that decentralized trials and farmer participation in plant breeding can increase the ability of breeding programs to develop varieties that work well for our region.

The Seed to Kitchen Collaborative is a community of practice including farmers, gardeners, plant breeders, extension educators, culinary professionals, non-profit organizations and other stakeholders interested in developing regionally adapted varieties with excellent quality. This network allows us to conduct participatory trials and selection with a large number of farmers, gardeners and culinary professionals. We are also able to trial a more diverse range of varieties from independent breeders, public sector breeders and genetic resource collections than we could in a single breeding program, which may help breeders respond to potentially new environmental conditions and market needs.

In partnership with public sector and independent breeders, this network has successfully contributed to the release of new wheat and tomato cultivars, as well as the adoption of new varieties from regional seed companies. We are working to provide tools for independent breeders who wish to work with on-farm trial networks in their breeding programs. Improving farmer engagement and the participation of other stakeholders can provide breeders with information to ensure their varieties are successful. We hope that this provides a potential model to support the development of regionally adapted varieties that will support agricultural and food system resilience.





THEME 8 **EARLY, SENSITIVE DETECTION OF BIOTIC AND ABIOTIC STRESSES VIA FUNCTIONAL PHENOTYPING OF PLANT WATER BALANCE**

Menachem Moshelion (Israel)¹; Itamar Shenhar (Israel)¹; Shani Fridman (Israel)¹

¹ - The Hebrew University

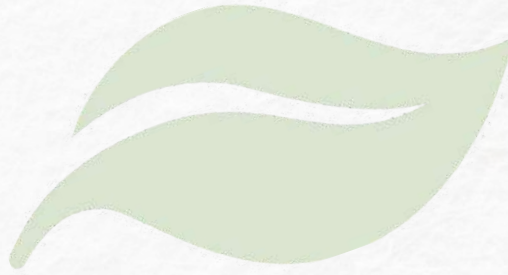
Early detection of stress in plants is critical for ensuring sustainable crop production, as both biotic and abiotic challenges can rapidly compromise physiological functions before visible symptoms appear. In this study, we tested the hypothesis that physiological responses to biotic and abiotic stresses will be faster than morphological, visual symptoms, thereby providing a more sensitive indicator for early stress detection.

In our investigation of biotic stress, tomato plants infected with *Fusarium oxysporum* f. sp. *lycopersici* were continuously monitored using the PlantArray system (Plant-Ditech, Yavne, Israel), a state-of-the-art functional phenotyping system. Our continuous measurements revealed a significant decline in daily transpiration rates several days before any external symptoms—such as wilting or chlorosis—became evident. Detailed analyses indicated that these early water-balance perturbations are likely linked to initial impairments in xylem conductivity and alterations in stomatal regulation. Leaf hydraulic conductance assays further supported the notion that early pathogen invasion disrupts water transport, thereby providing a reliable physiological marker for the onset of root and vascular diseases.

In a separate study addressing abiotic stress, leafy vegetables were subjected to a gradient of nitrogen treatments, with eight different N concentrations applied to facilitate a complex experimental design. Detailed ionomic analyses demonstrated that both nitrogen deficiency and excess rapidly induce measurable changes in the plant water-use efficiency, nitrogen-use efficiency, transpiration, and biomass accumulation. The functional phenotyping approach captured subtle shifts in these parameters, which occurred well before any significant differences in yield or foliar nutrient composition could be detected. Importantly, this approach also allowed us to determine an accurate optimization point for nitrogen fertilization, highlighting the specific nitrogen concentration at which water balance and physiological performance are maximized.

Together, these independent investigations underscore the remarkable sensitivity of continuous water-balance monitoring for early stress detection. The functional phenotyping system not only enables the precise quantification of early deviations in transpiration and hydraulic conductance induced by pathogen attack, but also provides insights into the rapid physiological responses elicited by nitrogen imbalances. By objectively capturing these early-stage changes, this approach offers a robust framework for deciphering the complex interplay between plant water relations and stress responses. Ultimately, integrating continuous functional phenotyping into crop management as well as fertilization and biostimulants development practices holds significant promise for enhancing timely interventions, optimizing resource use, and improving crop resilience under a range of challenging environmental conditions.





THEME 8 NUTRITIONAL IMMUNITY IN PLANTS: THE ROLE OF MICRONUTRIENTS IN HOST-PATHOGEN INTERACTIONS

Marta Nunes da Silva (Portugal)¹

¹ - Universidade Católica Portuguesa, CBQF - Centro de Biotecnologia e Química Fina – Laboratório Associado, Escola Superior de Biotecnologia, Rua Diogo Botelho 1327, 4169-005 Porto, Portugal.

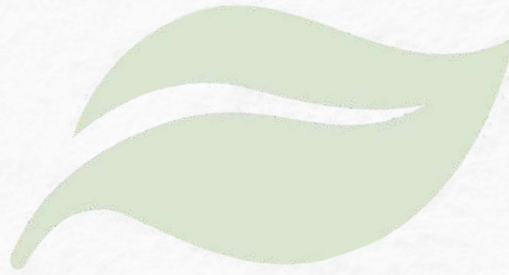
As agricultural systems face increasing pressure from climate change and pathogen emergence, aligning nutrient management with plant defence requirements offers a strategic path forward for enhancing resilience and productivity. In this context, micronutrients play a critical, yet often underappreciated, role in shaping the outcome of plant-pathogen interactions. At the same time, pathogens have evolved sophisticated mechanisms to acquire these nutrients, resulting in a dynamic competition that directly influences disease progression and plant resilience. For instance, pathogens produce specialized transporters and chelators, such as siderophores, to scavenge iron from host tissues, while plants respond with localized nutrient sequestration and enhanced uptake systems to maintain internal homeostasis.

Within this complex crosstalk, plants seek to limit micronutrient availability in the apoplast to suppress pathogen proliferation, while simultaneously increasing internal demand for these elements to support defence-related processes such as lignin biosynthesis, antioxidant activity, and the production of signalling molecules. Micronutrient sufficiency is, therefore, essential not only to restrict pathogen access, but also to enable the full activation of effective plant immune responses.

Despite their importance, micronutrients remain overlooked in many cropping systems, where fertilization strategies are predominantly focused on macronutrients such as nitrogen, phosphorus, and potassium. These conventional practices often prioritize yield over resilience, leading to imbalances that can compromise the plant's ability to respond to biotic stress. Widespread deficiencies of elements like zinc and boron, especially in calcareous or intensively farmed soils, highlight the need for more balanced nutrient strategies. As such, a more integrated approach, accounting for both macro- and micronutrient needs, is crucial to strengthening plant health and disease resistance.

Recent advances in plant nutrition, phytopathology, and molecular biology have highlighted the central role of micronutrients in modulating plant immunity, with case studies in both model plants and crops illustrating the potential of targeted micronutrient interventions, including soil or foliar application, seed treatment, or tailored fertilizers, in reducing disease incidence and improving stress resilience. Ultimately, a deeper understanding of nutritional immunity not only enhances our ability to manage crop diseases, but also offers a promising foundation for the development of resilient and sustainable agricultural systems.





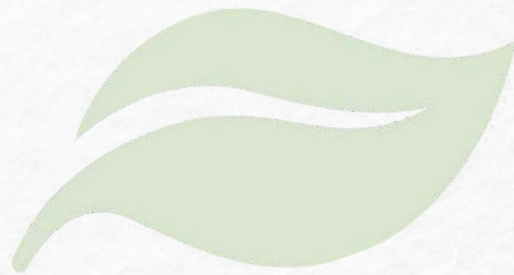
PLENARY SESSION **POTASSIUM IN PLANTS – STILL A HOT TOPIC**

Ingo Dreyer (Chile)¹

¹ - Universidad de Talca, Facultad de Ingeniería, CBSM - Center of Bioinformatics, Simulation and Modeling

Potassium (K^+) is the most abundant inorganic cation in plant cells and is of crucial importance for plant growth. Together with nitrogen (N) and phosphorus (P), K^+ is one of the three most important elements whose availability has a decisive influence on crop yield. International research efforts in recent decades have provided a very detailed molecular insight into the uptake and transport of K^+ in plants. However, research on K^+ transport in plants has also been a constant driving force influencing research on nutrient transport in general. In particular, the mathematical-theoretical investigation of K^+ transport in plant cells led to the discovery of fundamental processes of plant nutrition and homeostasis. Modelling approaches initially implemented for K^+ transport could show that it is not individual transporters but rather transporter networks (homeostats) that control membrane transport and associated homeostatic processes in plant cells (doi: 10.1017/qpb.2024.8). Proper homeostatic control requires at least two different types of transporters for the same nutrient, which are energized differently. This cellular control of cytosolic concentration comes at the expense of energy-consuming nutrient cycles at the membrane, suggesting that these supposedly “futile” cycles are not as futile as they seem (doi: 10.1093/plphys/kiab217). Besides controlling nutrition, the homeostats with their dynamic properties also provide the basis for electrical, chemical, hydraulic, pH and calcium signaling in plants as shown exemplarily for the K homeostat (Quant. Plant Biol., in press). In an initial modeling approach to K^+ transport in the phloem, the concept of the “ K^+ battery” was established, which energizes the (re)loading of sugars into the phloem (doi: 10.1073/pnas.1009777108) and which also enables the remote control of membrane transport at neighboring membranes (doi: 10.1111/nph.14667). In combination with the homeostat concept, this approach could be further developed and recently the sequential transport of K^+ across the plasma membrane and the tonoplast could be investigated in unprecedented detail (doi: 10.1111/nph.19436). The recent new mechanistic insights may support the statement that potassium in plants is still a hot topic. An exciting, but highly challenging question for the future is the role of Na^+ in combined K^+/Na^+ homeostats. This topic, which is highly relevant for agricultural yields, will probably again require strong support from theoretical and modeling approaches.





PLENARY SESSION **A NEW ROLE OF POTASSIUM IN DROUGHT STRESS MITIGATION**

Ismail Cakmak (Turkey)¹

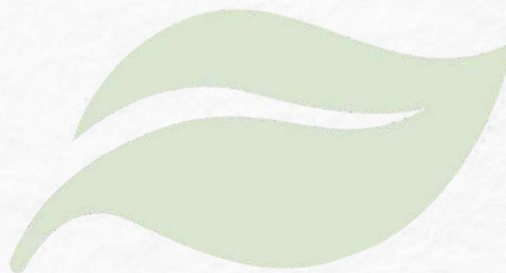
¹ - Sabanci University, Faculty of Engineering and Natural Sciences, 34956 Istanbul, Turkey

Insufficient potassium (K) nutrition decreases plant capacity to resist drought stress drought stress due to impairments in osmoregulation, photosynthetic carbon metabolism, and carbon allocation within the plant. However, our understanding of the major mechanisms underlying the drought stress-mitigating effects of K remains limited. Drought stress is common during the grain-filling stage in many environments around the world and can result in severe impacts on yield, especially in cereals. Grain yield typically depends on (i) recent photosynthesis and the subsequent transport of assimilates from the leaves to developing grain, and (ii) the remobilization of reserve carbohydrates from vegetative tissues to developing grains. Published reports indicate that under drought stress, grain filling largely relies on the remobilization of stored water-soluble carbohydrates (WSC), especially from stems. The contribution of stored stem WSC to grain yield of wheat grown under drought stress ranges between 40 and 60%. These findings highlight that plants with a high capacity to synthesize and store large amounts of WSC in their stems before anthesis, and effectively mobilize them into developing grains post-anthesis, have a great potential to yield well in dry environments.

Among mineral nutrients, K has particular effects on assimilate production and allocation within plants, as well as in increasing the WSC reserves in stem. Low K supply has been shown to cause a significant assimilate shortage in stem tissues and impair stem growth and stability, which aligns with the large accumulation of K in the stem (up to 70% of the total K in the plant). Our recent findings in maize and wheat demonstrated that low K supply impairs stem growth more than shoot growth. When K supply to maize plants increased, whole shoot dry matter production improved by 4.4-fold, while dry matter in the stem increased 6.4-fold, and the accumulation of soluble sugars in the stem rose even further (11.4-fold). These results underscore the critical relevance of K in photosynthate allocation to stem tissues, contributing to high WSC reserves and proper stem development.

Building on published reports and our recent findings, this paper proposes a new K-related mechanism for mitigating drought stress. Specifically, it suggests that K may promote the production and partitioning of carbohydrates into stem tissues and their subsequent mobilization into developing grains under drought stress conditions, especially when leaves lose their ability to produce and deliver sufficient assimilates to the grains.





PLENARY SESSION **ASSESSING GLOBAL POTASSIUM LIMITATIONS TO CROP YIELDS**

Patricio Grassini (United States)¹; Walter Carciochi (United States)¹; Fernando Aramburu-Merlos (United States)¹; Achim Dobermann (United States)²

¹ - University of Nebraska-Lincoln; ² - International Fertilizer Association

High crop yields are associated with large potassium (K) requirements. Unfortunately, K management has received comparably less attention than that of other mineral nutrients such as nitrogen and phosphorus. Here we assessed the degree of K limitation in major agroecosystems around the world and investigated the underlying drivers. To do that, we followed an approach that combines use of existing data collected after year 2000, including soil and plant K ($n=3.6$ M), K input-output balances ($n=111,000$), and yield responses to K fertilizer addition in short and long-term experiments ($n=66,300$ and 103 , respectively), with crop modeling and advanced statistical methods. Based on their yield response and current K balance, cropping systems can be classified in four groups. The first one includes cropping system where K fertilizer addition is not common yet, but crops are becoming increasingly responsive to K fertilizer and exhibit negative K balances (e.g., South American Pampas and Western & Central US Corn Belt). The second group includes cropping systems where yield response to K fertilizer is widespread (two third of cases or more) but current K balances are negative due to a combination of insufficient K fertilizer addition, high crop intensity, and straw removal (e.g., Southeast and South Asia). The third group also includes cropping systems where soil K supply is not sufficient to meet crop requirements; however, their current K inputs seem sufficient or even excessive given current average yields (e.g., Brazilian Cerrado and China). The last group includes low-input, low-yield regions where the K limitation was erratic, probably due to other limiting factors (e.g. Sub-Saharan Africa). Overall, our study shows that soil K supply is rarely sufficient to meet crop requirements over longer period of cropping, and that closing yield gaps will require a substantial increase in global K fertilizer use coupled with better K management in agro-ecosystems, including how crop residues are managed.

* We acknowledge the large number of researchers and organizations that shared published and unpublished data for this study. Due to space limitations, their names could not be added to the list of authors.





THEME 10 COMPARISON OF POTASSIUM INTERNAL EFFICIENCY, REQUIREMENT, AND REMOVAL WITHIN AND ACROSS CROP SPECIES

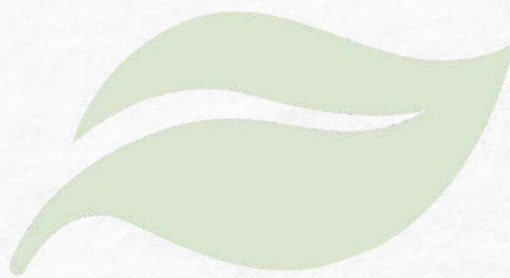
Walter Carciochi (United States)¹; Achim Dobermann (France)²; Nicolas Cafaro La Menza (United States)¹; Sylvie M. Brouderc (United States)³; Christopher Donough (United States)¹; Deborah Jo Heuschele (United States)⁴; Thomas Oberthür (Morocco)⁵; Patricio Sandaña (Chile)⁶; Bello Muhammad Shehu (Nigeria)⁷; Jessica Thainara S. Pereira (Brazil)⁸; Rogério P. Soratto (Brazil)⁸; Jeffrey J. Volenec (United States)³; Ruli Wandri (Indonesia)⁹; Yajing Wang (China)¹⁰; Su Su Win (Myanmar)¹¹; Ping He (China)¹⁰; Patricio Grassini (United States)¹

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Detailed quantification of crop yield produced per unit of potassium (K) uptake, referred to as K internal efficiency (KIE), and associated parameters, such as the K requirement per unit of yield (KRE) and K removal, is essential for informed K management and for addressing global yield gaps in agricultural systems. The objectives of our study were to determine KIE, KRE, and K removal for several crops at different yield targets while assessing the factors driving both intra- and inter-species variation. We generated two datasets: one with several observations per crop [maize (n = 8768), wheat (n = 1756), rice (n = 4590), and soybean (n = 969)] to analyze intra-species variation in the K parameters, and another comprising 14 crop species (alfalfa, banana, canola, cassava, cotton, maize, oil palm, peanut, potato, rice, soybean, sugarcane, sunflower, wheat) to assess inter-species variation.

Our results showed that KIE decreased and KRE increased with crop yield. On average, cereals exhibited a two-fold greater KIE (50 versus 27 kg kg⁻¹ K), a smaller KRE (22 versus 41 kg K Mg⁻¹), and a four-fold lower K removal (3.8 versus 15 kg K Mg⁻¹) compared to soybean. Within crops, variation in KIE was related to the K harvest index (KHI) in maize and wheat and to the K concentration in the harvested product (KCHP) in soybean. Among crops, KIE ranked as follows: cassava and sugarcane (87 kg kg⁻¹ K) > cereals, potatoes, and alfalfa (41–58 kg kg⁻¹ K) > banana and oil-rich crops (10–30 kg kg⁻¹ K). The observed variation in KIE across crops was attributable to differences in KHI and KCHP, with the latter being associated with protein and moisture content. On the other hand, K removal increased with higher yield, KHI, and crop residue removal. For example, K removal was largest in sugarcane (225 kg K ha⁻¹) and alfalfa (123 kg K ha⁻¹) due to high annual yields combined with relatively high KHI, whereas the lowest K removal corresponded to annual crop species without residue removal and low KHI (average: 16 kg K ha⁻¹). This study provides a foundation for quantifying K requirements and removals across crop species and target yields, offering essential insights for sustainable K management in agroecosystems.





THEME 10 **POTASSIUM MANAGEMENT IN GREENHOUSES AND INTENSIVE AGRICULTURE**

Patricia Imas (Israel)¹

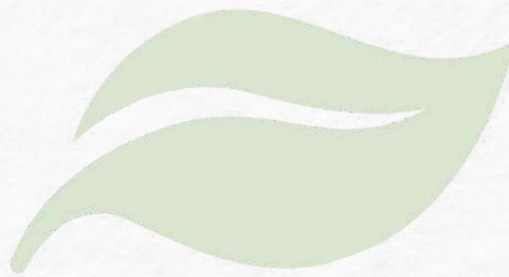
¹ - ICL Group

Fertigation is an effective method for providing plant nutrients to crops, relying on farmers' knowledge of both irrigation and fertilization. Water-soluble fertilizers (WSF) used in fertigation vary in physical and chemical qualities, with common use of urea and KCl as sources of nitrogen (N) and potassium (K), along with complex mixtures of N, phosphorus (P), K, and secondary and micronutrients. Potassium salts like KCl, K_2SO_4 , KNO_3 , and KH_2PO_4 (MKP) are fully soluble, though their solubility rates differ, with KCl and KNO_3 being more soluble than K_2SO_4 .

Chloride (Cl) has been recognized as an essential plant nutrient since the 1950s, required in small quantities for photosynthesis, osmoregulation, nutrient transport, enzyme function, and stomata regulation. Chloride also suppresses diseases and physiological disorders in various crops such as corn, wheat, rice, barley, coconut, and celery. However, Cl toxicity can occur in specific situations, such as saline water irrigation, high water tables, poorly drained soils, and crops sensitive to Cl like grapes and avocado. In cases where Cl is a problem, chloride-free K fertilizers like MKP can be used as an alternative K source.

Research indicates that KCl can replace non-chloride K sources in fertigated crops like tomatoes, citrus, and strawberries without affecting growth and yield. The Cl anion is highly mobile in soil and can be leached out with proper irrigation management, preventing salinity issues. Efficient irrigation regimes ensure Cl anions do not accumulate in the soil, with extra water applications leaching out soluble salts. The presence of Cl in WSF, when managed correctly, should not hinder their use in soil-grown outdoor crops. KCl is widely used in greenhouses in countries like France, Israel, the Netherlands, and Florida (USA) as part of nutrient solutions for hydroponic tomatoes to enhance fruit firmness and flavor. KCl-based WSF are highly effective and trouble-free for intensive soil-grown outdoor crops, offering great value for money. These fertilizers are reliable and commonly used worldwide, delivering good yields, no environmental damage, and cost-effectiveness for farmers.





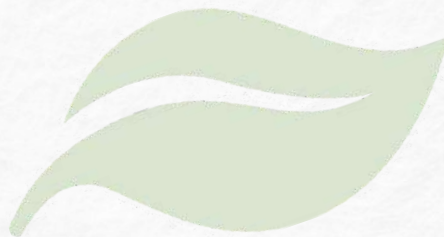
THEME 10 **MODELLING SOIL-PLANT NP AND K DYNAMICS**

Antonius G.T. Schut (Netherlands)¹

¹ - Plant Production Systems group, Wageningen University

Nutrient use efficiency (NUE) in intensified systems is low due to excess applications of mineral and organic inputs. In many parts of the world, soil fertility is low and unbalanced N and P applications, typically without K, also result in low NUE. Better balancing fertilizer supply and crop demand is key to improve NUE and reduce nutrient losses to the environment. This requires a quantitative understanding of short- and long-term effects of fertilizer applications on crop uptake, crop nutrient offtakes and soil fertility. The effects of N limitations on crop growth are well known and incorporated in many crop growth models where some of these models also include P limitations. Very little work has been done on K limitations in crop growth models. However, actual uptake of each of the three major macronutrients strongly depend on supply of other nutrients. At present, there are no models available with reliable predictions of soil N, P and K supply and potential crop uptake of N, P and K, especially for situations where P and K are suboptimal or deficient. A better understanding of the dynamics in demand and supply is needed to optimise amounts applied and timing of N, P and K applications. Crops moderate uptake of nutrients when other nutrients are deficient, affecting N, P and K concentrations in the plant too. Data from detailed field experiments with cassava on three locations during two seasons in Nigeria were used to model crop biomass, yields and NPK uptakes. The nutrient equivalent approach in the LINTUL-cassava-NPK model allowed to accurately predict N, P and K uptake based on known soil supply (Adiele et al., 2022, Field Crops Research 281). Long-term experiments from Kenya, Germany and the United Kingdom were used to model soil supply of P and K with the RC-KP model (Schut and Reymann, 2023, Plant & Soil 492). This model was able to describe the soil available P and K and annual crop uptake in crop rotations accurately. This work shows that better knowledge of soil K supply and plant K uptake is key to improve NUE and better balance fertilizers in both temperate and tropical farming systems.





THEME 12 **RELEVANCE OF NITROGEN FERTILIZER MANAGEMENT AND NITROGEN USE EFFICIENCY FOR LOW-CARBON CROP PRODUCTION**

LUIS TORRES (Germany)¹; Frank Brentrup (Germany)¹; 2; Marco Politeo (Italy)¹; 2; Carlos Bergudo (Colombia)¹; 2

1 - Yara International ASA; 2 - Research Centre Hanninghof

FAO estimates a need for a 60 percent increase in food production by 2050. The use of mineral fertilizer plays a crucial role in sustainably achieving this goal. To achieve food security, we must either enhance crop production per unit of cropland or expand agricultural land area. Agriculture currently accounts for about 20% of global greenhouse gas (GHG) emissions, with land use change being the major contributor. Producing more from the existing cropland is vital to meeting the growing demand for food and preventing the conversion of natural land into cropland, which exacerbates GHG emissions and puts pressure on biodiversity. This cannot be achieved without mineral fertilizers.

However, incorrect fertilizer use, in particular of nitrogen (N) can have negative environmental and climate impacts. Carbon footprinting (CFP) following life-cycle assessment (LCA) approach was followed to quantify GHG emissions per unit of crop from raw material extraction up to the harvest in a holistic way. Literature and field trials data was used to calculate CFPs at farm gate. Literature and reports on emissions for the production and use of fertilizers were used and data were supplemented by internal CFP analysis run with the Cool Farm Tool. The assessments included annual, multiyear- and long-term field trials carried out as part Yara's R&D programs aiming to develop products, tools and agronomic practices to improve NUE in crop production.

The assessments showed contributions of N fertilizer production and use to the total CFP per ton of harvested crops at farm gate can account up to >70%. The share of production and in-field emissions related to N fertilizer varies depending on agroecological conditions with higher share derived in-field e.g. 29% for production and 38% for in-field emissions in malting barley, 26 and 47% in coffee, 25 and 33% in potato, 28% and 42% in wheat respectively. In cereals for instances, improved N management e.g. N rate and sources resulted in yields improvements at reduced N rates leading to 33% reduction in CFP vs farmer practices across 23 field trials in Argentina.

The current study elucidates the relation between NUE and CFP per ton of crop produce and importance to both production and in-field emissions from nitrogen fertilizers. The NUE can be addressed with crop-specific and balanced nutrition programs, correct selection of nitrogen fertilizer sources, and employment of digital tools optimizing fertilizer application for improving NUE and sustainability of crop production.





5

CHAPTER

ORAL COMMUNICATIONS

Theme 1 – Page 43 / 47

Underutilized Crops, Crop Wild Relatives, and Forgotten Foods for Better Nutrition

Theme 2 – Page 48 / 53

Breeding and Genetics for Nutrition and Quality

Theme 3 – Page 54 / 59

Nutrient Uptake, Transport and Homeostasis

Theme 4 – Page 60 / 64

Plant Nutrition Challenges in the Mediterranean Climates – Australia, Europe, and others

Theme 5 – Page 65

Beneficial Elements (A Tribute to Epstein)

Theme 6 – Page 66 / 70

Plant nutrition challenges towards nutritional Sustainability – Africa

Theme 7 – Page 71 / 77

Plant-based Foods for Human Health

Theme 8 – Page 78 / 83

Abiotic & Biotic Stresses and Plant Nutrition

Theme 9 – Page 84 / 90

Nanonutrition & nano-fertilizers

Theme 10 – Page 91 / 93

Advances in Potassium Research and Management

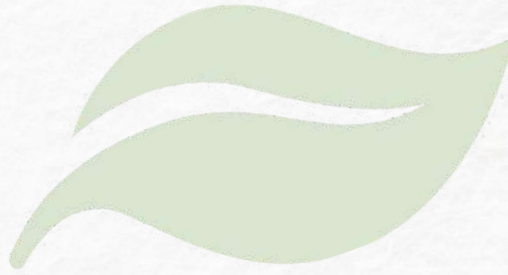
Theme 11 – Page 94 / 98

Plant Mineral Nutrition, from the Genes to the Harvest (A tribute to Phillip White)

Theme 12 – Page 99 / 102

Novel Technologies

Marschner Session – Page 103 / 106



THEME 1 IMPROVING THE NUTRITIONAL PROFILE OF PASTA USING GRASS PEA

Gabriela Ines Najarro Saavedra (Peru)¹

¹ - UCP

The incorporation of legume flours into pasta has been shown to enhance its nutritional profile by increasing protein and dietary fibre content, while also contributing to amino acid complementarity. 'Fava Feneou' and 'Fasolia Vanilies Feneou'—varieties of *Lathyrus sativus* and *Phaseolus vulgaris*, respectively—are locally cultivated legumes in the Feneos Valley (Greece), valued not only for their nutritional content but also for their role in preserving traditional agricultural practices. These include unique cultivation techniques, harvesting time, and seed selection adapted to the valley's distinct soil and climatic conditions.

This project aimed to develop two dry pasta prototypes in which 50% of durum wheat semolina was replaced (on a dry weight basis) with either 'Fava Feneou' grass pea (GP) or 'Fasolia Vanilies Feneou' white bean (WB), offering a value-added alternative to conventional 100% durum wheat pasta (control). The pasta prototypes seek to enhance nutritional diversity, promote the use of underutilised legume crops and contribute to shorter value chains.

During the development process, several parameters were tested and optimised, including legume roasting temperature and time prior to milling, milling speed and particle size, and drying conditions. These adjustments were required to achieve a dough with low stickiness and adequate extensibility, as well as a final product with a desirable texture and colour comparable to traditional pasta. Cooking quality parameters—such as optimal cooking time, water absorption, cooking loss, and colour—were assessed, along with textural properties like firmness, adhesiveness, and the work required for the first bite. Nutritional composition was analysed, including protein and fibre content, and the presence of bioactive compounds such as phenolics and tannins. A sensory evaluation involving 64 volunteers was conducted to assess consumer acceptance across key attributes.

Results showed that the GP and WB pastas had significantly improved nutritional profiles. Protein content increased by 44.4% and 40% respectively compared to the control, qualifying both prototypes for a "high in protein" claim. Dietary fibre content rose by 59.45% in GP pasta and 197.30% in WB pasta, enabling WB pasta to also carry a "high in fibre" claim.

In terms of sensory analysis, GP pasta received positive ratings across all attributes (appearance, aroma, texture, taste, and mouthfeel). WB pasta also scored positively for appearance, aroma, and taste, though ratings for texture and mouthfeel were more neutral. Overall, both pasta prototypes were well accepted by consumers, demonstrating the potential for pasta containing legumes to meet nutritional goals without compromising sensory quality.





THEME 1 INTEGRATING LEGUME-BASED ROTATIONS AND LARGE-SCALE ENVIRONMENTAL ASSESSMENT FOR SUSTAINABLE CROP PRODUCTION

Umut Kartal (UK)1; Colm Duffy (Ireland)2; Sophie Saget (Ireland)3; Frances Sandison (UK)1; Andrew Christie (UK)4; Cathy Hawes (UK)4; Becky Howard (UK)5; Roger Vickers (UK)5; Dimitrios Savvas (Greece)6; Pietro Iannetta (UK)4; 7

1 - Dept Information & Computational Sciences, James Hutton Institute; 2 - Ryan Institute, University of Galway; 3 - Trinity College Dublin; 4 - Dept Ecological Sciences, James Hutton Institute; 5 - Processors & Growers Research Organisation; 6 - Dept Crop Sci., Agricultural University of Athens; 7 - CBQF, Universidade Catolica Portuguesa

Agriculture faces pressure to reduce environmental impacts while maintaining productivity and this research reports on two key approaches to address this using a special focus on the potential of *Vicia faba* L. (field- or faba-beans). Findings of a Life cycle assessment (LCA) of crop sequences are reported alongside an introduction to the novel assessment tool “CropGOBLIN”.

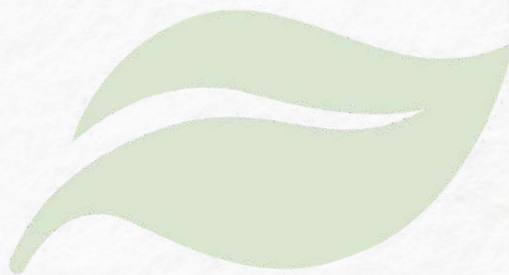
LCA of data from a long term (2009-2023) experimental platform (the Centre for Sustainable Cropping, www.csc.hutton.ac.uk) quantified impacts of a spring field bean to spring barley (*Hordeum vulgare* L.) cropping sequence. Field beans were shown to decrease the environmental impact of spring barley cropping, though this was weather dependent. Of the 6 impact categories (acidification, climate change (GWP100), eutrophication (freshwater), ozone depletion, resource use (fossils), water use), field beans reduced the impact of the following barley crops by 25 %. Additionally, spring barley yields increased by an average of 1.2 t ha⁻¹ following field beans. A ‘combined index analysis’ revealed that [humidity, maximum temperature, previous-year field bean yields] were strong determinants of spring barley production.

Additionally, CropGOBLIN is a national-scale landscape model developed to estimate greenhouse gas (GHG) emissions and sustainability metrics for UK crop production. Validated against National Inventory Data (NID) from 1990-20, the model will allow scenario analysis for optimizing land-use strategies. Incorporating indirect emissions, soil-carbon dynamics, and rotational elements, CropGOBLIN provides a robust framework for guiding policy and industry efforts towards climate-neutral agriculture.

Findings underscore the synergy between LCA studies and large-scale modelling and demonstrate how data-driven decision-making helps drive the transition to more sustainable home-grown legume-based agri-food systems.

Acknowledgements: This research is supported by the InnovateUK project www.ncsproject.co.uk; and European Commission projects www.radiantproject.eu, www.econutri-project.eu, and www.legumESproject.eu. JHI is supported by the Rural and Environment Science and Analytical Services (RESAS), a Division of the Scottish Government.





THEME 1 THE POLICY PARADOX OF UNDERUTILISED CROPS

Orsolya Lazányi (Hungary)¹; Kata Fodor (Hungary)¹; Ágnes Neulinger (Hungary)¹; Bálint Balázs (Hungary)¹; Alex Czeglédi (Hungary)¹

¹ - ESSRG

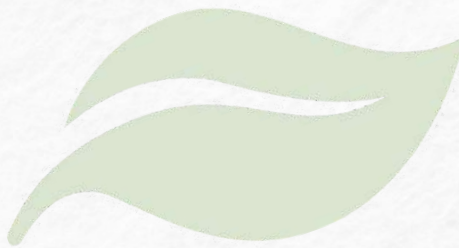
The EU's main strategies (e.g. Green Deal, Farm to Fork strategy, etc.) hold ambitious promises to increase agrobiodiversity, provide food security, and promote sustainable agricultural practices in Europe. However, looking at the European food system, a fragmented landscape can be observed characterised by contradictory policies. The prioritization of a few major crops, in line with global trends of the agro-industry, dominates the value chain from production to consumption. The focus on a limited number of edible plants leads to severe negative environmental and social consequences, from the decline of cultivated diversity on farms to the shrinking nutritional value of our daily meals. Against this backdrop, underutilised or forgotten crops (UCs) hold great potential to provide locally available, fresh and nutritious food (containing high levels of micronutrients, fibre, protein, etc.) while diversifying and increasing the resilience of agricultural systems (Pinto et al., 2022).

Within the European RADIANT project, we investigated how EU policies could support the cultivation and improvement of UCs, in spite of current barriers. Through an interpretive policy analysis complemented with case studies from six European countries, we identified existing policy barriers and leverage points for UCs. This analysis was followed by a policy Delphi study with experts of the European food system to prioritize policy instruments and the most promising solutions for the valorisation of UCs.

While no policy tool explicitly supports the mainstreaming of UCs, sectorial policy instruments provide some windows of opportunity. We identified eight policy areas which can effectively have an impact on the use of UCs, providing a basis for policy recommendations. These include (1) raising farmers' awareness about the ecological benefits of UCs through education and extension services, (2) facilitating the marketization of UC seeds through seed policies, (3) increasing cultivated diversity through breeding with underutilized crops, (4) providing access to decentralized technological solutions and sharing benefits, (5) strengthening the role of short food supply chains, (6) increasing consumer awareness about the health benefits of UCs, (7) recognising and protecting the cultural heritage value of UCs, and (8) using existing labels (e.g. PDO/PGI) to increase consumer awareness about UCs.

Beyond sectorial improvements, however, diversifying the food system would require multiple and simultaneous changes along various value chains. A first step towards this change would be to translate the messages of EU strategies into mandatory policy instruments, and to develop a coherent food policy for the EU.





THEME 1 USING LANDRACES OF BARLEY TO IDENTIFY MICO-NUTRIENT EFFICIENCIES FOR IMPROVED TOLERANCE OF MARGINAL SOILS

Lawrie Brown (UK)1; Sidsel Birkelund Schmidt (Denmark)2; John Wishart (UK)3; Andreaa Spiridon (Austria)4; Eva Oburger (Austria)4; Peter Martin (UK)3; Joanne Russell (UK)5; Timothy George (UK)5

1 - The James Hutton Institute; 2 - Innovation Centre for Organic Farming; 3 - The Agronomy Institute; 4 - University of Natural Resources and Life Sciences; 5 - The James Hutton Institute

Introduction Limited availability of micronutrients is a common problem in agriculture. It is thought that many modern cultivars have lost useful traits for nutrient acquisition through breeding under optimal conditions. Some of the most ancient landraces still cultivated in Scotland include Bere barley which was first grown in the Highlands and Islands over 1000 years ago. These landraces have the potential to be a source of genes and traits for micronutrient efficiency.

Purpose We investigate both the unprecedented abilities of Bere to cope with Mn deficiency and maintain photosynthesis under deficient conditions and the potential of Bere lines to efficiently acquire other micronutrients via the exudation and re-uptake of metal chelating phytosiderophores (PS).

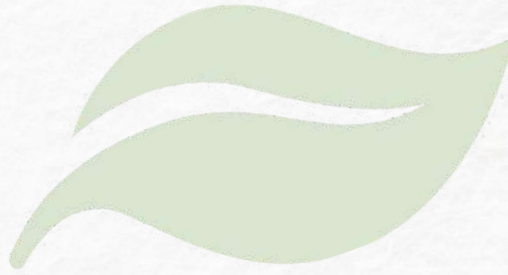
Methods Bere barley lines were grown in marginal field conditions. Plants were screened by chlorophyll a fluorescence to assess the functioning of photosystem II and shoot and grain samples were taken for ICP-MS analysis. The ionic response of the lines was assessed and yield was measured. This information was used to do two things 1) select contrasting genotypes to assess for PS production under different micronutrient deficiencies and 2) produce a cross population between a Mn efficient Bere line and an inefficient elite line. Selected lines were then grown in hydroponics and PS in exudates and PS gene expression in root tissues assessed. While crosses of various stages of development were grown in marginal field conditions (Mn deficient, pH 8.5) and selections made and phenotyping for chlorophyll fluorescence, Mn uptake and yield performed

Results Genotypes selected to be efficient and inefficient in micronutrient uptake had variation in PS production and expression of PS genes, with the efficient lines producing more PS in exudates and taking up more Fe, Zn and Cu.

Crosses between Mn efficient and inefficient lines showed diversity in the Mn-deficiency tolerance trait inherited from Bere and QTL analysis of the advanced cross population showed a strong QTL for Mn efficiency and chlorophyll fluorescence on chromosome 6H.

Conclusions Our data suggest that Bere barley genotypes have a superior ability to accumulate Mn, Zn and Cu compared to elite and other heritage lines. Our results have identified genes and QTLs that are selected for in the Bere populations for both PS production and Mn efficiency traits. Identifying and utilising such genes and phenotypes from ancient germplasms has the potential to provide breeders with novel markers and help develop crops for future agricultural sustainability and marginal soils.





THEME 1 **UNLOCKING THE POTENTIAL OF GRASS PEA: IMPROVING NUTRITIONAL TRAITS THROUGH INVESTIGATION OF NATURAL DIVERSITY**

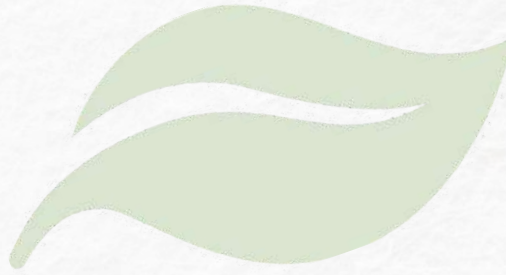
Jasmine Staples (UK)¹; Cathie Martin (UK)¹; Peter Emmrich (UK)¹; 2

1 - John Innes Centre; **2** - NISD

Climate change is exacerbating the frequency and severity of drought events (Cook et al., 2018), increasing need for climate stress-resistant crops that provide adequate nutrition (Luo et al., 2019). Grasspea is a hardy legume with a rich nutritional profile including high levels of protein (Longvah et al., 2017) and diverse important micronutrients (Ramya et al., 2022). However, a diet heavily reliant on grasspea over a period of several months can result in neurolathyrism and irreversible paralysis of the lower limbs (Sarkar et al., 2019), due to the presence of β -ODAP (Ross et al., 1989). The assembly of a reference-quality genome (Vigouroux et al., 2024) and greater understanding of the genes responsible for β -ODAP synthesis (Edwards et al., 2023) will allow further improvement of grasspea as a resilient and versatile crop.

As part of this PhD project, β -ODAP content has been measured in a diverse collection of resequenced grass pea germplasm and GWAS used to identify loci involved in β -ODAP content. In addition, a population of RILs between the reference line LS007 and the low β -ODAP Indian line Mahateora has been investigated, identifying a region associated with low β -ODAP. Due to this toxin, grasspea has experienced fewer agronomic and nutritional improvements than many other legume crops. Sulphur-containing amino acids are essential in the diet and may decrease the risk of neurolathyrism (Getahun et al., 2005; Kusama-Eguchi et al., 2011). As with most legumes, grasspea is low in cysteine and methionine, therefore this diversity panel is being screened by a combination of bioinformatic and experimental approaches for sulphur content in seed storage proteins. In addition, this panel has also been screened for tannin content, and a subsection selected for cell-culture based bioavailability testing, in order to understand the impact of grasspea tannins on iron availability.





THEME 2 IRON AND ZINC BIOFORTIFICATION OF JAPANESE AKITAKOMACHI RICE BY GENOME EDITING OF METAL TRANSPORTERS, OSVIT1 AND OSYSL9

Hiroshi Masuda (Japan)¹; Katsumi Takahashi (Japan)¹; Maho Arakawa (Japan)¹; Takanori Kobayashi (Japan)²; Hiroki Rai (Japan)¹; Takehiko Matsumoto (Japan)¹; May Sann Aung (Japan)¹

1 - Akita Prefectural University; 2 - Ishikawa Prefectural University

Iron and zinc deficiencies are serious malnutrition problems. Approximately 40% of children and 30% of women are affected by iron deficiency anemia worldwide (WHO, 2023). Zinc deficiency is also a problem. Increasing iron and zinc concentrations in rice grains will mitigate these deficiencies, especially in Asian countries including Japan where rice is a staple food and those deficiencies are severe. OsVIT1 is a vacuolar iron and zinc transporter involved in their accumulation in vacuoles. OsVIT1 T-DNA-knockout increased 1.5-fold iron and zinc in brown seeds (Zhang et al., 2012). OsYSL9 is an internal iron-nicotianamine transporter from the endosperm to the embryo during maturation. OsYSL9 knockdown by RNAi increased iron concentration about 2-fold in polished seeds (Senoura et al., 2017). However, the rice produced by transgenic methods is still difficult to apply practically. In this study, we used the well-known, good-tasting Akitakomachi Japanese rice variety and produced high iron and zinc rice through a genome editing approach. First, hygromycin sensitivity tests of Akitakomachi rice calli and seed germination were performed to optimize the hygromycin concentration in selecting transformants. Then, the CRISPR-Cas9 vector that mutates OsVIT1 or OsYSL9 was produced and introduced into rice. We obtained Akitakomachi genome-edited rice, achieving 24 lines of OsYSL9- and 27 lines of OsVIT1-edited rice. Iron concentrations increased up to 1.7 or 1.9 folds in T₁ polished seeds of OsYSL9- or OsVIT1-edited rice, respectively and zinc concentrations were also increased. We performed sequencing of the target genes and confirmed homo or hetero mutations. Then, the mutated lines with high iron and zinc in their grains were selected and cultivated for further T₂ analysis. Our results showed that OsYSL9-edited lines had up to a 2-fold increase in iron concentration (5.4 µg/g) in T₂ polished seeds compared to that of wild type (2.6 µg/g). OsVIT1-edited lines had up to a 3-fold increase in iron concentration (8.04 µg/g) compared to wild type (2.6 µg/g). Zinc concentrations also increased up to 1.3-fold in T₂ polished seeds of OsVIT1-edited lines. For practical application as genome-edited rice, we conducted PCR and hygromycin sensitivity tests during the germination period and confirmed that some mutated lines had Cas9 vector-free in T₂ generation. Taken together, we successfully produced rice with high iron and zinc in polished seeds by genome-editing of the metal transporter OsVIT1 or OsYSL9. This biofortification approach could be applied to other rice varieties.





THEME 2 **PRODUCTION OF IRON-RICH RICE BY MUTATION OF IRON-SENSING HRZ UBIQUITIN LIGASES**

Takanori Kobayashi (Japan)¹; Haruka Shinkawa (Japan)¹; Akari Murota (Japan)¹; Takato Ihara (Japan)¹; 2; Karen Kanamaru (Japan)¹; Hiroshi Masuda (Japan)³; Hiromi Nakanishi (Japan)²; Naoko K. Nishizawa (Japan)¹

1 - Research Institute for Bioresources and Biotechnology, Ishikawa Prefectural University, Nonoiichi, Ishikawa, Japan; 2 - Graduate School of Agricultural and Life Sciences, The University of Tokyo, Bunkyo-ku, Tokyo, Japan; 3 - Faculty of Bioresource Sciences, Akita Prefectural University, Akita, Japan

Iron is an essential element in living organisms. Although abundant in soils, iron is sparingly soluble in alkaline soils which account for approximately 30% of the world's arable soils. This causes iron deficiency in plants, decreasing yield and quality. Moreover, plant iron is the main source of iron in humans. More than 2 billion people worldwide are suffering from iron deficiency. Rice is a major staple food in many Asian countries, thus is a main target for biofortification.

To take up adequate amount of iron, plants sense iron abundance, and transcriptionally induce the expression of various genes involved in iron uptake and translocation in response to iron deficiency. We previously identified candidate iron sensors in rice: hemerythrin motif-containing RING- and zinc-finger proteins (HRZs) (Kobayashi et al. 2013 Nat. Commun. 4:2792). HRZs and their homologs BRUTUS (BTS) and BTS-like, collectively HRZ/BTS, are ubiquitin ligases that repress the expression of major genes involved in iron uptake and translocation. HRZ/BTS targets positive regulators of iron deficiency responses, such as bHLH and bZIP transcription factors, for subsequent degradation to repress their function (Kobayashi et al. 2022 Plant J. 110:1731-1750).

In the present study, we characterized the four C-terminal domains of rice HRZs, i.e. CHY-, CTCHY- and RING-Zn-fingers, and rubredoxin-type fold, because all of these are deduced to bind iron or zinc (Kobayashi et al. 2013). We present evidence that some of these domains are involved in self-ubiquitination and subsequent degradation of HRZ proteins themselves in vitro, predominantly under zinc-bound or iron-deficient conditions. We produced and selected rice mutants of HRZ genes, OsHRZ1 and OsHRZ2, by CRISPR/Cas9-induced mutation or Tos17 insertion. Representative mutant lines at one or more of the C-terminal domains of either OsHRZ1 or OsHRZ2 showed increased tolerance to iron deficiency. Expression of iron deficiency-inducible genes involved in iron uptake and translocation was upregulated in their roots. These phenotypes were much stronger in the OsHRZ1 mutants than in the OsHRZ2 mutants. OsHRZ1 and OsHRZ2 mutants also showed increase in iron concentrations in brown rice, i.e. 1.9-2.4 times and 1.2-1.6 times, respectively. Moreover, both the OsHRZ1 and OsHRZ2 mutants showed marked increase in iron concentrations in polished rice, i.e. 2.4-3.7 times and 1.5-4.4 times compared to wild-type, respectively. These results indicate that OsHRZ mutations enhance iron uptake and translocation, especially into white rice (endosperm). This research provides a promising approach for practical non-transgenic rice iron fortification.





THEME 2 FROM TOXICITY TO TOLERANCE: RETHINKING TIPBURN THROUGH ELEMENTAL CLUES AND HYDATHODE DYSFUNCTION TO PAVE A PATH TOWARDS BREEDING RESILIENT LETTUCE

Alan Pauls (Netherlands)¹; Chris Dijkstra (Netherlands)¹; Yoojeong Hwang (Netherlands)¹; Dennis Brueckner (Germany)²; Tearlach Barden (Netherlands)¹; Ilja van Lierop (Netherlands)¹; Esther Blommert (Netherlands)¹; Kiki Spaninks (Netherlands)³; Sarah L. Mehrem (Netherlands)⁴; René Boesten (Netherlands)¹; Basten L. Snoek (Netherlands)⁴; Remko Offringa (Netherlands)³; Antony van der Ent (Netherlands)¹; Mark. G. M. Aarts (Netherlands)¹

1 - Wageningen University; 2 - DESY; 3 - Leiden University; 4 - Utrecht University

Tipburn in lettuce (*Lactuca sativa*) is a physiological disorder that causes necrotic lesions at young leaf margins, historically attributed to localized calcium (Ca) deficiency and laticifer cell collapse. In heading lettuce varieties, younger leaves are hidden from view, and symptoms emerge just before harvest, leading to economic losses. While the prevailing hypothesis suggests that low Ca compromises cell membrane integrity, leading to tissue collapse and necrosis, our study explores an alternative mechanism involving nutrient dynamics and localized metal toxicity. We hypothesize that prevailing low Ca conditions upon rapid plant growth increase accidental uptake of divalent cations such as zinc (Zn) and manganese (Mn), which accumulate at hydathodes and when guttation is limited, this triggers oxidative stress thereby accelerating tissue damage around these hydathodes. To explore this hypothesis, we used four lettuce genotypes—tipburn-sensitive and tolerant *L. sativa* and *Lactuca serriola*—grown hydroponically under control, low Ca, and low/high Mn/Zn conditions. Synchrotron-based X-ray fluorescence elemental imaging revealed that Ca, Zn and Mn were consistently accumulating at hydathodes, at concentrations that were significantly higher in necrotic tipburn tissue than in adjacent healthy tissue. This raises critical questions about whether their buildup precedes tissue damage or occurs as a secondary response. Our findings suggest a potential feedback loop: oxidative stress from excessive Zn/Mn at environmental conditions that suppress guttation, may disrupt hydathode function, further impair guttation, and accelerate lesion expansion by triggering further oxidative stress and activating cell damage immunity signaling pathways. SEM imaging confirms hydathode disruption as one of the earliest steps in tipburn lesion development. Our findings not only propose a novel mechanistic explanation for tipburn but also have direct implications for breeding. A more precise understanding of the molecular basis of tipburn helps narrow down candidate genes and identification of genetic markers for marker assisted breeding. Leveraging our high-throughput phenotyping system, we identified quantitative trait loci (QTLs) for tipburn severity in lettuce, and its close relative, *L. serriola*, demonstrating that breeding for tipburn tolerance is achievable with a combination of mechanistic insights, refined genetic mapping, and effective phenotyping strategies. Our study challenges the conventional view of tipburn as a simple Ca deficiency disorder, highlighting complex nutrient interactions. Future work should use time-lapse imaging and live Ca/Zn/Mn tracking to further resolve the sequence of events. By bridging fundamental plant physiology with breeding applications, our findings provide a roadmap for developing lettuce cultivars with enhanced tipburn tolerance.





THEME 2 FINE MAPPING QUANTITATIVE TRAIT LOCI CONTROLLING BORON EFFICIENCY IN BRASSICACEAE BY COMBINING GENETIC AND PHENOTYPIC INFORMATION FROM NATURAL AND GENERATED POPULATIONS

Thomas D Alcock (Germany)¹; Manuela Désirée Bienert (Germany)³; Astrid Junker (Germany)⁴; Rhonda C. Meyer (Germany)⁴; Christian Flügge (Germany)⁵; Jiline Tölle (Germany)¹; 2; Eva Heinrich (Germany)⁶; Nicolaus von Wirén (Germany)⁷; Thomas Altmann (Germany)⁴; Antje Schierholt (Germany)⁵; Gerd Patrick Bienert (Germany)¹; 2

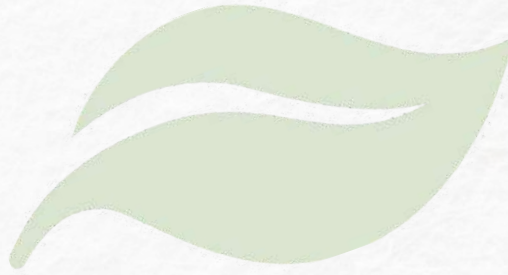
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Boron (B) is an essential plant micronutrient critical for cell wall stability. Brassicaceae have a high B requirement and access to B throughout the plant life cycle is necessary for developmental and reproductive success. However, B is soil-mobile and easily leached, and therefore not always optimally available. To improve tolerance to low B conditions, it is crucial to understand adapted responses to B limitation and to identify associated genetic loci.

We leveraged a doubled-haploid (DH) population of *Brassica napus* derived from B-efficient and B-inefficient parents, as well as a natural population of 185 *Arabidopsis thaliana* accessions, to dissect the physiological and genetic basis of B efficiency in Brassicaceae. Both populations were cultivated in B-sufficient or B-deficient conditions in soil-substrate in an automated phenotyping system which measured >50 visible light and fluorescence-based traits daily over up to 20 days. The *A. thaliana* population was additionally cultivated on Phytigel to assess root responses to B limitation. Associated genetic loci were identified using quantitative trait loci (QTL) mapping and genome wide association studies (GWAS) for *B. napus* and *A. thaliana* populations, respectively.

Biomass accumulation suffered at least a 60% reduction across the *B. napus* DH population in response to B limitation, albeit with over 25-fold variation between the most B-deficiency tolerant and sensitive lines. Whilst profound shoot- and root-growth inhibition was observed in most *A. thaliana* accessions under B limitation, seven highly B-deficiency tolerant accessions with <20% reduced biomass were identified. Boron-efficient *A. thaliana* accessions were characterised by sustained lateral root growth under B limitation. Efficient B uptake did not explain the performance of B-efficient lines in either population, with even the most B-deficiency tolerant accessions suffering an 80% decrease in shoot B concentration. In addition, similar transcriptomic responses of B transporters were observed in both B-deficiency tolerant and sensitive *A. thaliana* accessions, overall suggesting increased B-use rather than B-uptake efficiency in tolerant accessions. Genetic mapping associated loci on three *B. napus* chromosomes with variation in multiple developmental and ionomic traits. Candidate genes and phenes have also been identified from genetic association with *A. thaliana* traits, including those linked to optimised root systems for continuous B access.

In summary, B-efficient Brassicaceae genotypes do not appear to rely on increased B uptake to tolerate B limitation but rather maintain development through increased B-use efficiency and ensuring continued B access. Fine mapping of B-efficiency QTL and testing of candidate genes is currently underway.



THEME 2 **GENETIC VARIATION FOR MINERAL UPTAKE AND PARTITIONING IN WHEAT**

Malcolm J Hawkesford (UK)¹; Petros Sigalas (UK)¹; Andrew Riche (UK)¹

¹ - Rothamsted Research

Wheat is an important source of mineral micronutrients for human and livestock nutrition. It is well-established that commercial wheat cultivars exhibit low genetic diversity compared to older varieties, including landraces. Furthermore mineral density in the grain is relatively low. Exploiting the A. E. Watkins landrace cultivar collection, a historical germplasm collection dating back a century, we aim to elucidate novel genes controlling the accumulation of essential minerals in wheat, partitioning between organs, and accumulation in the grain. Key objectives include assessing natural variation for accumulation of key minerals in the wheat landraces and identifying germplasm with enhanced accumulation for introduction into breeding programmes.

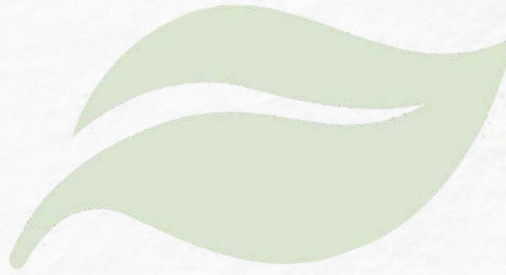
The set of 821 Watkins lines, recently sequenced (Cheng et al., 2024), were grown in two successive years in replicated field trials at Rothamsted in the UK. In addition, selected biparental populations (Paragon x Watkins lines) and NAM panels focused on variation in specific traits (Zn, P, N) were also grown in multiple years and subject to QTL or GWAS analysis (Sigalas et al., 2024). Grain and straw yield were recorded and subsampled for mineral analysis by ICP-AES, as well as grain weight, size and shape. This enabled total mineral offtake, partitioning from grain straw (mineral harvest index) as well as grain content and concentration to be determined. In addition, in season phenotyping recorded growth and developmental stage. Data will be presented showing the diversity of mineral uptake and partitioning between grain and straw along with variation in phenotype, allowing insights into mechanistic control mineral uptake and distribution. First data indicating candidate genes at key genetic loci will be presented.

Cheng et al., (2024) Harnessing Landrace Diversity Empowers Climate-resilient Wheat Breeding. Nature, <https://doi.org/10.1038/s41586-024-07682-9>

Sigalas et al., (2024) Improving wheat grain composition for human health by constructing a QTL atlas for essential minerals. Communications Biology. 7, p. 101. <https://doi.org/10.1038/s42003-024-06692-7>

This study is supported by the UK BBSRC to Rothamsted Research through the Delivering Sustainable Wheat strategic programme (BB/X011003/1).





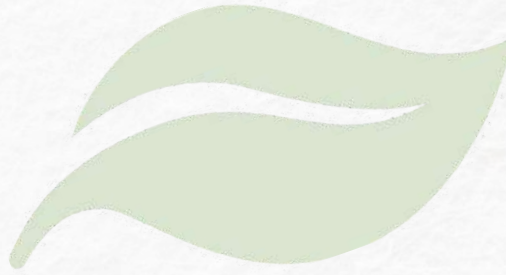
THEME 2 IDENTIFYING GENETIC VARIATION FOR PHOSPHORUS USE EFFICIENCY IN LACTUCA SERRIOLA, A WILD PROGENITOR OF LETTUCE

Chris Dijkstra (Netherlands)¹; Rick H.J. van de Zedde (Netherlands)²; René Boesten (Netherlands)¹; Mark G.M. Aarts (Netherlands)¹

1 - Laboratory of Genetics, Wageningen University and Research; 2 - Netherlands Plant Eco-phenotyping Centre, Wageningen University and Research

Crop wild relatives are a source of genetic variation that can be utilized to improve their domesticated counterparts. The EU-COUSIN project (www.cousinproject.eu) examines crop wild relatives of wheat, barley, pea, cabbage/oilseed rape, and lettuce for the potential to ameliorate crops. The presented research explores the genetics of *Lactuca serriola*, a close relative of domesticated lettuce (*L. sativa*), in the context of phosphorus use efficiency (PUE). Phosphorus is an essential element for plants which is naturally present in many soils. However, modern agricultural practices quickly deplete soil phosphorus contents which limits yields. While phosphorus can easily be applied to crops through fertilization, this relies on non-renewable mineral deposits. Furthermore, excess phosphorus fertilization leads to pollution of the environment and drinking water sources. The yield-limiting effects of phosphorus deficiency, combined with the environmental consequences of agrochemical dependency, create a need for crops with enhanced PUE. We hypothesize that the *L. serriola* germplasm contains genetic variation that enhances plant performance in low phosphorus conditions because *L. serriola* naturally inhabits regions with varying soil phosphorus levels concentrations. The presented research aims to identify such genetic variation, the Quantitative Trait Loci (QTLs) involved, and the causal allelic variants in *L. serriola* that may contribute to improved PUE in *L. sativa*. To achieve this, a diversity panel of 180 *L. serriola* accessions was grown and phenotyped under phosphorus-deficient conditions. Plant performance was assessed over time by measuring projected leaf area, leaf color, and chlorophyll fluorescence. Projected leaf area of plants was determined from top-down red-green-blue (RGB) imaging. The same RGB images were also used to determine leaf color, which serves as a proxy for anthocyanin accumulation. Chlorophyll fluorescence parameters Φ_{PSII} and F_v/F_m , representing the operating and maximum efficiencies of Photosystem II, were calculated to assess the impact of limited phosphorus supply on photosynthesis efficiency. The phenotypic data were used for a Genome Wide Association Study to identify QTLs associated with plant performance under phosphorus-limiting conditions. The identification of genetic variation that supports plant performance under such conditions, thereby adding to PUE, provides breeding targets for introgression into domesticated lettuce. In addition, this study highlights the potential of *L. serriola* as a source of resilience against abiotic stresses for *L. sativa*.





THEME 3 **ROLE OF NUDIX HYDROLASES IN PHOSPHATE SIGNALING AND PLANT DEFENSE**

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Phosphorus (P) is an essential nutrient that often limits crop growth, as only a small fraction of soil P is readily available to plants. With global P deposits being limited and considering that P is a strong global pollutant of open water bodies, enhancing crop P-use efficiency is a pressing agricultural challenge. Additionally, a significant portion of P in plant seeds is stored as phytic acid (InsP₆) which chelates essential micronutrients such as iron and zinc, reducing their bioavailability for humans and non-ruminant animals. In plants, phosphate (Pi) homeostasis is tightly regulated by the interaction between Pi starvation response transcription factors (PHRs) and SPX proteins, which act as high affinity receptors for inositol pyrophosphates (PP-InsPs), such as InsP₇ and InsP₈, highlighting their crucial role in Pi signaling. However, the turnover of these signaling molecules remains poorly understood. Using a non-hydrolysable PP-InsP analog, we identified a family of Arabidopsis Nudix hydrolases (NUDTs) clustering into two subclades. Biochemical and genetic analyses revealed that these NUDTs function as enantiomer-selective, Mg²⁺-dependent PP-InsP pyrophosphatases. Subclade I NUDTs preferentially hydrolyze 4-InsP₇, while subclade II NUDTs target 3-InsP₇. Higher-order subclade II mutants exhibited defects in Pi and iron homeostasis. Although ectopic NUDT expression induced local Pi starvation responses (PSRs), RNA-seq analysis suggested additional PSR-independent roles, potentially involving 1-InsP₇ in plant defense. Our findings provide new insights into PP-InsP metabolism and offer potential strategies for improving P-use efficiency and micronutrient content in crops and modulating plant-microbe interactions, with broad implications for sustainable agriculture.





THEME 3 EFFECTS OF CONTRASTING PHOSPHORUS-IMPOVERISHED HABITATS IN SOUTHWEST AUSTRALIA ON SPECIES-DEPENDENT PHOSPHORUS-ACQUISITION STRATEGIES IN PROTEACEAE, FABACEAE, MYRTACEAE AND ERICACEAE

**Ling-ling Chen (Australia)¹; Patrick M. Finnegan (Australia)¹; Kosala Ranathunge (Australia)¹;
Hans Lambers (Australia)¹**

¹ - The University of Western Australia

Severely phosphorus (P)-impoverished soils are one of the pivotal environmental features of southwest Australia, a biodiversity hotspot where species have evolved traits over millions of years that enhance their P-acquisition efficiency. Species in this region can express various and/or multiple P-acquisition strategies. However, the effect of soil P concentration ([P]) on the natural selection of P-acquisition strategies and whether these strategies have converged within families remain unknown.

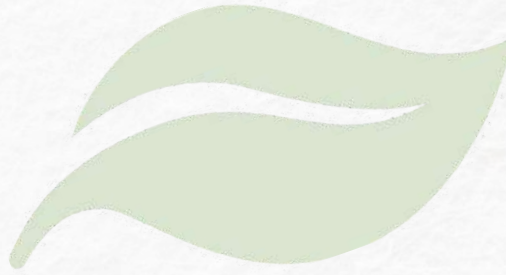
This study aims to understand the diversity of P-acquisition strategies of different species and families on severely P-impoverished soils. We hypothesised that: (1) the P-acquisition strategy of a species is highly context-dependent. For each species, we expect different strategies to be expressed in habitats with different P availabilities. (2) There was a convergence of P acquisition strategies within families, except for species with different root characteristics (e.g., tufted roots) within families.

We investigated the P-acquisition traits of 12 coexisting species from Proteaceae, Fabaceae, Myrtaceae and Ericaceae, including release of root carboxylates and phosphatases, and assessed soil [P] in the rhizosphere and bulk soil. Three species were located only on a deep dry sand dune, two species were only on surrounding winter-wet flats, and seven species were found in both habitats. These contrasting habitats have soils with different depths, volumetric water content and [P].

We determined that there was little convergence of P-acquisition strategies within families, and each species exhibited a unique pattern of P acquisition. The expressed P-acquisition strategies were affected by bulk soil [P]. In particular, the structural equation model (SEM) analysis revealed that soil total [P] and organic [P] strongly affected leaf manganese concentration, which is a proxy for rhizosheath carboxylate concentration. Thus, species in P-impoverished habitats expressed multiple P-acquisition strategies based on their taxonomic background and bulk soil [P].

This study highlights how contrasting habitats with different bulk soil [P] influence P-acquisition strategies and demonstrates the variation in P-acquisition strategies among species in P-impoverished environments. These findings contribute to a deeper understanding of how plants efficiently obtain P to allow their coexistence in P-limited landscapes.





THEME 3 NAVIGATING PLANT NUTRITION IN ACID SOIL BY ALUMINUM ACTIVATED MALATE TRANSPORTERS (ALMTs) AS ANION CHANNELS

Min Yu (China)¹

¹ - International Research Center for Environmental Membrane Biology, Foshan University

Aluminum-Activated Malate Transporters (ALMTs) are classified as anion channels, named after the first family member identified in wheat (*Triticum aestivum* L.), which are activated by aluminum (Al) and exhibit significant permeability to malate. Different ALMT family members serve distinct functions and collectively transport organic and inorganic anions within plant cells. However, it is still unknown if ALMTs are permeable to other organic anions, such as ascorbic acid (AA), which is estimated to be present at approximately 20 mM in the cytosol. By analysing the molecular evolution and protein structure of ALMTs, we highlighted the crucial role of the ALMT protein family in fundamental physiological processes of plants. These processes include Al resistance, mineral nutrition, and stomatal regulation for plant nutrition from both soil and foliar fertilization. In a case study of ALMTs under Al stress, we observed that ALMT1 was permeable to ascorbate in addition to malate, and the exudation of AA and its oxidated form of dehydroascorbate (DHA) were detected after Al exposure, exhibiting time- and dosage-dependent effects. The potential involvement of ALMT1 in ascorbate efflux in the pathway of reactive oxygen species (ROS) metabolism and its effects on cell wall dynamics and mechanical properties were suggested by Al-activated increases in superoxide anion radicals ($O_2^{\cdot-}$) and hydroxyl radicals ($\cdot OH$), along with a decrease in hydrogen peroxide (H_2O_2). Further study indicated that Al also activated ascorbate oxidase, which has been found to be localized in the apoplast to catalyse AA to DHA. The exudation of malate and ascorbate into the apoplast alters the solubility and form of nutrient ions, e.g., P, N, Fe, Mn, Cu, Zn, Ni, Ca, Mg, and S. Therefore, we suggest that the ALMT family has a significant impact on both foliar and soil nutrition. We discussed that the high hotspot concentration of malate and ascorbate, as well as hydroxyl radicals in the apoplast of root and shoot (stomatal) cells, may play an overlooked major role in nutrient movement through the cell wall and its transport across the plasma membrane into the cytosol. This discussion aims to provide fundamental insights for a better understanding of the role of ALMTs in Al resistance, mineral nutrition, and stomatal regulation, which are crucial for both foliar and root nutrition / fertilization, as well as the promotion of sustainable agricultural practices.





THEME 3 WHEN A DROPLET LANDS IN A MICROSCOPIC LEAF LANDSCAPE AND DECIDES TO STAY: WHAT HAPPENS NEXT?

Max Frank (Denmark)¹; Emil Visby Kristensen (Denmark)²; Augusta Egelund Szameitat (Denmark)¹; Idil Ertem (Denmark)¹; Rikke Dahl (Denmark)¹; Katie Gràinne Dempsey (Denmark)¹; Rajmund Mokso (Denmark)²; Søren Husted (Denmark)¹

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The development of foliar water films and subsequent water uptake mechanisms affect how nutrients, pathogens, particles, and water enter crop plants through the foliage. Various factors that affect leaf wetting dynamics have been identified in the past. However, due to a lack of appropriate methods, little is known about how droplet properties affect leaf wetting dynamics based on varying leaf morphology and topography on a micrometer scale. Similarly, it remains unknown how the atmosphere around the leaf affects wetting and ultimately contributes to stomatal or cuticular water uptake.

Here, we present a novel X-ray micro-CT based method that allows us to study the formation of foliar water films on leaves of barley and potato growing in a controlled atmosphere. With this method, we investigate how varying surface tension and leaf morphologies affects the foliar water uptake pathways through stomata and sclerenchyma cells over time.

Under low CO₂ conditions, >90 % relative humidity and growth light, stomata of barley and potato plants were forced open. Under these conditions, we successfully managed to maintain and observe the foliar water film over several hours and to CT scan plants repeatedly without any structural damage originating from the X-ray beam. Water droplets with high surface tension did not establish physical contact with most stomata on barley leaves within 7h. Instead, water uptake occurred through pectin rich fiber cells. In contrast, trichomes on potato leaves facilitate droplet spreading and hydraulic activation of stomata occurred within 5h. In both cases, formed a continuum from the cuticle and all the way into the vasculature. At low surface tensions, leaf surface morphology and topology regulated water film spreading. Raised stomata on potato leaves were not covered by water films at 20 mN m⁻¹, while the sunken stomata on barley leaves resulted in water filled depressions.

We have developed a synchrotron X-ray micro-CT procedure that allows detailed and systematic studies of the interactions between foliar water and leaf surfaces, which has largely constituted a knowledge gap in plant science. In future work, the CT based methodology can be used to investigate how leaf surface characteristics altered by leaf age, nutritional status, stress, and plant species affect leaf wetting and hydraulic activation of the continuum between the cuticle and the substomatal cavity. Furthermore, it improves the basis to study effects of climate change and atmospheric pollution on foliar uptake of water, elemental ions as well as micro- and nanoscale particles.





THEME 3 **UPREGULATION OF SPECIFIC “METHYLTRANSFERASE-TYPE-11-DOMAIN- CONTAINING-PROTEINS” PROTECTS BORON- DEMANDING DICOTYLEDONOUS PLANTS AGAINST GROWTH DEFECTS UNDER BORON DEFICIENCY**

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1 - Technical University of Munich; 2 - Xinjiang Academy of Agricultural Sciences; 3 - Leibniz Institute of Plant Genetics and Crop Plant Research (IPK); 4 - Martin Luther University Halle-Wittenberg

Background: Despite its vital role for plant performance, fertility and yield, boron (B) is still the least understood essential plant micronutrient. To date, root-localized B transporters, such as NIP5;1 variants, are the only known genes in plants which transcriptionally react in any case and distinctly to B deficiency. Surprisingly, shoot responsive genes as well as transcript patterns associated with non-transport-related B deficiency responses or mechanisms allowing plants to tolerate B-limited growth conditions remain mostly unknown.

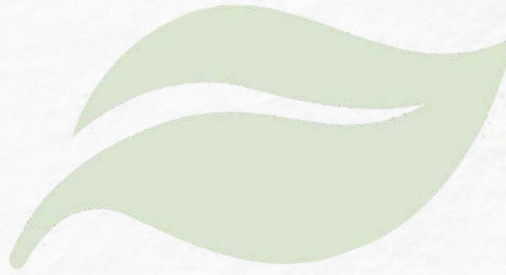
Aims: Identification and characterization of Boron Deficiency Induced (BDI) genes in Arabidopsis and other B-demanding plant species.

Methods: Transcriptoms comparing B-deficient and B-sufficient plants have been analyzed to identify B-responsive genes. Phylogenetic studies, diverse molecular genetic methods, expression analysis, plant growth assays and elemental analysis were combined to characterize identified B-responsive genes.

Results: Here, we identified and characterized a gene, AtBDI1, that is highly and non-transiently induced in roots, leaves and flowers of Arabidopsis thaliana under B-deficient growth conditions. In databases, AtBDI1 is listed as a gene of unknown function. AtBDI1 expression is not induced by other mineral nutrient deficiencies or abiotic stresses causing root inhibition phenotypes similar to those observed upon B deficiency. Increased transcript levels of AtBDI1 can be detected earlier than those of the typical B deficiency marker gene, AtNIP5;1, a root-localized channel, essential for the uptake of B into roots. AtBDI is a member of the poorly characterized Methyltransferase-type-11-domain-containing-Protein family (MT11) and forms together with homologous genes of other, only highly B-demanding plants, a defined phylogenetic clade.

Our transcript analyses revealed that all tested BDIs from this, but not from closely related MT11 clades, are highly responsive to B-deficient growth conditions. Promoter-GUS analysis and single cell transcriptomic results unveiled tissue-specific and B-dependent expression of BDIs in different plant organs. AtBDI seems to be associated to the Golgi apparatus. Importantly, bdi knockout mutants in Arabidopsis and Lotus displayed lower biomass production and increased sensitivity of shoot and root development under B limitations compared to the corresponding wild types, while displaying similar B concentrations under B-deficient and B-sufficient growth conditions.

Conclusions: In summary, we identified BDI genes as the first reliable transcriptional markers instantly labeling B-deficient cells and tissues in roots and shoots of highly B demanding plants. Moreover, we demonstrated that BDIs are crucial for an asymptomatic plant growth and development under B deficiency. The molecular function of BDIs is currently under investigation.



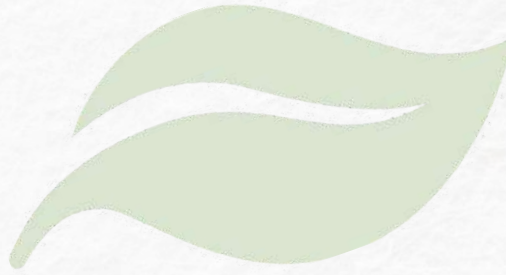
THEME 3 **ROLE OF ROOT ENDODERMAL CASPARIAN STRIP IN MINERAL ELEMENT UPTAKE IN RICE**

Toshiki FUJII (Japan)¹; Naoki YAMAJI (Japan)¹; Jian Feng MA (Japan)¹

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Rice roots are characterized by the presence of two Casparian strips (CS) located at the exodermis and endodermis, where transporters for mineral nutrients are expressed. However, the exact role of the CS in regulating the expression of these transporters and their subsequent impact on nutrient uptake remains poorly understood. In this study, we investigated the role of the CS in manganese (Mn) and boron (B) uptake using a rice mutant (*oscasp1*) defective in the formation of the endodermal CS. We cultivated the *oscasp1* mutants alongside their wild-type (WT) rice in a nutrient solution containing varying concentrations of Mn or B and compared their mineral concentrations using inductively coupled plasma-mass spectrometry (ICP-MS). Additionally, we examined the cellular localization of transporters involved in Mn and B uptake through immunostaining and performed suberin staining to assess suberin deposition. Under Mn-limited conditions, the knockout of *OsCASPI* resulted in chlorosis in new leaves, which was associated with reduced Mn uptake. Conversely, under high Mn concentrations, the *oscasp1* mutants exhibited increased Mn uptake. Similarly, under B-limited conditions, the *oscasp1* mutants displayed chlorosis in new leaves and reduced B uptake, while under high B concentrations (300 μ M), B uptake was enhanced. We observed that the knockout of *OsCASPI* did not alter the cell-specific localization of key transporters, including *OsNramp5* and *OsMTP9* for Mn uptake, and *OsLsi1* and *OsBOR1* for B uptake. These transporters were polarly localized at the distal side (*OsNramp5* and *OsLsi1*) and proximal side (*OsMTP9* and *OsBOR1*) of both the exodermis and endodermis. While there was no difference in the protein abundance of these transporters at the exodermis between the *oscasp1* mutants and WT, their abundance was significantly reduced at the endodermis in the mutants. Furthermore, we found that overaccumulation of suberin at the endodermis of the *oscasp1* mutants suppressed the expression of the four transporters. Transporter expression was only detected in endodermal cells without suberin deposition and was absent in cells with suberin deposition. Collectively, our findings demonstrate that the CS plays a dual role in Mn and B uptake: (1) it maintains the normal expression of transporters under Mn- and B-limited conditions, and (2) it prevents the diffusion of Mn and B into the stele under high Mn and B conditions.





THEME 4 SMARTROOT: ROOT ARCHITECTURE AND PLASTICITY TRAITS FOR N-EFFICIENT BARLEY VARIETIES

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Increased nitrogen (N) use efficiency (NUE) is key to stabilize crop yields under the challenging conditions imposed by climate change and more restrictive fertilization policies. Although root systems are key for N acquisition, root architectural traits and root plasticity are still rarely considered in breeding programs. To investigate the potential of root traits in increasing NUE, we used the automated root phenotyping platform of IPK's PhenoSphere to track the dynamic responses of barley roots to limited N and to placed N fertilizer (labelled with ¹⁵N) in a genetically diverse panel comprised of 200 genetic resources (GR) and 40 cultivars. Daily imaging over a period of up to 40 days and the analysis of more than 25,000 root images with a newly developed deep-learning based root segmentation and classification method, revealed significant variation in growth trajectories and developmental outputs as roots grew through low-N soil or encountered the placed N fertilizer. Compared to cultivars, the GRs exhibited significantly higher variation and maximum values for seminal root depth, total root length within the N patch and shoot ¹⁵N concentration. Additionally, these two root traits exhibited a strong positive correlation with shoot N and ¹⁵N concentrations, suggesting that there is great potential to improve these plastic root traits and NUE in modern cultivars. The most obvious plastic response induced by N was a highly-localized branching of roots contacting the N fertilizer, the extent of which varied significantly among the assessed genotypes. Using genome-wide association studies, over 50 QTLs for root architectural and plasticity traits contributing to NUE were identified. Genes related to N uptake, N assimilation, seminal root elongation and lateral root development were selected as candidates. These candidates are being prioritized by RNA-seq across contrasting genotypes and validated by phenotyping mutants or CRISPR-Cas9-generated knockout lines. Alleles improving root-soil contact and NUE will be selected and introduced into modern cultivars.





THEME 4 ROOT CARBOXYLATE-EXUDATION PHOSPHORUS-MINING STRATEGIES AND TRAIT DIVERSIFICATION OF EUCALYPTI FORESTS IN GLOBAL BIODIVERSITY HOTSPOTS IN SOUTH- WESTERN AND SOUTH-EASTERN AUSTRALIA

Li Yan (China)¹; Xiao Wang (China)²; Shutong Liu (China)¹; Dan Tang (China)¹; Clément E. Gille (France)¹; Patrick E. Hayes (Australia)¹; Francis J. Nge (Australia)³; Erin I.E. Rogers (Australia)⁴; Ian J. Wright (Australia)⁴; Kosala Ranathunge (Germany)¹; Patrick M. Finnegan (Australia)¹; Marion Cambridge (Australia)¹; David S. Ellsworth (Australia)⁴; Hans Lambers (Australia)¹

1 - University of Western Australia; 2 - Shandong University; 3 - Botanic Gardens of Sydney; 4 - Western Sydney University

Australia's severely phosphorus (P)-impoverished soils have driven extraordinary evolutionary innovations in plant nutrient acquisition, exemplified by non-mycorrhizal species from families like Proteaceae and Cyperaceae, which release root carboxylates that mobilise poorly-available soil P. In contrast, the P-acquisition strategies of mycorrhizal species in the dominant family Myrtaceae—including ecologically pivotal eucalypts (genera *Angophora*, *Blakella*, *Corymbia* and *Eucalyptus*), remain poorly understood, despite their prevalence in P-limited ecosystems. This knowledge gap limits our ability to predict how these foundational taxa sustain populations and diversity in nutrient-impoverished landscapes. Here, we investigated carboxylate-linked P-mining mechanisms in Australian eucalypts, using leaf manganese concentration ([Mn]) as a proxy for carboxylate exudation in the field, and evaluated trait diversification across genera to unravel their ecological success.

We conducted field surveys in two global biodiversity hotspots—south-western and south-eastern Australia, by collecting leaves and soils from 98 eucalypt species at 72 sites spanning diverse habitats and soil P concentrations. Leaf [Mn], total [P], and stable isotope nitrogen and carbon ($\delta^{15}\text{N}$, $\delta^{13}\text{C}$) were analysed to assess nutrient-acquisition strategies and environmental adaptations. Complementing field data, we selected 10 representative eucalypt species for hydroponic experiments, quantifying root carboxylate exudation in nutrient solutions with 0.5 and 50 μM P.

Our findings reveal that high leaf [Mn] (a hallmark of carboxylate exudation) is widespread but not universal in eucalypts, with field [Mn] similar to those in non-mycorrhizal carboxylate-releasing Proteaceae. This challenges the paradigm that carboxylate-mediated P mining is restricted to non-mycorrhizal lineages, suggesting convergent evolution of this trait in mycorrhizal taxa. Hydroponic experiments confirmed significant root carboxylate release. Strikingly, interspecific variation in leaf [Mn] and [P] highlighted divergent strategies among genera such as *Angophora* and *Eucalyptus*, implying genus-specific trade-offs between carboxylate exudation and alternative P-acquisition mechanisms.

We conclude that root carboxylate exudation is a critical yet overlooked mechanism underpinning the dominance of mycorrhizal Myrtaceae in Australia's P-impoverished ecosystems. By mobilising soil P, carboxylates enable niche differentiation, evidenced by genus-level distribution patterns across Australia's edaphic gradients, and contribute to the family's remarkable biodiversity. These results redefine our understanding of plant-soil feedback in mycorrhizal systems, emphasising the synergy between carboxylate exudation and fungal partnerships in nutrient acquisition. Furthermore, linking leaf [Mn] to carboxylate release provides a scalable tool for predicting species' P-acquisition strategies in ecological surveys. Our work advances trait-based models of forest resilience, offering critical insights for conserving and restoring Australia's iconic ecosystems under global change.



THEME 4 **WATER AND NITROGEN TREATMENTS SHAPE GRAPEVINE RESPONSES ACROSS DEVELOPMENTAL STAGES**

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Water and nutrient availability strongly influence grapevine yield and wine quality, thus developing strategies towards an improvement of both water and nutrient use efficiency is crucial for sustainable production. The isohydric or anisohydric behavior of grapevine influences plant resilience to water stress. Moreover, the interaction between water deficit and nutrient deficiency effects is still poorly understood.

This study aims to assess the combined effects of water and nitrogen (N) availability in two grapevine cultivars with different sensitivities to water stress. Two-year-old Cabernet Sauvignon (near-anisohydric/S.O.4.) and Grenache (near-isohydric/S.O.4.) plants were grown in 20L soil pots under semi-environmental conditions. Plants were either maintained well-watered or subjected to a water deficit irrigation and treated with different N fertilization doses.

Morpho-physiological measurements revealed that water deficit significantly reduced plant growth, with Grenache exhibiting a slower growth rate compared to Cabernet Sauvignon, confirming its isohydric tendency to conserve resources. Notably, the response of Cabernet Sauvignon to water and N limitations showed seasonal variation, both at the physiological and nutritional level. Water treatment was the dominant factor in modulating plant response at flowering stage. Water deficit reduced stomatal conductance (gs), thereby increasing water-use efficiency, while enhancing the concentration of several nutrients, likely due to a reduced dilution effect compared to well-watered plants. Conversely, the physiological response and the nutrient composition at the maturity stage were strongly modulated by N fertilization. The higher N supply led to a decrease in gs and in the concentration of key elements such as potassium, phosphorous, and sulfur, highlighting the interconnected nature of nutrient metabolism.

To identify marker genes linked to the different Cabernet Sauvignon and Grenache behaviors, leaf transcriptomic analyses through RNAseq are ongoing. Data integration of analyses referred to flowering, veraison, and maturity stages will help to clarify the molecular bases of water resilience in grapevine. These results will contribute to clarifying the interplay between water and nitrogen availability in grapevine to improve strategies for sustainable viticulture.

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THEME 4 CONTRASTING PHOSPHORUS-MINING STRATEGIES: BIOMASS INVESTMENT IN COMPOUND CLUSTER ROOTS VS. EFFICIENCY OF SIMPLE CLUSTER ROOTS IN SEVERELY PHOSPHORUS-IMPOVERISHED ENVIRONMENTS

Hirotsuna Yamada (Japan)¹; Clément E. Gille (Australia)²; Pallavi (Australia)²; Li Yan (Australia)²; Gareth Nealon (Australia)³; Jun Wasaki (Japan)¹; 4; Erik Veneklaas (Australia)²; Hans Lambers (Australia)²

1 - Graduate School of Integrated Sciences for Life, Hiroshima University; 2 - School of Biological Sciences, University of Western Australia; 3 - Centre for Microscopy, Characterisation and Analysis, and the School of Molecular Sciences, University of Western Australia; 4 - Seto Inland Sea Carbon Neutral Research Center, Hiroshima University

INTRODUCTION

Proteaceae and Fabaceae naturally occur on severely phosphorus (P)-impoverished soils, such as those in biodiverse shrublands of south-western Australia. Some of them produce distinct cluster roots (CRs), which have many dense short rootlets along lateral roots and abundant root hairs. Two types, compound and simple CRs have been identified based on their morphology (Lamont et al., 2002). While both types enhance P acquisition via carboxylate exudation (Lambers et al., 2008, 2018), their difference in P-mining strategies remains unexplored. Here, we address this gap in knowledge by combining field and glasshouse experiments.

METHODS

We designed a glasshouse experiment using eight species in three groups: *Daviesia physodes* (Fabaceae; compound CRs), *Banksia attenuata*, *B. nivea*, and *B. sessilis* (Proteaceae; compound CRs), and *Hakea erinacea*, *H. prostrata*, *H. trifurcata*, and *Grevillea vestita* (Proteaceae; simple CRs). After six months of cultivation in pots using P-poor soil, we determined CR biomass, rhizosheath soil amount, the concentration of total P and organic P compounds in the rhizosheath soil and bulk soil using ³¹P-NMR spectroscopy. We also collected mature leaves of 15 CR-producing species and related reference species in the field to measure manganese concentration which is as a proxy for rhizosphere carboxylate concentration (Hayes et al., 2014 and Lambers et al., 2015, 2021).

RESULTS AND DISCUSSION

Daviesia physodes produced a significantly lower amount CRs than Proteaceae, resulting in the lowest net P-absorption ability. *Banksia* species produced a greater amount of CRs per whole root system and consistently accumulated more manganese in their leaves in the field. On the other hand, *Hakea* and *Grevillea* species invested less in CRs but held three times as much soil per unit CR biomass. However, both *Banksia* and *Hakea* species significantly decreased common soil organic P pools in the rhizosphere: α-glycerophosphate and adenosine 5'-monophosphate, compared with the rhizosheath soil. Additionally, the rhizosheath of all species was significantly depleted in the “unavailable P” pool that is not extractable with NaOH-EDTA.

CONCLUSIONS

We highlighted the high investment in compound CRs maximizing net absorbed P, while high P-acquisition efficiency in simple CRs despite lower CR proportion, achieved by maintaining similar rhizosheath soil amounts as compound CRs. Both types of CR access common P pools. Furthermore, CRs might have a distinct mechanism to access “unavailable” P pools. By linking CR morphology to functional outcomes, this work advances our understanding and predictive framework for nutrient cycling in nutrient-imp





THEME 4 THE EFFECT OF NITROGEN FERTILIZATION ON THE YIELD AND QUALITY OF SHELLY MANGO FRUIT

Nativ Rotbart (Israel)1; Mery Dafny Yelin (Israel)2; Noam Alkan (Israel)3; Liora Shaltiel-Harpaz (Israel)2; Eyal Nevo (Israel)1; Yohanan Mertzbach (Israel)1; Shay Tzaidi (Israel)4; Carmit Sofer-Arad (Israel)4

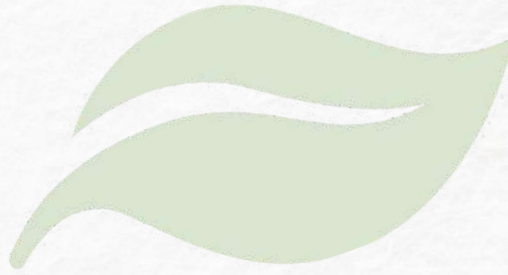
1 - 1. Shamir Research Institute, University of Haifa; 2 - Northern Research and Development, Migal; 3 - Agricultural Research Organization, Volcani Institute; 4 - Extension Service, Ministry of Agriculture and Food Security

Nitrogen fertilization plays a crucial role in vegetative growth, photosynthesis, water-use efficiency, fruit quality, and skin color of mango trees. It also significantly influences disease susceptibility and pest attraction in mango orchards. This study, conducted over three years in a 'Shelly' mango orchard near the Sea of Galilee, and aims to optimize fruit size and yield while maintaining postharvest quality, reducing fertilization, and minimizing environmental contamination.

The study examined the effects of different nitrogen fertilization regimes—including varying application rates (0–200 kg/hectare), nitrogen sources, and fertilization timing—on fruit yield, disease occurrence, pest populations, and fruit quality. Results indicate a strong correlation between nitrogen application levels and soil nitrate concentrations. Ammonium-based fertilization led to higher soil nitrate accumulation than nitrate-based treatments, suggesting increased leaching and nitrification activity. A polynomial relationship ($R^2 = 0.88$) was observed between total soil nitrogen and fruit nitrogen absorption, peaking at 25 mg/kg soil nitrogen. Notably, fruit nitrogen content decreased significantly from 120 to 0 kg/hectare, with no additional uptake beyond 120 kg/hectare.

Despite variations in nitrogen levels, total nitrogen removal via fruit tissues (peel, pulp, and seed) remained statistically unchanged, confirming a saturation curve for nitrogen uptake. Excessive nitrogen application did not enhance yield but negatively impacted fruit quality, increasing postharvest decay and jelly seed. The optimal nitrogen application range for balancing yield, quality, and disease susceptibility was between 50 and 120 kg/hectare. Higher fertilization levels were associated with increased (i) incidence and severity of Powdery mildew in inflorescences ($R^2 > 0.85$), (ii) Botryosphaeria disease in tree skeletons ($R^2 > 0.8$) and in the fruit (iii) Jelly seed disorder after storage in the 200 kg/hectare treatment, (iv) Side and stem end rots in fruit, with lowest infestation at 50 kg/hectare of nitrogen and highest at 200 kg/hectare. Pest infestation at harvest, including mango aphids and branch dieback, remained low, though trends indicated cleaner fruit at lower nitrogen levels. Red aphid (*Aonidiella aurantii*) presence was significantly higher at 120 kg/hectare applied throughout the year. Apart from the red aphid, nitrogen source and distribution timing had no significant effect on pest or disease susceptibility. These findings highlight the importance of precision fertilization and nitrogen management in mango orchards to optimize yield and fruit quality while minimizing disease pressure, pest attraction, and environmental impact.





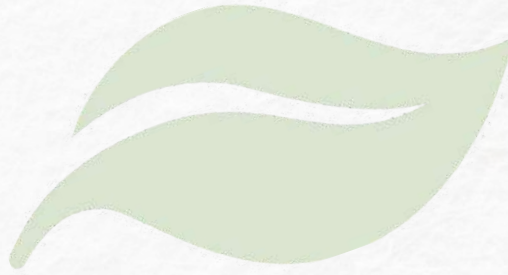
THEME 5 COMPREHENDING SILICON-MEDIATED DROUGHT STRESS TOLERANCE IN BARLEY

Gabriel de Oliveira Ragazzo (Germany)¹; Nicolaus von Wirén (Germany)¹

¹ - Leibniz Institute of Plant Genetics and Crop Plant Research (IPK)

Silicon (Si) is the most abundant mineral element in the earth's crust. While Si is present in diverse forms in the soil, only mono-silicic acid is taken up by plant roots. Most crops, including barley, take up Si by a specific aquaporin-type influx channel called Low silicon 1 (Lsi1) or Nodulin 26 Intrinsic Protein 2.1 (NIP2.1), which allows to permeate Si across the plasma membrane of outer root cells. Other Si transporters (Lsi2 and Lsi3) mediate efflux of Si from endodermal or pericycle cells towards the xylem for root-to-shoot translocation by mass flow with the transpiration stream. Si is known to promote growth and alleviate biotic and abiotic stresses, including drought. While the precise underlying mechanisms remains unclear, the hypothesis has been raised that water binding by Si in soils is as important as in plant tissues. To address this hypothesis, we investigated the role of Si in enhancing drought tolerance in barley and CRISPR-generated *lsi1* and *lsi1/lsi2* knock-out mutants. Plants were grown in soil substrate with or without Si fertilization for 21 days under optimal conditions, followed by 14 days of drought stress. Only wild-type plants accumulated Si in their shoots (1.0-1.5% of shoot dry weight) and, under drought, exhibited increased biomass, plant height, and tiller number than the mutants. Si-fertilized wild-type plants also maintained higher relative water content in drought-stressed leaves, whereas mutants showed no such response. Moreover, Si-treated wild-type plants exhibited lower abscisic acid (ABA) levels under drought, suggesting involvement of Si in modulating ABA and drought stress signaling. RNA-seq analysis revealed upregulation of water transport genes and downregulation of ABA-responsive genes in response to Si. These findings highlight that Si accumulation in plant tissues is crucial for drought tolerance in barley, and that the water-binding capacity of Si in the soil alone is not sufficient to confer this tolerance.





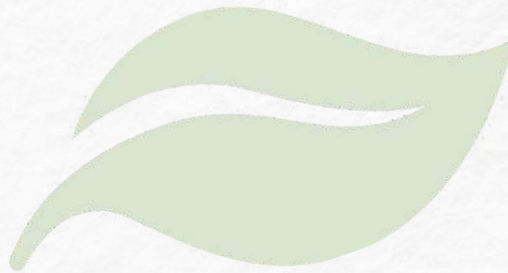
THEME 6 **QUANTIFYING OIL PALM NUTRIENT REQUIREMENTS ACROSS DIFFERENT YIELD POTENTIAL**

Rana Farrasati (Indonesia)1; Ya Li Lim (Malaysia)2; Walter Carciocchi (United States)2; Christopher Donough (Malaysia)2; Hendra Sugianto (Indonesia)2; Tiemen Rhebergen (Australia)3; Shamie Zingore (Morocco)4; Thomas Oberthur (Germany)4; Asad Ata (Malaysia)5; Simon Siburat (Indonesia)6; Philip Ho Vun Vui (Malaysia)6; Dwi Asmono (Indonesia)7; Ruli Wandri (Indonesia)7; Juan Pablo Monzon (United States)2; Hafiz Ikham Osman (Malaysia)5; Noto Edy Prabowo (Indonesia)8; Siti Mashilah Binti Abd Malik (Malaysia)9; Rolf Hårdter (Germany)10; Patricio Grassini (United States)2

1 - Indonesian Oil Palm Research Institute; 2 - University of Nebraska-Lincoln; 3 - CSIRO/IPNI; 4 - APNI (African Plant Nutrient Institute); 5 - Asia School of Business; 6 - Wilmar International; 7 - Sampoerna Agro; 8 - Hasnur Group SBU Agri; 9 - KLK Sawit Nusantara Berhad; 10 - K+S KALI GmbH

Oil palm (*Elaeis guineensis* Jacq.) is the main source of world vegetable oil which cultivated in million hectares cropland across Southeast Asia, Sub-Saharan Africa, and Latin America. Despite the high annual potential yield of 30-40 t ha⁻¹, yield improvement remain stagnant with global average only reached half of potential. Recent yield gap studies highlighted nutrient limitations as one of the major constraint for smallholders and large plantation. This study explored the relationships between oil palm yield, nutrient uptake, estimate the associated internal physiological efficiency, and develop robust models to inform nutrient input requirements for a given yield target. We used extensive dataset from 2000-2022 with wide range of yield and environments from Southeast Asia and West Africa, focusing on N, P, K, Mg nutrient. Linear and spherical models were evaluated and the one with highest predictive power was chosen. The highest N accumulation found in fronds, while K, P and Mg in bunch (105.9, 91.5, 10.3, 15.2 kg ha⁻¹ y⁻¹). Across all sites, the average yield is 20 t ha⁻¹, the highest average nutrient harvest index (NHI) were found in P, Mg, K, and N with (0.40, 0.35, 0.30, and 0.22 kg kg⁻¹, respectively). As crop yields increase, there is a noticeable decline in nutrient internal efficiency (NIE) once the yield exceeds 75% of the potential yield for a given environment. Considering this yield level as a target, to reach 75% of yield potential in a hypothetical environment with yield potential of 40 t ha⁻¹ would require 142 (N), 16 (P), 178 (K), and 22 (Mg) kg ha⁻¹. The spherical model provides a more broadly applicable approach across different fields, making it a preferable choice for estimating the fertilizer inputs needed to achieve a desired yield target based on the maximum potential yield of that particular field or growing environment.





THEME 6 **LOW-MOLECULAR-WEIGHT ORGANIC COMPOUND RESEARCH IN FUKUSHIMA**

Marcel Pascal Beier (Japan)¹; Nuanon Nobchulee (Japan)¹; Naoto Nihei (Japan)¹; 2

1 - Fukushima Institute for Research, Education and Innovation, Soil and Plant Multi-Dynamics Research Unit; 2 - Fukushima University, Faculty of Food and Agricultural Sciences

Soils, which form the basis of agriculture, are being degraded worldwide due to excessive reliance on chemical fertilizers. In addition, due to the accident at TEPCO's Fukushima Daiichi nuclear power plant in 2011, the topsoil in Fukushima Prefecture has been stripped to remove radioactive substances, and soil preparation (restoration of the crop soil layer) is required to resume agriculture in this area.

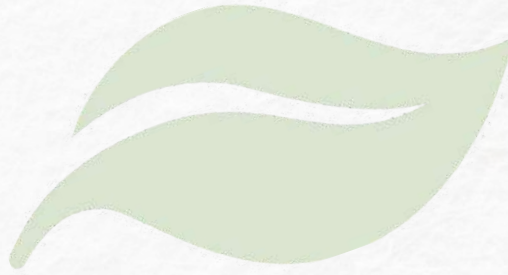
In April 2024, the Fukushima Institute for Research, Education and Innovation (F-REI) was established as a center for strengthening scientific and technological capabilities and improving the lives of residents for the reconstruction of Fukushima Prefecture. For this purpose, we started the Soil and Plant Multi-Dynamics Research Unit to analyze soil-plant interactions in the agricultural sector.

So far, soil fertility is assessed mainly by inorganic substance availability, such as nitrate and ammonia, but the scientific background for soil preparation is unclear, making it is necessary to rely on experience and intuition. In our research unit, we analyze factors that influence plant growth beyond inorganic matter with a focus on the total soil environment. This includes low-molecular-weight organic matter such as amino acids, sugars and organic acids, that are contained within soils and microorganisms.

Initially, the effects of different amino acids and sugars on root growth and root system development were examined under varying concentrations. The amino acids glutamine, asparagine and alanine affected root system development, while the sugar sucrose also had an effect on root hair growth and increased root diameter. Direct absorption was confirmed using isotopically labeled glutamine, and after absorption, glutamine-derived carbon and nitrogen were found to be metabolized to other amino acids. In the future, the value of low-molecular-weight organic matter as plant nutrient, especially under environmental stresses like light and temperature, and its relationship with microbial activity will be clarified. Furthermore, we will examine which soil management practices enable cultivation that makes the most of low-molecular-weight organic matter and micro-organisms.

The aim is to link our findings to grounded agricultural practices that don't rely on experience and intuition, and to provide a new axis for soil preparation evaluation in addition to inorganic substances.





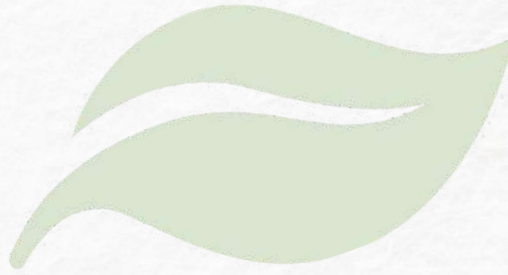
THEME 6 **INTERACTIVE EFFECTS OF NITROGEN, PHOSPHORUS AND SULFUR NUTRIENTS ON GROWTH, NUTRIENT UTILIZATION AND CROP PRODUCTIVITY**

Baoluo Ma (Canada)¹

¹ - Agriculture and Agri-Food Canada

Understanding of plant nutrient uptake and dynamics is a necessary step to develop site-specific, economically viable and environmentally responsible management practices. Field study data for canola (*Brassica napus* L.), oat (*Avena sativa* L.) and maize (*Zea mays* L.) were analyzed to determine plant dry matter (DM), yield and N, P and S uptake patterns. We found that i) balanced N and S applications increased both N and S use efficiency; ii) under hot and drought conditions, the yields of canola and oats decreased sharply regardless of fertilization; iii) relationship of lodging index and straw P was best-fit into a split-line model with a change-point of 13.6 kg P ha⁻¹, below which lodging rarely occurred; iv) canola seed accounted for 60-66% of total plant N and 59-63% of total plant P; and v) the highest yields of maize were achieved at approximately 201 kg ha⁻¹ of grain N and 255 kg ha⁻¹ of shoot N, corresponding to grain and shoot P of 36 and 43 kg ha⁻¹, respectively. Our data indicated that N, P and S uptake and their stoichiometry influence plant growth, nutrient utilization and final yield. Therefore, the application of balanced N, P and S fertilizers is critical to sustain crop production while minimizing negative environmental impacts.





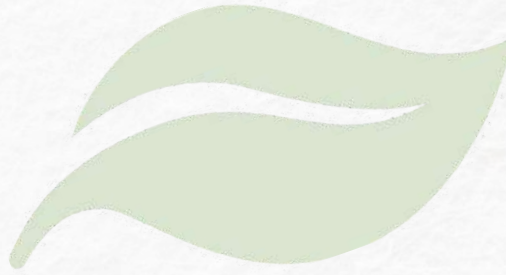
THEME 6 **CRF APPLICATION IN PLANTING HOLE AT INLAND HILLY AREA**

BERNARD KHOO HUANG CHAI (Malaysia)¹

¹ - Dr Sim Choon Cheak

Controlled release fertiliser (CRF) has been available on the market for years but have not yet been widely implemented under field conditions. Research indicates that CRF contribute to sustainability through their usage and release patterns. Consequently, CRF are being evaluated in the replanting process of oil palm plantations in hilly areas to assess their cost benefits and the physiological growth of immature oil palms. This experiment aims to determine the optimal CRF kg/palm/ha for supplementing nutrients (N, P, and K) to immature oil palm over 12 months in a field setting, particularly in hilly areas. It also seeks to reduce the use of tractors, diesel, and labour. Additionally, it will evaluate nutrient uptake efficiency by the palms and observe the release pattern to minimize fertiliser usage and nutrient loss. The experiment was conducted in a steep, immature planting area using Factorial Randomized Complete Block Design. Immature oil palm replanting coincided with CRF application at rates of 500g, 750g, and 1kg per palm. CRF was applied once a year into planting holes, compared to the common practice of using 5kg of compound fertiliser per palm. Data on vegetative measurements and foliar analysis was collected biannually, and the replanting motion study was recorded as well. Findings indicate no significant difference in vegetative measurements at level (alpha) 0.05 for seven months post-planting. No significant differences were observed for all parameters in the main and interaction factors. Lab analysis data revealed no significant difference in elemental content, except for Boron and Magnesium in foliar samples. The fertiliser dosage had little effect on CRF application at both 6th and 12th months. Both CRF Agroblen and Proficote showed similar nutrient elemental levels in foliar, with notable differences only in Magnesium and Calcium. Control release fertiliser could replace compound fertiliser for young oil palms in hilly areas for first year planting. It improves nutrient uptake efficiency through its coating mechanism, reduces environmental impact from leaching, and eases labour productivity as well reduce the usage of diesel in the field thus contributing to sustainable farming practices.





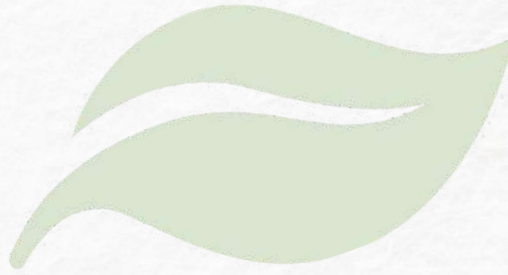
THEME 6 **GENETIC GAINS OVER FOUR DECADES IN MAIZE GRAIN YIELD AND KERNEL NUTRIENT CONTENTS UNDER NITROGEN-LIMITED CONDITIONS**

Raziel A. Ordóñez (United States)¹; Sotirios Archontoulis (United States)²; Slobodan Trifunovic (United States)³; Tony J. Vyn (United States)¹

1 - Purdue University; 2 - Iowa State University; 3 - Bayer Crop Science

Improving maize yields while ensuring nutritional quality is a critical challenge in breeding programs as increasing grain yield can compromise nutritional value. Although previous studies have shown positive maize yield gains over time under both limited and non-limited nitrogen (N) conditions, the impact of these yield improvements on grain nutritional levels and their interaction with N fertilizer remains poorly understood. Understanding this interaction is imperative to producing nutritious food and maintaining nutrient balance in maize production. Our study objectives were to quantify genetic gains (GG) in yield plus macronutrient (S, P, K, Ca, Mg) and micronutrient (B, Mg, Zn, Mn, Fe, Cu, Al) contents, and to investigate the relationship between harvest index (HI), nitrogen harvest index (NHI), and nutrient HI (NutHI) at physiological maturity in Bayer Crop Science legacy hybrids. Grain nutrients were analyzed in 38 commercial maize hybrids, released between 1983 and 2020 in the US Corn Belt with nearly identical maturity groups. Yield was measured in all hybrids at two locations (Jerseyville, Illinois, and Lebanon, Indiana), while aboveground biomass was measured in a subset of 23 hybrids in 2021, representing both old and modern hybrids. The study spanned two years (2021 and 2022) and two N rates (45 kg N ha⁻¹ as Low-N in both years, and 205 and 246 kg N ha⁻¹ in 2021 and 2022, respectively, as High-N). A split-plot design was used, with main plots assigned to N rates and subplots to hybrids. Our results show no decline in nutrient concentrations over time for macronutrients P and Ca, or for micronutrients Mn, Fe, Al and Cu. The kernel contents of all macronutrients and micronutrients consistently increased with time. While occasional increases in grain nutrient concentrations under Low-N compared to High-N (e.g., P and K) were observed, these did not alter the overall trends of increasing nutrient content due to yield improvements, plus consistently higher nutrient contents removed at High-N vs Low-N. Average NutHI at High-N was most improved for P and Fe, but was lower for Zn, Mn and Cu. Relationships of NutHI to NHI were consistently negative at High-N, but neutral to positive for all nutrients except Fe at Low-N levels. Although increasing maize NHI is a desirable outcome in terms of N fertilizer balance, genetic gains in NHI were generally accompanied by lower NutHI at High-N and little to zero NutHI gain for nutrients other than N at Low-N.





THEME 7 MANIPULATING ROOT AERENCHYMA FORMATION VIA OSRBOHH TO REDUCE ARSENIC ACCUMULATION AND METHANE EMISSION IN RICE

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¹ - College of Resources and Environmental Sciences, Nanjing Agricultural University, Nanjing 210095, China

Rice is typically grown under anoxic soil conditions, which leads to mobilization of toxic metalloid arsenic (As) and the production of the greenhouse gas methane. Rice is a major dietary source for As, and rice paddies are an important emission source of methane. Rice roots can release oxygen into the rhizosphere via the aerenchyma. We hypothesized that enhancing aerenchyma formation in rice roots may limit arsenic accumulation in rice grain and reduce methane emission. We used a root cortex specific promoter to over-express OsRBOHH, a respiratory oxygen burst homolog gene, in rice. Overexpression of OsRBOHH in root cortex significantly promoted aerenchyma formation and increased radial oxygen release from the roots, resulting in accelerated iron plaque formation on the root surface. Enhanced iron plaque formation provides a strong barrier for the uptake of arsenic, resulting in decreased arsenic accumulation in the shoots and grain. Methane emission was monitored at different growth stages in a pot and a field experiment. Overexpression of OsRBOHH significantly decreased methane emission compared with the wild type. In both pot and field experiments, grain yield and agronomic performance was unaffected by OsRBOHH overexpression. In summary, our study provides an important way to reduce arsenic accumulation in rice grain and greenhouse gas emissions from paddy rice.





THEME 7 EFFICACY OF LACTIC ACID FERMENTATION TO IMPROVE ZN, FE AND CA BIOACCESSIBILITY FROM PLANT-BASED FOODSTUFFS

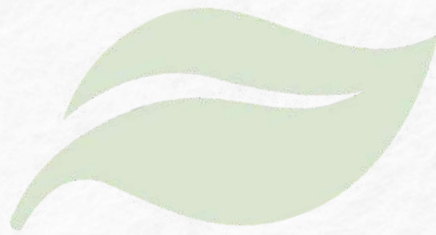
Paula Pongrac (Slovenia)¹; Maruša Ravnika (Slovenia)¹; Elizabeth H. Bailey (UK)³; Gregor Marolt (Slovenia)⁴; Polona Jamnik (Slovenia)¹

1 - Biotechnical Faculty, University of Ljubljana, Ljubljana; 2 - Jožef Stefan Institute, Ljubljana; 3 - School of Biosciences, Sutton Bonington Campus, University of Nottingham, Loughborough, Leicestershire, UK; 4 - Faculty of Chemistry and Chemical Technology, University of Ljubljana, Ljubljana

Plant-based foodstuffs are regarded as poor sources of Zn, Fe and Ca because they contain the so-called antinutrients, which efficiently bind essential elements in plant tissues. The most abundant antinutrients are phytic acid (in seed and grain) and oxalic acid (in leaves). Lactic acid fermentation is a promising food processing method in which bacteria may actively degrade antinutrients and hence improve the bioaccessibility of poorly available essential elements. To test the efficacy of lactic acid fermentation, three commercial flours (i.e. wheat, buckwheat and proso millet) were fermented using two lactic bacteria species, namely *Lactobacillus plantarum* or *L. brevis*. Initial Zn, Fe and Ca concentrations in raw flour samples and in fermented samples were measured with ICP-MS and their bioaccessible fraction was determined by the INFOGEST method. In addition, concentration of phytic acid, phosphate and oxalic acid was determined by ion chromatography. Flour of proso millet had higher bioaccessible amount (on average in mg kg⁻¹) of Fe (2.62) compared to buckwheat and wheat (1.56 and 1.30, respectively), with the opposite observed for bioaccessible amount of Ca, of which proso millet flour contained less than buckwheat and wheat flours (10.3, 24.2 and 23.7, respectively). By contrast, bioaccessible amount of Zn was higher in buckwheat flour (12.0) than in proso millet and wheat flours (2.93 and 2.19, respectively). There was a substantial decrease in phytic acid concentration due to fermentation, with *L. brevis* being slightly more effective compared to *L. plantarum*. Despite this significant decrease in phytic acid concentration, which was accompanied by an increase in phosphate concentration and no notable effect on oxalic acid concentration, there was only small increase in the bioaccessibility of the measured elements in fermented samples. There was an increase in bioaccessible amount of Ca from proso millet and wheat flours (to 18.7 and 28.8 for *L. plantarum* and to 15.6 and 29.4 for *L. brevis*, respectively) and for Fe in proso millet flour fermented with *L. brevis* (to 3.60). In terms of bioaccessible amounts of Zn, Fe and Ca, buckwheat flour was the least pliable substrate. These preliminary results indicate that lactic acid fermentation may be too species-specific, substrate-specific and element-specific to have applicative value in increasing the bioaccessibility of Zn, Fe and Ca from flours.

ACKNOWLEDGEMENTS: The work was supported by the Slovenian Research and Innovation Agency (ARIS) through research core funding no. P1-0212 and P1-0153, and project funding J4-3091 and N4-0346.





THEME 7 STRATEGIES FOR ENHANCING THE NUTRITIONAL VALUE OF PEAS FOR HUMAN CONSUMPTION – FERTILIZATION VERSUS GENOTYPE EFFECTS

Jens Axel Knuhtsen (Denmark)¹; Dorte Bodin Dresbøll (Denmark)¹; Conny Bruun Asmussen Lange (Denmark)¹; Kristian Holst Laursen (Denmark)¹

¹ - Department of Plant and Environmental Sciences, Faculty of Science, University of Copenhagen

Introduction: Enhancing the nutritional value of peas (*Pisum sativum* L.) for human consumption has traditionally focused on nitrogen fixation and the protein content. However, there has been limited research on plant nutrition and fertilization strategies for peas, targeting nutrients other than nitrogen.

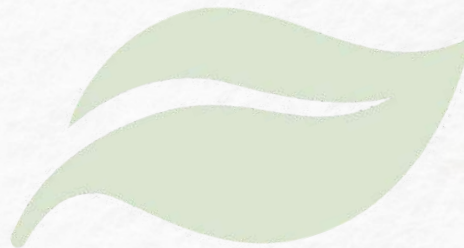
Purpose and aim: The overall aim of our study was to investigate methods to increase the nutritional value of peas for human consumption through genotype choice and fertilization strategy. The study aimed to increase the contents of iron (Fe), zinc (Zn), and sulphur (S) in two pea genotypes. The research questions were: i) do different pea genotypes respond similarly to fertilizer treatments, ii) can the content of Fe, Zn, and S be increased in the harvested product, and iii) can nutritional enhancement be obtained by both inorganic and organic fertilizers?

Methods: The two pea genotypes; cv. 'Ingrid' and the landrace 'Brunart fra Nakskov', are contrasting in morphology and origin, and both are currently used for food in Denmark. Both genotypes were fertilized with either an inorganic sulphur, phosphorus and potassium combination, an organic compost application or grown without soil amendments. Plants were grown to maturity under both field and greenhouse conditions. The peas were analysed with IR-MS and ICP-OES to reveal variation in yield, protein content, and nutrients including Fe, Zn and S.

Results: While the protein content of pea seeds in the field experiment only ranged from 17,6 to 24 % of dry matter (36% increase), the Fe content ranged from 20 mg kg⁻¹ to 64 mg kg⁻¹ (220% increase) and the content of S ranged from 1028 mg kg⁻¹ to 2014 mg kg⁻¹ (96% increase). Like Fe and S, the contents of Zn and calcium (Ca) showed large variation, while potassium (K), magnesium (Mg) and phosphorus (P) showed less or no variation. The contents of Fe, Zn and Ca were almost solely affected by genotype. Fe and Zn were highest in 'Brunart fra Nakskov', and Ca highest in 'Ingrid'. In contrast, S was highest following the inorganic fertilizer treatment regardless of genotype.

Conclusions: When considering the nutritional value of peas for human consumption, a narrow focus on yield and protein is inadequate. Instead, more emphasis should be placed on the content of plant nutrients. Depending on the element in question, either fertilizer strategy OR genotype choice is most important. This has implications for which route to take when planning for future, more nutritious plant-based food products.





THEME 7 HEALTH-PROMOTING PROPERTIES OF HIGH AMYLOSE NOVEL DURUM WHEAT MATERIALS AND DERIVED FOODS

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1 - Institute of Sciences of Food Production, CNR, Unit of Lecce, Italy; 2 - National Institute of Gastroenterology "S. de Bellis", Institute of Research, 70013 Castellana Grotte, Italy; 3 - University of Tuscia; 4 - University of Salento, 73100 Lecce

Whole wheat is a rich source of fibers and bioactive phytochemicals with health-promoting properties showing significant protection against chronic non-communicable diseases. There is evidence that wheat polyphenols are bioactive dietary agents able to prevent, delay, or even reverse chronic inflammation while supporting tolerance and tissue repair in a variety of inflammatory diseases, including intestinal disorders. In the present study we characterized the phenolic acid profile and health-promoting potential of a newly developed high-amylose durum wheat genotype, obtained by tilling from cv. Svevo and of Faridur, a durum wheat cultivar with soft kernel texture also derived from cv. Svevo by introgressing the wildtype Pina and Pinb from common wheat]. These materials and derived products were characterized through HPLC-DAD analyses to assess the phenolic acids profile and the associate antioxidant capacity (TEAC). The elevated content of amylose in Svevo HA induced an increase of polyphenol content and TEAC especially in semolina and bread compared to the same products derived from Svevo wild type.

To monitor health-related parameters in volunteers, two diets were compared: one including Svevo high amylose wheat-based foods (pasta: 100 g/die, crackers: 20 g/die and biscuits: 25 g/die), and a control diet including the same type and quantity of wheat-based foods but made with regular Svevo semolina. Both diets were tested in a clinical study over 12 weeks on two groups of subjects with low to moderate symptoms of chronic metabolic and inflammatory disease. The main inflammatory markers and metabolic parameters were monitored (i.e. cholesterol, triglycerides), together with the main gastrointestinal parameters at the start of the study and after 12 weeks.

The clinical study, still in progress, highlighted that high amylose diet was associated with a higher tendency to reduce circulating markers associated to metabolic syndrome including cholesterol, glycemia and triglycerides, together with the fat mass.

Another important result emerged by the study was related to the evacuation needs of IBD patients which is perceived as one of the major problems affecting patients' life quality. Our results clearly pointed out that the HA diet significantly reduced these parameters, which resulted in an improvement of the quality of life of the volunteers, as confirmed by no abandonment among the volunteers enrolled to follow the HA diet.





THEME 7 A QUANTITATIVE ANALYSIS OF THE SUFFICIENCY AND DIVERSITY OF NUTRIENT SUPPLY FROM PLANT-BASED FOODS IN CHINA

Wen-Feng Cong (China)¹; Yijun Li (Netherlands)²; 1; Johanna C Gerdessen (Netherlands)²; Tjeerd Jan Stomph (Netherlands)²; Anneleen Kuijsten (Netherlands)²; Sander de Leeuw (Netherlands)²; Shenggen Fan (China)¹; Wopke van der Werf (Netherlands)²

1 - China Agricultural University; 2 - Wageningen University

Introduction

The Chinese food system is characterized by a high consumption of animal-based products that is beyond the recommended level. The current food system is suboptimal from the view point of human health and environmental health. Increasing and optimizing the contribution of plant-based foods could improve nutrient provisioning to Chinese citizens and reduce environmental footprint, but an analysis is needed to clarify the contribution to nutrient provisioning of changes in the food supply system.

Purposes and aims

In this study, we analyse the contribution of plant-based foods to nutrient provisioning to the Chinese population by analysing the dietary energy and 17 nutrients derived from both plant-based and animal-based food sources from 1997 to 2018. The primary objective of this research is to evaluate the potential of plant-based food supply to meet nutrient needs in China.

Methods

We constructed bipartite networks that connect 24 crops from six crop categories (cereals, tubers, beans, fruits, vegetables, oil crops), along with animal-based products, to the supply of 17 nutrients and dietary energy to the Chinese population at both the national and provincial levels in China from 1997 to 2018. We calculated the coverage (supply/demand ratio) and source diversity (exponentiated Shannon entropy of sources) for each nutrient from plant-based and animal-based food sources. Nutrient supplies were categorized as insufficient, at-risk, or secure based on standard nutrient requirements captured in such metrics as estimated average requirement (EAR), recommended nutrient intake (RNI), and in the case of potassium adequate intake (AI) and in the case of energy the estimated energy requirement (EER).

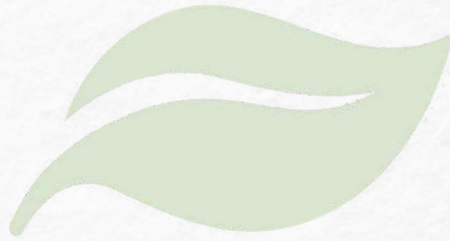
Results

Coverage was below one for calcium, selenium, riboflavin, and vitamin A, with source diversity below 4 for vitamins A and C. Minimal improvements were observed over time. Conversely, the supply of energy, protein, carbohydrates, dietary fibre, and nine other micronutrients was both sufficient and diverse. Transformations such as reducing avoidable nutrient losses, repurposing feed for food production through decreased red meat intake, and reallocating domestic crop use increased nutrient coverage by at least 19% on average across all nutrients, though source diversity remained largely unchanged.

Conclusions

Transitioning to more plant-based diets has the potential to enhance health outcomes and mitigate environmental impacts. However, the existing plant-based food supply in China faces challenges in fulfilling the comprehensive nutrient requirements. This study provides novel insights into strategies for enhancing micronutrient availability while reducing environmental strain through optimized plant-based food supply.





THEME 7 HOLLOW STEM FORMATION IN BROCCOLI: IMPACT OF LEVEL AND TIMING OF NITROGEN TOP-DRESSING

**Alexander Frieman (Germany)¹; Lea Wittmann (Germany)¹; Carsten Vorsatz (Germany)²;
Diemo Daum (Germany)¹**

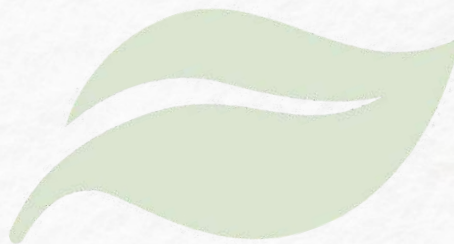
1 - University of Applied Sciences Osnabrück, Oldenburger Landstr. 24, 49090 Osnabrück; 2 -
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In broccoli cultivation, a considerable portion of the harvest can exhibit hollow stems. Severely affected lots are unsuitable for sale in the fresh market, leading to substantial food losses. The aim of an ongoing research project is to develop a cultivation strategy to prevent this physiological disorder. Preliminary studies have shown that high nitrogen fertilization promotes the occurrence of hollow stems. However, it is not yet known whether the temporal distribution of mineral nitrogen (N_{min}) availability in the soil during the cultivation period plays a role in this context.

To address this research question, a field trial was conducted with three fertilization levels (150, 225, and 300 kg N ha⁻¹) and two nitrogen top-dressing dates (cultivation week 4 and week 8). The broccoli variety 'Parthenon', which is known to be susceptible to hollow stems and widely used in cultivation, was selected. The growing period spanned from planting in late July to harvest in late October 2022 and was characterized by prolonged warm and dry weather conditions. At the end of the growing period, various parameters were determined, including the proportion of hollow-stemmed broccoli, stem width, head weight, and the N_{min} content in the soil.

At the common early nitrogen top-dressing date, the proportion of hollow-stemmed broccoli varied between 6 % (low soil N_{min} level) and 29 % (high soil N_{min} level). The intensity of hollow stem formation was strongly correlated with the head weight and stem width of the broccoli. A head weight of around 530 g and a stem width of 4.2 cm were identified as critical thresholds, beyond which the occurrence of hollow stems significantly increased. By shifting the fertilization date to the eighth week of cultivation, when the first flowers were visible, hollow stem formation could be almost completely prevented, regardless of the level of N_{min} availability. The timing of nitrogen fertilization had no effect on the head weight of the broccoli. However, at the lowest fertilization level of 150 kg N ha⁻¹, smaller heads were consistently harvested. The nitrate content in the soil at harvest was approximately the same across all treatments, reaching around 25 kg N ha⁻¹. By shifting the nitrogen top-dressing to the phase of highest nitrogen uptake, the risk of nitrate leaching during broccoli cultivation could potentially be reduced. Thus, the measure would positively impact both the marketability of the broccoli and the environmental sustainability of its cultivation.





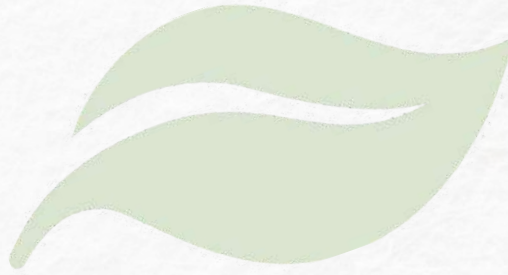
THEME 7 EFFECTS OF CONTRASTING PHENOLIC PEA GENOTYPES ON GUT FUNCTION: INSIGHTS FROM HUMAN IN VITRO GASTROINTESTINAL MODELS

**Rafael D. C. Duarte (Portugal)¹; Nelson M. Carvalho (Portugal)¹; Simão Pinho (Portugal)¹;
Pietro P. M. Iannetta (UK)¹; 2; Ana R. Madureira (Portugal)¹; Ana M. Gomes (Portugal)¹; Marta
W. Vasconcelos (Portugal)¹**

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Despite their potential benefits for human health and sustainable agriculture, pulses like peas (*Pisum sativum* L.) remain underutilized in European crop rotations (~4%). This limits their dietary value, highlighting the need to enhance their socioeconomic appeal. Peas are rich in dietary fiber and bioactive compounds, including phenolics, which influence gut microbiota composition, short-chain fatty acid (SCFA) production and fermentation dynamics. This study investigates how high- and low-phenolic pea genotypes, in whole grain and hull fractions (an industrial byproduct) affect gut microbial fermentation and metabolic outputs, offering insights into their role in functional foods and agroecological systems. Cooked pea samples, prepared to mimic typical consumption, underwent simulated gastrointestinal digestion (INFOGEST 2.0) followed by batch faecal fermentations. These fermentations were carried out in sealed anaerobic vessels at 37 °C with continuous mixing for a standardized period (48 h). Aliquots were collected at different time points (0, 6, 24, 48 h) to assess fermentation kinetics and metabolic shifts. Microbial composition shifts were analysed using high-throughput sequencing, while SCFA profiles- including acetate, propionate, lactate, and butyrate- were quantified. Results showed a significant increase in SCFA production, with phenolic content influencing the acetate-to-propionate ratio. High-phenolic samples favoured propionate production, potentially through selective inhibition of saccharolytic and proteolytic microbial groups. Notably, a dynamic cross-feeding mechanism between lactate and butyrate production was also observed. Lactate accumulated by 6 h, and then served as a substrate for butyrate-producing bacteria, leading to a subsequent increase in butyrate concentration by the end of the 48 h fermentation. Additionally, ammonia concentrations were measured to assess protein fermentation, as legume hulls have been suggested to modulate nitrogen metabolism by influencing microbial proteolytic activity, thereby shifting microbial metabolism towards carbohydrate fermentation. The findings provide new insights into the role of phenolics in modulating gut microbial communities, balancing saccharolytic and proteolytic processes, and influencing fermentation dynamics. By highlighting how different pea fractions and phenolic profiles influence microbial metabolism, this study contributes to the development of functional foods that support gut health, offering potential benefits for dietary strategies targeting gut microbiota modulation.





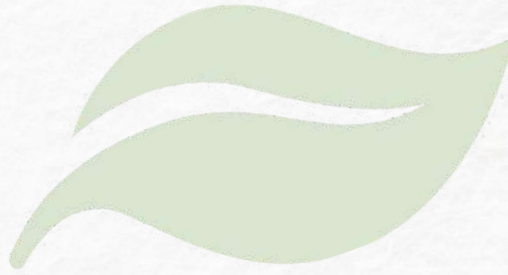
THEME 8 **BORON SUPPLY ALLEVIATES ALUMINUM TOXICITY-RESTRAINED POLAR AUXIN TRANSPORT AND PECTIN TRAFFICKING IN ROOT TRANSITION ZONE**

Lin Tao (China)¹; František Baluška (Germany)³; Shi Lei (China)⁴; Min Yu (China)¹

¹ - International Research Center for Environmental Membrane Biology & Department of Horticulture, Foshan University, Foshan 528000, China; ² - School of Environment and Energy, South China University of Technology, Guangzhou 510006, China; ³ - Institute of Cellular and Molecular Botany, University of Bonn, D-53115 Bonn, Germany; ⁴ - National Key Laboratory of Crop Genetic Improvement, Huazhong Agricultural University, Wuhan 430000, China

Boron (B) supply alleviates aluminum (Al)-induced root growth inhibition, as a result of reduced Al accumulation and amelioration of Al-induced decrease of rhizosphere pH based on auxin transport inhibition in the root apical transition zone, but the mechanisms remains elusive. Here, we used pharmacological, confocal imaging, immunolabelling, and molecular techniques to analyze the effects of B supply on the spatial-distribution of Al and its sequestration-dependent on pectin endocytosis in pea (*Pisum sativum* L.) roots, as well as polar auxin transport blocked by Al. Results revealed that Al preferentially accumulated in the cell walls of the epidermal and outer cortical cells, and B supply ameliorated the exocytosis of pectin and pectin methyl-esterases (PME), and transferred the cell-wall Al via the endocytosis of low-esterified pectin coupled with Al^{3+} toward the vacuoles, thus reducing Al accumulation in the root apical transition zone. Depolymerization of actin or tubulin filaments through latrunculin B or oryzalin, respectively, further confirmed that Al-inhibited low-esterified pectin endocytosis was dependent on actin but not tubulin. Co-localization of low-esterified pectin (labeled by anti-JIM5) and Al^{3+} (labeled by morin dye) revealed that the final destination of endocytic low-esterified pectin coupled with Al^{3+} was vacuoles which was promoted by B supply. Al stress increased the root apical auxin level, observed by *Arabidopsis* transgenic DII-VENUS and DR5rev::GFP lines, which was involved in the specific repression of PIN2 endocytosis caused by Al. Importantly, B supply efficiently promoted the recycling of endocytic PIN2 vesicles conjugated with IAA toward the outside of cells, finally alleviating Al-inhibited polar auxin transport from the transition zone to the elongation zone. Taken together, our results suggest B supply mediates PIN2 recycling to alleviate Al-inhibited polar auxin transport, and reduces Al accumulation in the transition zone via the regulation of pectin dynamics (biosynthesis, exoc





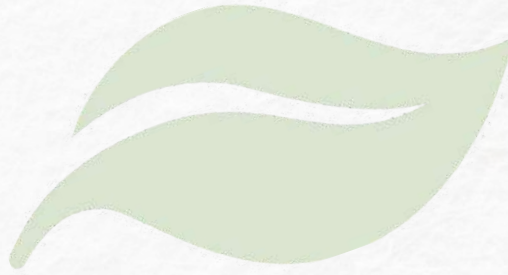
THEME 8 **ZFP36-CCAMK MODULE MEDIATED ARBUSCULAR MYCORRHIZAL SYMBIOSIS IN RICE**

Zhishan Guo (China)¹; Xinyi Luo (China)¹; Yibo Yang (China)¹; Jiayi Wu (China)¹; Yanshan Lu (China)¹; Yang Yang (China)¹; Junhuan Lv (China)¹; Hui Wang (China)¹; Lin Tao (China)¹; Min Yu (China)¹; Liping Huang (China)²

1 - Foshan university; 2 - Foshan University

Arbuscular Mycorrhizal Fungi (AMF) is favorable for plant growth and development and important for agricultural production. AMF complex is synergistically regulated by a variety of phytohormones. Melatonin, as a multifunctional molecule, is involved in the regulation of antioxidant defense, growth and development, and response to adversity in plants, which is precisely regulated by circadian rhythms, whether it plays a role in the establishment of symbiosis is unknown. In this paper, we investigated the effect of melatonin on AMF complex via a key transcription factor, ZFP36 via phenotypic analysis, RNA-sequencing, subcellular localization, yeast two-hybrid assay, fluorescent staining test, etc. The result revealed, (1) melatonin is participated in the AMF formation; (2) ZFP36 plays a role in melatonin-mediated AMF formation; (3) ZFP36 can interact with the protein UGT73C6; (4) ZFP36 influences the activity of CCaMK, which is a key role in AMF formation. Thus, our result showed ZFP36 plays a key role in melatonin-mediated arbuscular mycorrhizal symbiosis.





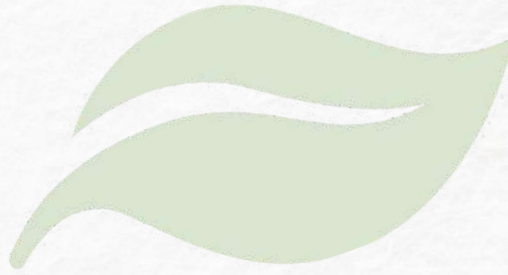
THEME 8 THE ROLE OF MINERAL NUTRIENTS (MAGNESIUM, IRON, SULFUR) IN SYMBIOTIC NITROGEN FIXATION

Zhi-Chang Chen (China)¹

¹ - Institute of Soil Science, Chinese Academy of Sciences

Symbiotic nitrogen fixation between legume plants and rhizobia provides a natural and sustainable nitrogen source in agriculture. The nutrient exchange between legumes and rhizobia forms the foundation of symbiotic nitrogen fixation. However, besides providing the carbon source required for nitrogen fixation, plants also need to supply essential mineral nutrients for rhizobial growth. Deficiency in mineral nutrients can impede root nodule development and decrease nitrogen fixation capacity. However, the specific roles of these mineral nutrients in symbiotic nitrogen fixation are not well understood. In soybean root nodules, we discovered that magnesium accumulates in the inner cortex of nodules primarily through the magnesium transporters MGT4/5. This magnesium, by regulating plasmodesmata permeability, controls the carbon-nitrogen exchange in nodules. Iron accumulates in the symbiosome of nitrogen-fixing zone primarily through the iron transporter VTL1a, where it serves as a component of nitrogenase, facilitating nitrogen fixation. Under iron-deficient conditions, soybeans can enhance iron transport from uninfected cells to infected cells through NRAMP2, meeting the iron demands of symbiotic nitrogen fixation. Sulfur accumulates in the nitrogen-fixing zone of nodules primarily through the sulfur transporters SULTR2.1 and SULTR3.5, and this sulfur is crucial for nodule redox balance. Insufficient sulfur in nodules leads to symptoms such as green nodules and premature senescence. In summary, our research reveals the transport processes and functional roles of mineral elements (magnesium, iron, sulfur) in nodules, providing a theoretical basis for efficient nitrogen fixation in genetic improvement efforts.





THEME 8 OMICS BASED APPROACHES TO DECIPHER THE ROLE OF IRON IN PLANT NUTRITION & IMMUNITY UPON TOBRFV INFECTION IN SOLANUM LYCOPERSICUM L.

Aditi Padmakar Thakare (Italy)¹; Maria Cristina Della Lucia (Italy)¹; Chandana Mulagala (Italy)¹; Giovanni Bertoldo (Italy)¹; Massimo Cagnin (Italy)¹; Piergiorgio Stevanato (Italy)¹

¹ - DAFNAE, University of Padova

The Tomato Brown Rugose Fruit Virus (ToBRFV) is a pathogen that mostly affects plants from the Solanaceae family. This virus wreaks havoc by severely affecting the yield of tomato (*Solanum lycopersicum* L.) plants and nutritional profile, thus creating an urgent need to research the basis of resistance to manage the disease. To understand the molecular basis of resistance, we employed omics-based approaches involving leaf ionomics and transcriptomics to help us decipher the interaction between elemental and nutritional composition and investigate its effect on the gene expression profile upon the ToBRFV infection in tomatoes. Ionomics was used to investigate the accumulation of trace elements in leaves, showcasing that the plants resistant to the virus had significantly higher concentrations of iron (p-value = 0.039) and nickel (p-value = 0.042) than the susceptible ones. By correlating these findings with transcriptomics, we identified some key genes involved in iron homeostasis and abscisic acid pathways, potentially responsible for conferring resistance against the pathogen. The role of iron in plant nutrition and immunity influences the activity of receptors involved in pattern recognition receptors (PRRs) triggering the immune response, while also promoting reactive oxygen species (ROS) and a hypersensitive response (HR). From the obtained list of differentially expressed genes, a panel of mutation profile was discovered with three important genes - Solyc02g068590.3.1 (K⁺ transporter), Solyc01g111890.3.1 (LRR), and Solyc02g061770.4.1 (Chitinase) showing persistent missense mutations. We ascertain the role of these genes and establish their association with plant resistance using genotyping assays. These findings showcase an example on how factors responsible for plant nutrition and genetics work in a conjoint manner to confer resistance against invasive pathogens.





THEME 8 PLANT NUTRIENT ELEMENTS DEFINED FROM PLANT'S AND FARMER'S PERSPECTIVE

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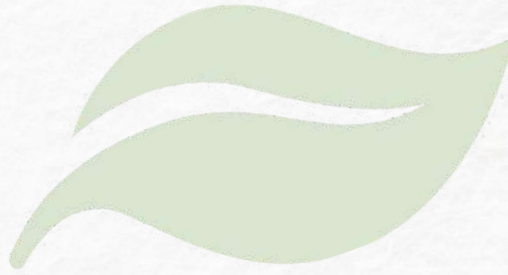
The search for and identification of plant nutrient elements has been the focus of plant nutrition research for ages. Widely accepted was the definition of Arnon and Stout (1939) according to which a nutrient element (e.g. P, while the term nutrient refers to the plant-available form, e.g. HPO_4^{2-}) to be considered essential must (1) be necessary for the completion of the plant's life cycle, (2) cause a specific deficiency that cannot be overcome by other elements, and (3) participate directly in plant metabolism. However, although criterion 1 was often considered more critical than the others (e.g. B, Ni), and in view of remaining candidate elements being ultra-trace nutrients, induction of significant growth impairments by their absence should satisfy criterion 1. Furthermore, it is generally accepted that essentiality should only be spoken of if the three criteria apply to all plants. In addition, Arnon and Stout (1939) already pointed out that there may be minerals that do not fulfil these three criteria but can be growth-promoting. In the plant nutrition literature, this heterogeneous group of elements, usually not covered by the term 'nutrient element', is mostly referred to as 'beneficial elements' (e.g. Si, Na, Co, Se, or Al).

To allow agriculture to benefit from our improved understanding of plant nutrition under various conditions, Brown et al. (2022) proposed expanding the concept of plant nutrients to include both the classically essential and the beneficial elements. Their proposal even explicitly covers elements improving quality attributes of harvested products. However, including quality, understood as 'the totality of features of a product that bear on its ability to satisfy given needs', in the proposed definition leads to uncertainty as to what a plant nutrient represents. For example, enriching crops with Cd and Cr, considered ultra-trace nutrients in human nutrition, using contaminated fertilisers could be considered biofortification.

Furthermore, levelling off the difference between nutrients in human and animal nutrition (organic compounds) and those of plant nutrients (minerals) as proposed by Brown et al. (2022) would deny the unique position of photoautotrophic plants converting inorganic into organic matter.

Putting the plant's and farmer's perspective centre stage, the following revision is proposed: A plant nutrient element is an element (1) that significantly improves growth or development of certain plant species when grown in their natural or cultivated environments, (2) whose deficiency cannot be overcome by other elements, and (3) whose function in plant biology has been established.





THEME 8 CHALLENGES AND PROSPECTS FOR NEXT-GENERATION ENHANCED EFFICIENCY FERTILIZERS

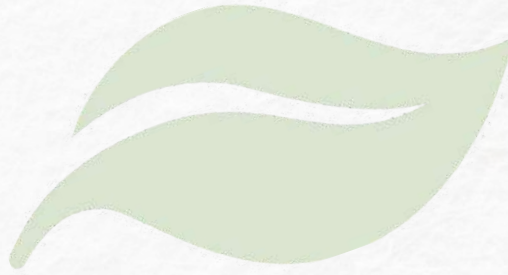
Prof Deli Chen (Australia)¹; A/Prof Shu Kee Lam (Australia)¹; Prof Helen Suter (Australia)¹

¹ - School of Agriculture, Food and Ecosystem Sciences (SAFES), Faculty of Science, The University of Melbourne

In the context of a growing global population, the increased reliance on synthetic nitrogen (N) fertilizers for global food production appears inevitable. Unfortunately, nearly half of the applied fertilizer N in agricultural systems is lost to the environment, posing significant threats to human health, environmental quality, and ecosystem services. Enhanced efficiency fertilizer (EEF) technology offers promise in mitigating N losses to the environment. EEFs regulate N release based on external stimuli (controlled-release fertilizers) and inhibit enzyme activities involved in processes that lead to N losses (urease and nitrification inhibitors). This presentation will explore the current limitations of EEFs and underscore the pressing need for breakthroughs in EEF development. Achieving this goal demands collaborative research efforts across multiple disciplines, including agronomy, soil science, synthetic chemistry, chemical engineering, plant physiology, and plant biochemistry. We argue that recognizing and quantifying the social costs avoided through EEF adoption are imperative to incentivize the use of innovative N fertilizers. This approach will not only prevent substantial expenditures on N pollution mitigation but also ensure global food security.

The Smart Fertilisers Research Hub, funded by the Australian Government, industry partners and universities, aims to enhance fertilizer use efficiency by at least 20% through the creation of next-generation smart, cost-effective fertilizers tailored to diverse soils, crops, and climates. This involves integrating new insights on inhibitors and fertilizer coatings, soil microbiome-plant interactions, and forming close partnerships with industry experts, farmers, and agribusinesses. A promising new class of nitrification inhibitors and engineered coatings has emerged from the efforts of the Hub.





THEME 9 **PLANT BIOSTIMULANTS: REVISITING PLANT NUTRITION**

Patrick du Jardin (Belgium)¹

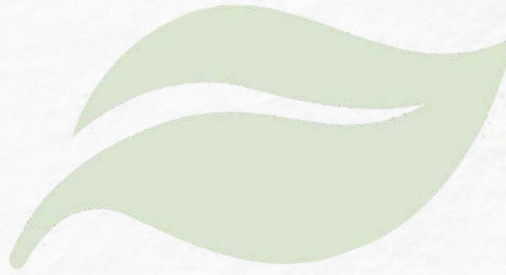
¹ - Gembloux Agro-Bio Tech, University of Liège

Plant biostimulants are increasingly adopted worldwide, covering substances and microorganisms applied to crop plants with the aim of improving nutrition efficiency, tolerance to environmental stress and finally yield. A milestone in the regulation of these products on the markets has been their recognition as a new functional category of fertilizing products by the European Regulation (EU) 2009/1009, enforced in 2022. Most notably, definition of biostimulants is based on claims, i.e. on their intended effects on plants, and not on the nature of their constituents. In consequence, the placing on the market is subject to validation of the claims by competent authorities ('notified bodies'), verifying compliance of the data supplied by companies to harmonized standards bearing on safety and efficacy. Compliance will lead to the CE-marking of the product, informing the grower. Such an approach based on functional claims has been largely followed, by OECD (ISO) and also in USA where current regulatory initiatives are taking place to clarify the status of biostimulants and to adopt the name 'biostimulant' in regulations and guidelines.

After setting the scene as above, this talk will address (i) the challenges of implementing this standardization approach to complex biological products and processes, (ii) ways forward to understand the modes of action of the products and build a sound advice on products uses, (iii) the expected and possible added value of these products for improving plant nutrition in the face of global change.

Regarding the latter point, it appears that plant biostimulants challenge scientists, agronomists and regulators to revisit such important concepts as plant nutrition and plant health. I will argue that plant health should be defined, not negatively (as today by the regulatory corpus) by the 'absence of diseases and physiological disorders', but positively as the 'capacity of plants to achieve growth and development to the best of their genetic potential'. If defined in that way, plant biostimulants should be regarded as directly contributing to plant health. Accordingly, plant nutrition should also be revisited by considering the capacity of growers to provide plants with substances and microorganisms helping them perform to the best of their genetic potential in suboptimal and stressful environments. 'Plant care' is more than 'plant cure' and biostimulant products seem to cross the roads of nutrition and health, opening new opportunities towards a sustainable agriculture.





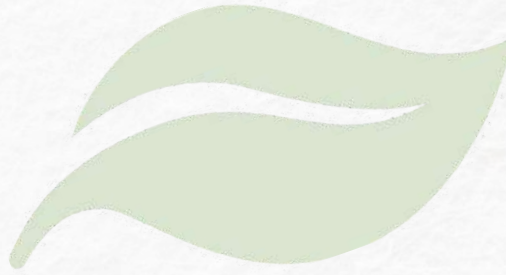
THEME 9 INTEGRATING ADVANCES IN PRECISION AGRICULTURE AND DATA SCIENCE TO SCALE, MEASURE, AND MODEL OPTIMUM NITROGEN FERTILIZER MANAGEMENT ACROSS THOUSANDS OF FARMER FIELDS

Mitch Baum (United States)¹; Michael Castellano (United States)¹

¹ - Department of Agronomy, Iowa State University, Ames, Iowa, USA

Forecasting the economically optimum N fertilizer rate for crop production is among the most difficult challenges facing agriculture. The optimum rate can vary by more than two-fold from field-to-field and year-to-year due to differences in the balance of soil organic matter mineralization, environmental losses, and crop demand. Here, we demonstrate how the latest advances in precision agriculture can be used to scale research across thousands of farmer fields to advance our ability to understand, manage, and forecast optimum N management. Every year, the Iowa Nitrogen Initiative deploys hundreds of fully replicated, scientifically robust experiments that are conducted on commercial farms, by commercial farmers, with commercial equipment. In doing so, for the first time, creating a unique database of various management practices and environments at this scale. Specifically, we used advanced mixed effect and Bayesian statistical models, which are common in fields such as ecology and crop breeding, to build N recommendations for USA maize production. Spatial variability of the optimum N rates was up to 47% different within a field but up to 207% different across fields within the same growing region and similar management. In addition, we directly compared our outcomes from commercial fields to research farms, which traditionally have been the sole source for university N recommendations. We found that commercial fields had a 7% lower optimum N rate while yield at the optimum N rate and N use efficiency were 9 and 15% higher. By comparing differences between commercial and research fields, along with quantifying the spatial variability of N fertilizer demand, we illustrate the importance of collaboration among public and private entities when making N recommendations that better reflect the realities of commercial crop production. To drive change on the landscape, we communicate our results with farmers through benchmarking and web-based decision support tools at <https://n-fact.ag/start>.





THEME 9 LEGUMES' DETRIMENTAL EFFECTS ON SUCCESSIVE MAIZE AND ITS LINKAGE TO P MOBILIZATION

Michelle Natalie Herrmann (Germany)¹; Michelle Ginter (Germany)¹; Melissa Rauch (Germany)¹; Franz Neundorff (Germany)¹; 2; Daniel Wanke (Germany)¹; Torsten Müller (Germany)¹; Günter Neumann (Germany)¹; Klara Bradáčová (Germany)¹

1 - University of Hohenheim; 2 - Thuringian State Office for Agriculture and Rural Areas, 07743 Jena

With their ability to mobilize P, integrating legumes in P-inefficient cereal-based rotations is considered a sustainable approach to increase P use efficiency (PUE). However, it still needs to be investigated if legume-induced changes in soil are relevant for the growth and P nutrition of successive crops and the PUE of the entire crop rotation. A pot and a field trial in Southern Germany under low soil P conditions were set up to evaluate different legume-based crop rotations for their impact on the P nutrition, the growth of successive maize, and the PUE of the entire crop rotation. The pot trial tested 4 crop rotations (alfalfa - maize, faba bean - maize, white lupin - maize, and maize - maize), while the 6-year field trial compared a soybean-maize-maize to a wheat-maize-maize rotation. Biomass and plant P uptake was assessed alongside soil P availability (calcium-acetate extractable P) and acid and alkaline phosphatase activity. Exudates were indirectly assessed by analyzing leave Mn concentrations. Additionally, organic P fractions in soil were determined with ³¹P-NMR. The P mobilization indicated by phosphatase activity, available P, and carboxylate exudation was significantly higher for legumes than maize. They persistently influenced the soil and P availability of the successive maize. In the pot trial, acid and alkaline phosphatase activities were strongly stimulated by white lupin and faba bean compared to the maize pre-crop (100% for acid and 22-23% increase for alkaline phosphatase activity). In the field trial, soil phosphatase activity was also higher in plots of maize after soybean compared to maize after winter wheat at the beginning of the growing season. However, biomass and P offtake of successive maize did not benefit from the previous cultivation of legumes. In contrast, lupin strongly inhibited the growth of successive maize (40% of aboveground biomass of maize after maize) in the pot trial, although lupin increased available P. The detrimental effect of pre-crop legumes was also evident in the field trial in which maize after soybean resulted in lower yields than maize after maize or maize after wheat in 3 out of 5 years. None of the legume-based rotations could compete with the maize monoculture regarding PUE due to the legumes' low aboveground biomass compared to pre-crop maize and their inhibiting growth effects on successive maize. Evidence is piling up that some legumes, under P limitations, inhibit rather than promote plant growth of the succeeding maize.





THEME 9 EXPLORING INTERACTIONS BETWEEN SOIL, ROOTS AND HYDROXYAPATITE NANOPARTICLES

Pauline Møss (Denmark)¹; Nicola Carrara (Italy)²; Grmay Hailu Lilay (Ethiopia)¹; Søren Husted (Denmark)¹

1 - University of Copenhagen, Department of Plant and Environmental Sciences, Plant & Soil Section, Plant Nutrition; 2 - École polytechnique fédérale Lausanne, School of Engineering, Institute of Materials, Polymers Lab

Phosphorus (P) is rapidly immobilized in soils due to chemical fixation and microbial activity. As a result, many fertilizers have low P use efficiency (PUE) and are often applied in excess to provide sufficient plant available P. Due to P accumulation in soils, a common externality of P application is eutrophication of surface waters due to nutrient losses from fields. Current fertilization practices are thus both costly and unsustainable, especially considering that P is a non-renewable resource.

During the past decade, there has been increased research into using nanotechnology to modify the physicochemical properties of phosphate minerals, to create nanofertilizers with enhanced PUE. We have synthesized hydroxyapatite nanoparticles (nHAPs) coated with citrate to produce a P fertilizer with a more negative surface charge and slow release of phosphate ions compared to conventional water-soluble fertilizers. By examining the behavior of these nHAPs in different soils and the rhizosphere, we are studying how nanotechnology can be used to create more soil mobile P fertilizers with improved PUE.

We examined the soil mobility and bioavailability of nHAP in soils with different P status, through soil column experiments and sequential P extractions. On soil with low sorption capacity, nHAP and the control (potassium phosphate) were equally mobile, but nHAP was more soil mobile across soils with medium to high P sorption capacities. Sequential extraction showed that the Ca-P pool decreased over 7 weeks, indicating some transformation of hydroxyapatite, but there were no temporal changes in the water and bicarbonate (i.e. "labile") fractions.

We also studied root uptake and translocation of P contained in radioactively labelled nHAP in spring barley (*Hordeum vulgare*) growing in rhizoboxes. Using autoradiography it was found that ³³P from nHAP was translocated to the shoot biomass and non-exposed roots and nHAP displayed higher PUE compared to the control.

To examine how plants acquire the P contained in nHAP we are studying pH changes in the rhizosphere of *Arabidopsis* growing in agar and examining the extracellular/intracellular movement of nHAP with incorporated tracers. In ongoing studies, we use various *Arabidopsis* mutants to decipher which mechanisms (e.g. proton or organic acid exudation) are involved in nHAP dissolution and uptake of P. The results of these experiments will be presented at the conference.

Our results, so far, show a potential for reduced soil fixation of phosphate through nanosizing and surface modification, resulting in increased soil mobility and PUE for nHAP compared to conventional P fertilizers.





THEME 9 FOLIAR APPLICATION OF POLYMERIC MANGANESE OXIDE NANOPARTICLES: MECHANISMS OF UPTAKE AND METABOLIC RESPONSES IN MANGANESE DEFICIENT BARLEY

Andrea Pinna (Denmark)¹; Asbjørn Krarup Grønbæk (Denmark)¹; Emil Visby Kristensen (Denmark)²; Noémie Thiébaut (Denmark)¹; Augusta Szameitat (Denmark)¹; Birte Martin-Bertelsen (Denmark)¹; Jean-Claude Grivel (Denmark)²; Rajmund Mokso (Denmark)²; Søren Husted (Denmark)¹

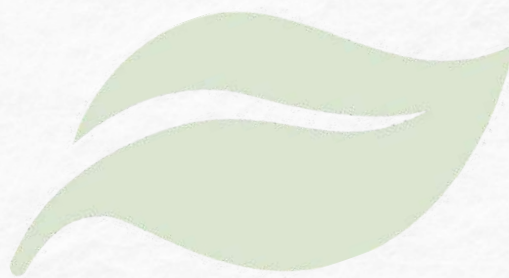
1 - University of Copenhagen; 2 - Technical University of Denmark

Conventional manganese (Mn) fertilization strategies are remarkably inefficient due to the inherent chemical properties of Mn. Especially in well-drained sandy soils, soluble Mn²⁺ is rapidly converted into plant unavailable forms. To prevent or alleviate Mn deficiency, Mn is supplied via foliar spray application as it is readily assimilated by crop leaves. However, poor mobility of Mn in the phloem prevents any significant remobilization from older to developing organs. Hence, multiple foliar applications are required during a growing season to supply adequate Mn to crops, representing a costly and time-consuming approach for farmers.

The use of nanoparticles (NPs) to deliver essential plant nutrients has been proposed as an alternative strategy to overcome some of the limitations of conventional methods. NPs can encapsulate mineral ions and, owing to their small size and ability to cross relevant plant barriers, promote their transport across the plant. Taking advantage of NPs' ability to enter the phloem and remobilize opens unique possibilities for developing novel Mn foliar fertilizers with increased nutrient use efficiency.

This study demonstrates that water-soluble, pH-responsive polyacrylic acid (PAA) based manganese oxide (MnO) nanoparticles (nPAA-MnO) can be designed to significantly restore key metabolic functionalities in manganese-deficient barley (*Hordeum vulgare*) within a few days. Using a combination of advanced bioimaging techniques - including confocal laser scanning microscopy, laser ablation-inductively coupled plasma-mass spectrometry, and X-ray nano-computed tomography, we mapped the uptake and distribution pathways of nPAA-MnO compared to ionic manganese. While soluble Mn ions primarily enter through hydrophilic cuticular pores, nPAA-MnO penetrates leaves via stomata, facilitated by the application of an organosilicone surfactant and glycerol to enhance wetting and hydraulic activation of stomatal pores. Within a few hours, nPAA-MnO accumulated in the sub-stomatal cavity and mesophyll apoplast, gradually releasing bioavailable Mn ions in the acidic apoplast environment. Moreover, labeling experiments with tracer ions revealed nPAA-MnO hot-spots around the vascular bundles and a limited but significant basipetal translocation of intact nanoparticles out of the foliar application zone, a pivotal step towards converting immobile nutrients such as Mn into mobile ones. Importantly, and unlike ionic Mn solutions, nPAA-MnO could be applied at high doses without causing leaf scorching and cytotoxicity, paving the way for more sustainable and efficient foliar fertilization practices. These novel aspects of nanoparticle uptake, translocation and assimilation underscores the potential of nanotechnology to address nutrient mobility challenges in agriculture, representing an important contribution to the green transition of modern crop production.





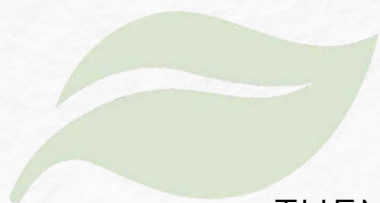
THEME 9 **BIOSTIMULANTS FOR SUSTAINABLE PLANT NUTRITION? STATE OF THE ART**

Klara Bradacova (Germany)¹

¹ - University Hohenheim

Biostimulants are of increasing interest as promising alternatives or substitutes to agrochemicals. European markets (valued at 14.6 billion US\$ in 2023) for agricultural biologicals are predicted to grow at rates of more than 13.5 % per year. Improved availability and use efficiency of mineral nutrients, tolerance to abiotic stresses, as well as biological control of pathogens are very relevant traits of biostimulants to be implemented in precision farming systems and well documented for controlled greenhouse systems. Under variable field conditions, the expression of desired effects is often hampered. BioFactor, a recent EU funded project, by developing integrated strategies in crop production, aimed to improve the efficiency crops against stresses. Results showed that benefits from the application of biostimulants, such as *Bacillus* and *Pseudomonas* species are influenced by site-, crop- and management-specific conditions. In tomato cultivation, reproducible yield increases of up to 100 % were produced by biostimulants. Combinations with precise placement and of fertilizer, such as the Controlled Uptake Long Term Ammonium Nutrition (CULTAN), could induce the formation of dense rooting zones providing favorable conditions for colonization by microbial inoculants to support the expression of root growth-promoting traits [2]. Promising results were also obtained with algae extracts, micronutrients and silicates to improve the resistance of abiotic stresses. The exploitation of synergistic interactions of microbial agents together with supportive natural compounds and adapted fertilization strategies (such as GPS assisted fertilizer placement) could favorably contribute to the development of sustainable agro-ecosystems.





THEME 9 OPTIMIZING PLANT NUTRITION AND CLIMATE RESILIENCE: THE ROLE OF SOIL BIODIVERSITY, RHIZOSPHERE PROCESSES, AND CROP MANAGEMENT

Markus Weinmann (Germany)¹; Günter Neumann (Germany)²

1 - LUFA Speyer, Obere Langgasse 40, 67346 Speyer; 2 - University of Hohenheim, Institute of Crops Science, 70599 Stuttgart

Climate change poses significant challenges to global agriculture, threatening crop yields, nutritional quality, and ecosystem stability. Enhancing soil biodiversity and optimizing plant nutrition are pivotal strategies for strengthening climate resilience and ensuring sustainable food production. This study explores innovative agronomic approaches, including the integrated application of biologicals, to improve nutrient uptake, soil functionality, and stress tolerance in cropping systems.

The BIOFAIR project investigated the complex interactions between soil biodiversity, rhizosphere processes, and cropping system management in wheat production. A combination of field trials and controlled Ecotron experiments assessed how climate change influences soil microbiota, plant performance, and nutrient dynamics across biodynamic, organic, and conventional farming systems. Results indicate that reduced tillage and organic fertilization foster beneficial microbial communities, promoting nutrient cycling and increasing resilience to drought stress. However, elevated atmospheric CO₂ levels and altered crop phenology were linked to declines in grain quality, notably a reduction in B-vitamin content, raising concerns about the risk of hidden malnutrition.

The BIOFECTOR project advanced integrated strategies for using bio-effectors, i.e. microbial inoculants and other biologicals, to enhance plant nutrition and stress resilience. Conducted across multiple European sites, the project tested 38 bio-effector products in over 150 field and greenhouse trials with wheat, maize, and tomato. Results demonstrated that bio-effectors, such as beneficial strains of *Bacillus*, *Pseudomonas*, *Penicillium*, and *Trichoderma*, can significantly improve nutrient acquisition, drought tolerance, and crop yields under specific soil and management conditions. Notably, microbial bio-effectors combined with organic fertilizers in tomato production led to reproducible yield increases of up to 100%. However, field performance varied due to environmental complexities, necessitating tailored application strategies, such as precision fertilizer placement, to maximize their effectiveness.

The KLIMACrops project examined the potential of catch cropping and relay cropping to enhance resource use efficiency and soil health. Trials involving maize, wheat, barley, and soybean demonstrated that innovative cropping systems can improve soil cover, nitrogen retention, and overall agroecosystem stability. Nevertheless, interspecies competition and pathogen pressure posed challenges to crop establishment, highlighting the need for refined management strategies to optimize productivity and resilience.

These findings emphasize the key role of soil biodiversity, integrated biological applications, and tailored crop management in mitigating climate-related stressors. Future research should focus on advancing these approaches to develop more adaptive, resilient, and sustainable agricultural systems capable of maintaining high yields and nutritional quality under changing environmental conditions.



THEME 10 **POTASSIUM DYNAMICS AND SUSTAINABILITY OF SOIL HEALTH AND CROP PRODUCTIVITY IN LONG-TERM FERTILIZER EXPERIMENTS IN INDIA**

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INTRODUCTION

All too often, the importance of potassium is overlooked in Indian crop production systems. It has often been stated that there is no need to apply potassium fertilizer in most of the Indian soils due to the soils' naturally high potassium levels, particularly in North-West (NW) India. This statement may have been true forty years ago, but it now appears that potassium levels are declining at a very fast rate due to higher productivity and altering potassium dynamics. This depleting K fertility is adversely affecting the soil health as well as the crop yields.

METHODS

Data was analyzed from several on-going long term fertilizer experiments (LTFE) being conducted in 11 major agro-climatic zones of the country since 1971 for studying the effect of cropping and fertilization on sustainability of soil and crop productivity and N use efficiency. A long-term fertilizer experiment is going on Sorghum (fodder)-Wheat cropping system since 1985 at PRII, Gurgaon and detailed analyses of data was made on contribution of different pools of soil K and crop yields over 35 years of different fertilizer treatments.

RESULTS AND DISCUSSION

LTFE data have clearly showed that nutrient response ratios in cereal based systems are declining and so as the Sustainability Yield Index (SYI) due to declining soil health caused by the continued imbalanced use of fertilizers. Highest SYI was obtained in 100% NPK+FYM followed by 100%NPK+lime in acid soils, 100%NPK, 100% NP, 100%N and control.

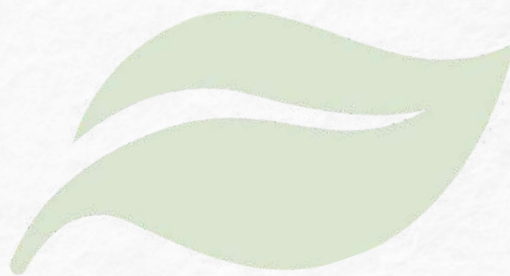
Partial N and K nutrient balances in different crops indicated that N is applied far in excess of removal in almost all crops and in all the states whereas reverse was observed for K except for rice in some of the southern and eastern states. However, situation is worse in northern states of Punjab, Haryana and U.P. in case of rice, wheat, maize and sugarcane which indicates severe K depletion and serious soil health problems in future.

Similarly, in a LTFE being conducted since 1985 on an inceptisol at PRII, Gurgaon, results indicated that for sustainability of sorghum fodder yields at high levels, it is essential to apply 200% K while application of FYM with 100% of K could be sufficient for a wheat grain crop. Despite 77.3% K contribution from the structural form to the total K removed by sorghum and wheat in 35 crop cycles, K fertilizer was needed to both sustain the yield and maintain soil K fertility. Both water soluble and exchangeable forms of soil K contributed least and K contribution of non-exchangeable form was also much less than that of structural form which also indicated a serious challenge for maintaining soil productivity under long term cropping without K application.

Application of K indicated an increase of 10-15% in N use efficiency of maize-wheat crops in Inceptisols and about 4-5% in rice-wheat crops grown in Mollisols.

CONCLUSIONS

- Continuous K mining may lead to irreversible damages to soil health in the long run.
- Benefit from the higher nitrogen use efficiency with K use is tremendous-Even modest 10% increase will save 2.0 million t N which will further save the environment.



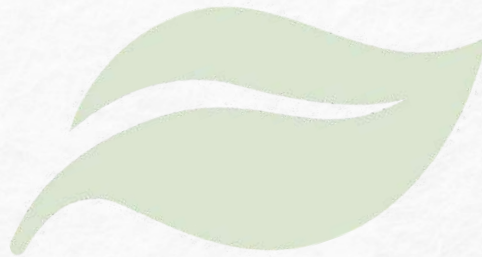
THEME 10 **POTASSIUM AVAILABILITY IN HIGHLY CONCENTRATED FERTILISER BANDS: INFLUENCE OF SOIL PROPERTIES AND FERTILISER TYPE**

Yili Zang (Australia)¹; Brigid A. McKenna (Australia)¹; Jianyin Huang (Australia)¹; Enzo Lombi (Australia)²; Kathryn Bartlett (UK)³; Peter M. Kopittke (Australia)¹

1 - The University of Queensland; 2 - University of South Australia; 3 - Anglo American Crop Nutrients

Improving soil potassium (K) availability is essential for plant nutrition, with only 1–2% of total soil K accessible to plants. Although there has been considerable work examining K in bulk soil, the dynamics and transformations of K within highly concentrated fertiliser bands remain unclear. In the present study, we examined K behaviour across 30 highly diverse Australian soils that differed markedly in a wide range of properties, including pH, cation exchange capacity (CEC), and clay content. We investigated three different K fertilisers applied at a constant rate of K: muriate of potash (MOP), sulfate of potash (SOP), and polyhalite (POLY4, $K_2SO_4MgSO_4 \cdot 2CaSO_4 \cdot 2H_2O$), with the latter being a low-chloride, low-carbon alternative that also contains K, calcium (Ca), magnesium (Mg), and sulfur (S). In addition, we examined the co-application of monoammonium phosphate (MAP) to assess P interactions. Fertilisers were applied under simulated fertosphere conditions, with soils incubated for two months. Changes in K availability were assessed using sequential extraction methods as well as DGT, with concomitant changes in K speciation examined in situ using synchrotron-based X-ray absorption near edge structure (XANES) spectroscopy. Results showed that soils with high clay content (especially Vertosols) had considerably lower K availability, indicating that clay content is a critical factor in controlling K availability from fertilisers. Differences in availability were also observed between the three K fertilisers, with water-extractable K being higher for polyhalite than for MOP and SOP, while non-exchangeable K (NaTPB extractable) was lower for polyhalite compared to other the forms K fertilisers. This was likely due to competition from co-supplied Ca and Mg in the polyhalite, with this reducing K binding and enhancing its availability. Co-application of P only reduced availability of K in a light-textured acid soil, presumably due to precipitation of K as taranakite and other insoluble forms of K. Additionally, polyhalite-treated soils showed substantially higher sulfate levels than MOP and SOP, providing more plant-available S. These findings highlight the strong influence of soil type on K availability from fertilisers. Moreover, polyhalite demonstrates potential advantages as a K source due to its comparatively high K availability and its capacity to supply other essential nutrients.





THEME 10 **UNDERSTANDING AND CHARACTERIZING POTASSIUM SOIL VARIABILITY IN THE ALMOND SYSTEM TO IMPROVE POTASSIUM MANAGEMENT**

Margherita A Germani (United States)¹; Patrick H Brown (United States)¹

¹ - University of California Davis

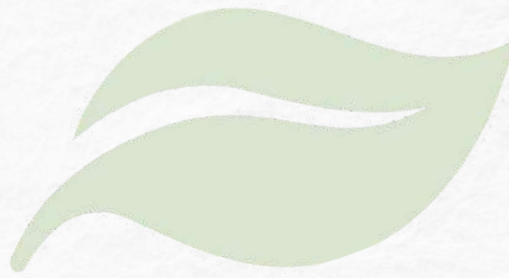
Potassium (K) management represents a worldwide challenge for growers, given the unpredictable response of soil to K fertilization, the high spatial variability of plant-available soil K in uniformly managed orchards, and the weak correlations between soil K and plant response. Although abundant in the soil, only a small part of K is available for plant uptake, with its availability being influenced by the interaction of a series of factors, such as soil moisture, soil texture, clay mineralogy, history of previous treatment, and plant uptake rate. The complexity of soil K dynamics is difficult to characterize and is not captured by most commonly utilized soil K tests making them of limited utility to guide fertilization plans.

Almond trees (*Prunus dulcis*) have an extremely high K demand, with a total of 248-388 kg K/ha allocated to fruits in high-yielding crops. To meet the high K requirements and to avoid deficiencies, almond growers rely intensively on fertilization and regularly apply large amounts of K fertilizers in an attempt to overcome sampling uncertainty, and to avoid current season and subsequent season K deficiency. However, this is not economically viable and does not provide a benefit for the yield, in addition to not solving the problem of spatial heterogeneity of plant-available K.

A multi-year research was conducted in two commercial almond orchards (60 and 35 ha) located in Northern and Central California. Intensive soil and plant sampling was conducted across both sites to determine the physical, chemical, and biological determinants of soil K availability and plant K uptake, and to establish accurate and reliable measurement protocols for soil and leaf testing, to ultimately improve K management and K use efficiency.

Results showed that the drivers of K variability are determined by local soil properties and therefore one unique solution to guide K fertilization cannot be offered. Soil texture, soil cation exchange capacity, and soil cation interactions were often found to have an effect on the availability to plant of soil K, and were used to create a model to improve the accuracy of description maps. The confluence of different types of sensors in this research represented a unique opportunity to compare traditional soil sampling with more advanced systems, and to elaborate a multifactorial approach to map K that takes into account all the different factors that regulate K availability.





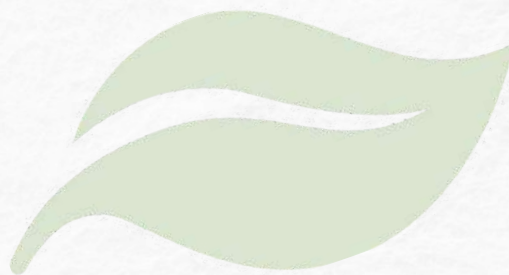
THEME 11 THE ENHANCED ACTIVITY OF GLUTAMINE SYNTHETASE BY INCREASING BNA02.GLN1;2 EXPRESSION PROMOTES NITRATE UPTAKE AND NITROGEN USE EFFICIENCY IN BRASSICA NAPUS

Hao Zhang (China)¹; Lulu Ren (China)¹; Chuang Wang (China)¹; Lei Shi (China)¹; Hongmei Cai (China)¹; Sheliang Wang (China)¹; Fangsen Xu (China)¹; Guangda Ding (China)¹

¹ - College of Resources and Environment/Microelement Research Center/Key Laboratory of Arable Land Conservation (Middle and Lower Reaches of Yangtze River), Ministry of Agriculture and Rural Affairs, Huazhong Agricultural University, 430070, Wuhan, China

Nitrate (NO_3^-), as one of the important nitrogen (N) sources, significantly impacts the growth and development of *Brassica napus*. Therefore, it is crucial to analyze the genetic variation of NO_3^- utilization in *B. napus* varieties. Here, we have identified the natural differentiation of *B. napus* population based on chlorate (ClO_3^- , NO_3^- analogues) sensitivity, which is primarily related to NO_3^- transport and metabolism. When reducing GS activity appropriately, we found that the ClO_3^- sensitivity of *B. napus* could be decreased, indicating an improvement in its NO_3^- uptake and assimilation ability. Meanwhile, we identified the glutamine synthesis (GS) isoenzyme BnaA02.GLN1;2 through genome-wide association analysis (GWAS), which was mainly expressed in roots and significantly induced by NO_3^- . Importantly, chlorate sensitive genotypes with higher BnaA02.GLN1;2 expression levels had higher yields and NUE (N use efficiency) under normal N fertilizer application compared to insensitive genotypes. Further, enhanced expression of BnaA02.GLN1;2 significantly promoted N assimilation in *B. napus*, resulting in a decrease in free ammonium (NH_4^+) concentration and an increase in glutamic acid concentration to promote plant growth. Moreover, based on feedback regulation, the NO_3^- uptake rate improved with the acceleration of NH_4^+ assimilation pathway. In general, BnaA02.GLN1;2Hap1 could be applied to NUE molecular breeding of *B. napus* combining haplotype analysis.





THEME 11 ELUCIDATION AND RECONSTITUTION OF THE PRECURSOR BIOSYNTHESIS OF ALUMINUM-DETOXIFYING HYDROLYZABLE TANNINS IDENTIFIED IN EUCALYPTUS CAMALDULENSIS

Chihiro Oda-Yamamizo (Japan)¹; Carsten Milkowski (Germany)²; Ko Tahara (Japan)¹

1 - Forestry and Forest Products Research Institute (FFPRI); 2 - Martin Luther University Halle-Wittenberg

Aluminum toxicity is the main factor limiting the elongation of plant roots on acid soils that cover about 30% of the total land area worldwide. The mechanism of aluminum resistance in herbaceous plants has been well investigated, but not in tree species. The extraordinary resistance level of tree species *Eucalyptus camaldulensis* compared to herbaceous model plants is caused by the detoxification capacity of hydrolyzable tannins (HTs), such as oenothien B, accumulating in roots. To elucidate the biosynthetic pathway and roles of HTs, we established a method for pathway reconstitution in the HT-nonaccumulating model plant *Nicotiana benthamiana* (Oda-Yamamizo et al. 2023).

The HT biosynthetic pathway branches off from the shikimate pathway, which is universally conserved in plants and microorganisms. In *E. camaldulensis*, shikimate dehydrogenases (EcSDH2 and EcSDH3), which catalyze the reaction to synthesize gallic acid, and UDP glycosyltransferases (UGT84A25 and UGT84A26), which catalyze the reaction from gallic acid to β -glucogallin, have been identified as enzymes after branching from the shikimate pathway (Tahara et al. 2024). Here, we describe *Agrobacterium tumefaciens*-mediated transient co-expression of *E. camaldulensis* genes EcSDH2, EcSDH3, UGT84A25 and UGT84A26 in leaves of *N. benthamiana*. Results showed that transgenic leaf areas of *N. benthamiana* synthesized gallic acid and β -glucogallin, the universal metabolic precursors of HTs including oenothien B. This indicates that the upstream portion of the HT biosynthetic pathway can be reconstituted in a plant species that does not naturally accumulate HTs. In the future, we will use *N. benthamiana* leaves for transient co-expression with other candidate genes supposed to act more downstream in HT biosynthesis.

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THEME 11 **VARIOUS HYDROLYZABLE TANNINS CONTRIBUTE TO ALUMINUM DETOXIFICATION IN A HIGHLY ALUMINUM-RESISTANT TREE, EUCALYPTUS CAMALDULENSIS**

Ko Tahara (Japan)¹; Hideyuki Ito (Japan)²; Mitsuru Nishiguchi (Japan)¹; Carsten Milkowski (Germany)³

1 - Forestry and Forest Products Research Institute; 2 - Okayama Prefectural University; 3 - Martin Luther University Halle-Wittenberg

Introduction

Aluminum toxicity is a major factor limiting plant productivity in acidic soils, which comprise approximately 30% of the global ice-free land area. Aluminum inhibits plant root elongation, leading to decreased water and nutrient uptake and subsequent growth restriction of the entire plant. *Eucalyptus camaldulensis* is a Myrtaceae tree species that is highly resistant to aluminum toxicity. Previously, we identified oenothetin B in *E. camaldulensis* roots; this hydrolyzable tannin contributes to aluminum detoxification (Tahara et al. 2014). The present study aimed to identify additional hydrolyzable tannins that can detoxify aluminum in *E. camaldulensis* and to elucidate their roles in aluminum resistance.

Materials and Methods

Hydrolyzable tannins in roots and leaves of *E. camaldulensis* were extracted using aqueous acetone, isolated by various types of column chromatography, and identified based on NMR and MS analyses. Root extracts were also analyzed using UPLC-Q-TOF-MS by matching chromatographic retention times and mass spectra of authentic standards. To assess the aluminum detoxification abilities of hydrolyzable tannins, we conducted bioassays in which the aluminum-sensitive plant *Arabidopsis thaliana* was grown in a culture medium containing aluminum and hydrolyzable tannins. To clarify the roles of hydrolyzable tannins in aluminum resistance, we developed transgenic *E. camaldulensis* lines that suppressed hydrolyzable tannin production through antisense or RNAi knockdown of the biosynthetic genes UGT84A25 and UGT84A26 (Tahara et al. 2018) and evaluated their aluminum resistance.

Results and Discussion

Five hydrolyzable tannins were isolated by column chromatography and identified as 1,6-digalloylglucose, strictinin, tellimagrandin I, pedunculagin, and oenothetin B. UPLC-Q-TOF-MS analysis identified six more hydrolyzable tannins, namely β -glucogallin, 1,2,6-trigalloylglucose, 1,2,3,6-tetragalloylglucose, 1,2,3,4,6-pentagalloylglucose, casuarictin and tellimagrandin II in the roots. UPLC-Q-TOF-MS analysis also indicated that oenothetin B and pedunculagin were the two primary metabolites among the identified hydrolyzable tannins in the roots. Bioassays demonstrated that all hydrolyzable tannins exhibited aluminum detoxification abilities, with a tendency for greater efficacy in compounds with higher molecular weights. Some UGT84A25/26 knockdown lines of *E. camaldulensis* displayed lower concentrations of hydrolyzable tannins and lower aluminum resistance compared to the empty vector control line. Collectively, these findings suggest that various hydrolyzable tannins, in addition to oenothetin B, contribute to aluminum detoxification and resistance in *E. camaldulensis*.

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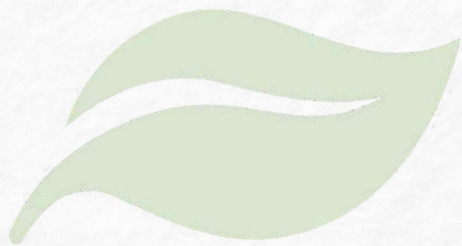
THEME 11 **COMPREHENSIVE UNDERSTANDING OF THE MECHANISMS OF NUTRIENT UPTAKE REGULATION: STARTING FROM RIBOSOMAL SENSING OF CYTOSOLIC NUTRIENTS LEADING TO TRANSLATIONAL AND TRANSCRIPTIONAL REGULATION**

Toru Fujiwara (Japan)¹; Naoyuki Sotta (Japan)³; 1; Mayuki Tanaka (Japan)³; 1

1 - University of Tokyo; 2 - University of Tokyo; 3 - Graduate School of Agriculture, Osaka Metropolitan University

Mineral nutrients in soils are not evenly distributed, and their concentrations change over time due to nutrient depletion by plants, leaching, fertilization, etc. Plants regulate nutrient uptake rates in response to environmental nutrient availability, allowing them to grow under diverse and changing nutrient conditions. This regulation is especially important for essential mineral nutrients that become toxic at high concentrations. For such elements, plants need to efficiently absorb nutrients when their environmental concentrations are low, while quickly shutting down uptake when concentrations increase. To achieve this precise regulation, plants must sense nutrient levels and adjust their nutrient uptake capacity accordingly in a timely manner. In some cases, the processes involved in nutrient uptake regulation have been described. However, a comprehensive understanding of the sequence of events from nutrient sensing to uptake regulation is still lacking. As an example of such a regulatory system, we have been investigating the mechanisms of boron sensing and the regulation of boron uptake transport. About two decades ago, we identified the first boron transporters in living systems from *Arabidopsis thaliana* (Takano et al., *Nature*, 2002; *Plant Cell*, 2006) and studied their regulation in response to boron conditions using a wide range of approaches, including molecular genetics, structural biology, and cell biology. In the case of NIP5;1, a boron uptake transporter, its mRNA accumulation is strictly regulated in response to boron conditions (Tanaka et al., *Plant Cell*, 2011, 2016). This regulation is initiated by ribosomal sensing of cytoplasmic boron concentration (Tanaka et al., *Nature Chem Biol*, 2024). Boron interferes with the translational termination process, leading to reduced translation of NIP5;1 and degradation of its mRNA. This regulation at the levels of translation and mRNA degradation enables the rapid shutdown of transport activity, which is beneficial for plants to avoid boron toxicity in a timely manner. However, such a mechanism is inefficient in terms of resource utilization unless transcription is also regulated. Recently, we discovered that degradation products of NIP5;1 mRNA regulate NIP5;1 transcription through the action of AGO1 (Tanaka et al., in press). Overall, these studies revealed the sequence of events from nutrient sensing to translational and transcriptional regulation. This system enables the rapid shutdown of transport activity to prevent excessive boron uptake, while in the long term, it facilitates cost-effective transcriptional regulation of NIP5;1, representing a sophisticated mechanism of nutrient transport regulation.





THEME 11 TRANSPORTERS OF SUGAR AND AMINO ACIDS DOMINANT NITROGEN-CONTROLLED YIELD FORMATION IN RICE

Guohua XU (China)¹; Shunan Zhang (China)¹; Jinfei Zhang (China)¹; Zhiyuan Wang (China)¹; Hongye Qu (China)¹; Le Luo (China)¹; Ying Liu (China)¹

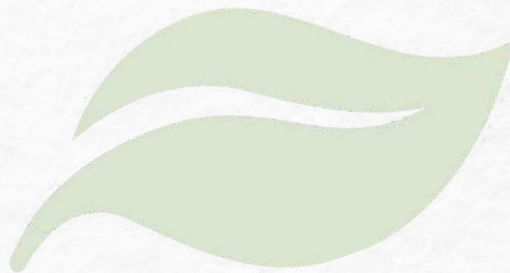
¹ - Nanjing Agricultural University

Coordinated assimilation and distribution of carbon (C) and nitrogen (N) determine the genetic potential of crop yield and N use efficiency (NUE). Both growth duration and architecture including plant height, tiller number in addition to grain number and weight dominate grain yield in cereal crops. The basic processes of N acquisition, C and N assimilation have been well characterized, while how C and N distribution regulates crop yield formation and NUE remains to be elucidated.

We performed genome-wide association analysis (GWAS) of fully sequenced rice germplasms exploring the flowering time (heading date), height and tillering responses to different levels of N fertilization, and identified NRH1 (N-regulated height-1) and TRN11 (tillering response to N-11) in paddy field. NRH1 encodes an amino acids transporter, its over-expressors and the elite haplotype of NRH1^{HapB} show early flowering time, elevated height and lodging resistance, grain yield and N redistribution. NRH1 functions as a dominant factor of plant height responses to N supply independent on green revolution gene *sd1* in modern rice cultivars. TRN11 encodes a Sugar (glucose) Transporter Protein 28 (OsSTP28) and functions as a key regulator of N-responsive tillering and yield formation in rice. N supply inhibits the expression of OsSTP28, resulting in glucose accumulation in the apoplast of tiller buds, which in turn suppresses the expression of a transcriptional inhibitor OSH15 via an epigenetic mechanism to activate GA2oxs-facilitated gibberellin catabolism in shoot base. Thereby, OsSTP28-OSH15-GA2oxs module reduces the level of bioactive gibberellin in shoot base upon increased N supply, and consequently promotes tillering and grain yield. Moreover, we identify an elite allele of OsSTP28 that can effectively promote N-responsive tillering and yield formation, thus representing a valuable breeding target of NUE improvement.

We also found that the N-mediated alteration of flowering time and shoot architecture is genotype-dependent. Increasing glutamine, the primary product of N assimilation, can upregulate the expression of Nhd1 (N-mediated heading date-1) and its downstream florigen OsHd3a. Nhd1 impacts C-N balance by activating the transporters of OsSUT1, OsAMT1;3 and OsNRT2.4, and suppressing the activity of OsFd-GOGAT. Nhd1-mediated up-regulation of Ghd7 at high N and Ghd7 induced suppression of Nhd1 at low N dominant the responses of heading date in the U-shape curve, particularly in its Ghd7-none/weak allele or Nhd1-strong allele in natural long-day condition. Nhd1 thus balances the flowering time and NUE in addition to photoperiod in rice.





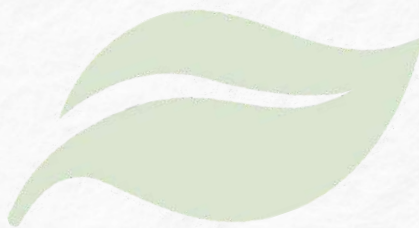
THEME 12 **HIGH NITROGEN ENHANCED PS I CYCLIC ELECTRON TRANSPORT TO INDUCE PROTON MOTIVE FORCE $\Delta\Psi$ FOR HIGHER CO₂ ASSIMILATION RATE**

Hayato Satoh (Japan)¹; Yuri Ohara (Japan)¹; Ginga Shimakawa (Japan)¹; Chikahiro Miyake (Japan)¹

¹ - Graduate School for Agricultural Science, Kobe University, 1-1 Rokkodai, Nada-Ku, Kobe 657-8501, Japan

The capacity of plants to protect themselves from stress and to assimilate CO₂ efficiently depends on dynamic regulation of photosynthetic electron transport (PET). There are two PET pathways: linear electron transport (LET) and cyclic electron transport around photosystem I (PS I -CET). LET forms a proton gradient (ΔpH) and membrane potential ($\Delta\Psi$) established between the thylakoid lumen and the stroma, as proton motive force (pmf) needed to drive sufficient ATP synthase activity for CO₂ assimilation. In PSI-CET, the ferredoxin (Fd) reduced by PSI donates electrons to plastoquinone (PQ), which then enter LET. However, there was no reliable assay system of PS I -CET in vivo. Therefore, its molecular mechanism and its physiological role are not elucidated. Recently, it was shown that evaluating the oxidation rate of reduced Fd (vFd) is an effective indicator for evaluating PSI-CET activity in vivo. vFd reflects the rate of reactions of consuming electrons from Fd. The rate of PSI-CET has been quantified as excess vFd due to LET, which we term vFd(CET). In this study, we tried to elucidate the effects of the redox states of both Fd and PQ on PSI-CET and the physiological role of PSI-CET. We analyzed the effect and pmf in relation to the dependence of CO₂ assimilation on light intensity with a cutting-edge spectrophotometer: Dual/KLAS-NIR. For the analysis, we grew C3 plant sunflower (*Helianthus annuus*) under two different nitrogen levels: control and high nitrogen (HN) with fertilizer. The rate of CO₂ assimilation saturated with high light intensities in control, while it didn't saturate in HN. In contrast to the rate of CO₂ assimilation, vFd demonstrated two phases of acceleration and deceleration as the light intensity increases. The estimated vFd(CET) demonstrated two phases as well as vFd. vFd(CET) was accelerated in Fd reduction phase, while vFd(CET) was decelerated in steady state of Fd and reduction state of PQ. HN grown plants exhibited a similar trend, but with higher CO₂ assimilation rate, more oxidized PQ, and greater vFd(CET). Furthermore, the peak response of vFd(CET) exhibited a strong correlation with induction of the $\Delta\Psi$ on light intensity. These findings demonstrate that PSI-CET is regulated by the redox states of both Fd and PQ. Furthermore, PSI-CET contributes to ATP synthesis through its role in inducing $\Delta\Psi$ as part of the proton motive force in vivo. On the day, we will present these plus the analysis of plants grown with low nitrogen.





THEME 12 **HIGH-THROUGHPUT ANALYSIS OF PLANT NUTRIENTS BY LASER INDUCED BREAKDOWN SPECTROSCOPY**

Frederikke Neergaard Mikkelsen (Denmark)¹; Daniel Adén (Sweden)²; Jens Axel Knuhtsen (Denmark)¹; Jonas Andersen (Denmark)²; Dorthe Horn Larsen (Denmark)¹; Kristian Holst Laursen (Denmark)¹

1 - UCPH; 2 - FOSS

Background and aims:

Multi-element analysis of plant tissue is an important tool for determining plant nutrient status and optimizing fertilization strategies in agriculture. However, existing methods based on atomic spectrometry are laborious and expensive. The aim of the study was to develop a novel and high-throughput method for analysis of plant nutrients based on laser induced breakdown spectroscopy (LIBS)

Methods:

The LIBS setup consisted of a press, a searing unit, and an analyser with an Nd: YAG laser with a pulse energy of 0.15 mJ operating at a central wavelength of 1064 nm in a nitrogen (N) atmosphere. The LIBS measurements were conducted on 257 leaf samples from eight different plant species (wheat, faba bean, tomato, soybean, rapeseed, oat, pea, and maize). The plant samples were analysed with inductively coupled plasma optical emission spectroscopy (ICP-OES) to obtain reference values for phosphorus (P), potassium (K), magnesium (Mg), sulphur (S), calcium (Ca), iron (Fe), zinc (Zn), manganese (Mn), boron (B), and copper (Cu). Based on the reference values and the LIBS spectra, partial least squares regression was used to build prediction models for each nutrient. Mixed species models and specific models for wheat and faba bean were developed.

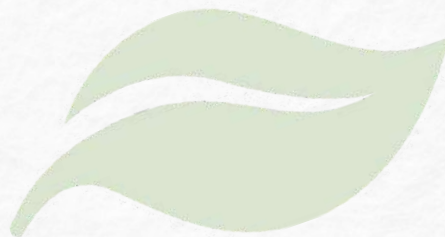
Key results:

The nutrients P, K, Mg, S, Ca, Fe, Zn, Mn, B and Cu could all be quantified by LIBS. Species specific models performed better than mixed species models suggesting that for future use specific models for each plant species should be build. Prediction models for P, K, Mg, S, Ca, Zn, Fe, B and Cu for wheat were superior to the faba bean models and were sufficiently precise and accurate to enable detection of plant nutrient deficiencies. The combination of sample searing before analysis and purging with N gas during analysis makes it possible to quantify S, a previously challenging element in LIBS analysis, with a certainty that enables diagnosis of S deficiency in plants. Regarding time consumption and complexity, the LIBS system used in this study is considerably faster and requires less skilled labour, as compared to ICP-OES analysis. Preparation and analysis of 60 samples can be conducted in less than two hours.

Conclusions:

The results document the usefulness of the novel LIBS setup for plant tissue analysis and for detection of plant nutrient deficiencies. It is now being further developed and tested for analysis of grain samples of cereals and legumes, and results will be presented at the conference.





THEME 12 **SMART B100 ADVANCED RESEARCH CENTER (CCD-SB100): A NOVEL APPROACH FOR NUTRIENT MANAGEMENT IN THE FIELD SUPPORTED BY GENERATIVE AI**

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1 - Instituto Agronômico (IAC); 2 - UNESP, Faculdade de Ciências Agronômicas; 3 - Faculdade de Tecnologia de São Paulo (Fatec/ Cotia); 4 - Faculdade de Tecnologia de São Paulo (Fatec/ Pompeia); 5 - UNESP, Faculdade de Filosofia e Ciências; 6 - UNESP, Faculdade de Arquitetura, Artes, Comunicação e Design; 7 - CIAg, Centro de Inovação no Agronegócio; 8 - USP, Escola Superior de Agricultura Luiz de Queiroz; 9 - Fundação Shunji Nishimura de Tecnologia (FSNT)

The Bulletin 100 System is an institutional program in the state of São Paulo, Brazil, that has provided farmers with soil fertility management tools for best decisions for more than 40 years. This System presents recommendations for liming and fertilization for 130 crops. The objective of the Smart B100 Advanced Research Center (CCD-SB100) project is to build a B100 digital platform, named Smart Bulletin 100 (SB100), incorporating scientific knowledge in environment and soil and plant biology with cutting-edge generative artificial intelligence technologies, such as the ChatGPT language model. The project's backbone stands on: (i) building an advanced interface between agronomic knowledge and the SB100 digital platform, (ii) creating multi-criteria decision indices to increase the efficiency of using fertilizers and bio-inputs, and (iii) transforming research results and data, collected from researchers and stakeholders, into increasingly precise agronomic recommendations. In addition to soil physical-chemical attributes, SB100 will incorporate information on the microbiological quality of the soil, carbon cycle processes and knowledge regarding physiological responses and gene expression of plants, to recommend the use of nutritional inputs. The SB100 represents the new generation of B100, supported by scientometrics, which will initially be validated for sugarcane and citrus crops, and later for other crops of economic interest. SB100 will be developed using a Large Language Model (LLM), supported by curation process that will select data from open science agricultural databases. This information will be accumulated, vectorized and accessed by a computer system, based on AI technology. The expected results of the project are: (i) provide more assertive and safe recommendations for managing soil fertility and the nutritional status of plants, (ii) provide tools to increase the efficiency of input use, (iii) accelerate the production and transferring of scientific knowledge from academia to farmers, through efficient, profitable, and environmentally sustainable processes and (iv) promote digitalization in the field. SB100 aims to transform current research into an integrative model of efforts and areas of knowledge, providing broad and assertive solutions via machine learning, developing the bases for modeling a Living Lab and an On-Farm Experimentation (OFE) system.





THEME 12 **HIGH-THROUGHPUT SCREENING OF ACID-TOLERANT AND HIGH-YIELD RAPESEED VARIETIES BASED ON MULTI-TEMPORAL UAV RGB AND MULTISPECTRAL IMAGES**

Pengchao Zhang (China)¹; Wen Zhang (China)¹; Chuang Wang (China)¹; Fangsen Xu (China)¹; Guangda Ding (China)¹

¹ - College of Resources and Environment/ Microelement Research Center/ Key Laboratory of Arable Land Conservation (Middle and Lower Reaches of Yangtze River), Ministry of Agriculture and Rural Affairs, Huazhong Agricultural University, Wuhan 430070, China

In China's major winter rapeseed production regions, progressive soil acidification poses a significant challenge to sustainable cultivation. While developing acid-tolerant, high-yielding rapeseed cultivars is critical for maintaining productivity under acidic soil conditions, a persistent gap exists in linking soil acidification dynamics with accurate yield prediction for high-throughput screening of superior genotypes. To address this, we developed an Acid-Tolerance and High-Yield Index (AHI) to systematically evaluate rapeseed performance under acidic stress. Comparative analysis demonstrated AHI's superior utility over eight existing stress tolerance metrics.

Multispectral and RGB imagery of 65 rapeseed varieties was collected under acid-stressed and ameliorated conditions across six critical growth stages in moderately and strongly acidic soils. From these datasets, 21 multispectral and 12 RGB-derived vegetation indices (VIs) were extracted. Among the 33 VIs, RLCI, NDRE, and RECI exhibited the strongest correlations with grain yield across all growth stages. Key predictive VIs were subsequently identified using the Random Forest-Recursive Feature Elimination (RF-RFE) algorithm, enabling the development of a robust Random Forest (RF) yield prediction model.

The silique development stage demonstrated optimal predictive capacity for grain yield in both moderately ($R^2 = 0.79$) and strongly acidic ($R^2 = 0.83$) soils, with model accuracy further enhanced by integrating key VIs from three critical developmental phases spanning pre- and post-bolting stages. AHI values derived from measured and predicted yields showed strong concordance, with top-performing varieties achieving 50-70% and 60-80% consistency rates under moderate and strong acidity, respectively. These results confirm that AHI can be reliably estimated using remote sensing data from targeted growth stages or their strategic combination.

This study establishes a novel framework combining yield prediction modeling with AHI scoring for high-throughput identification of acid-tolerant, high-yield rapeseed varieties. The methodology enables efficient large-scale evaluation of genetic resources while addressing the urgent need for climate-resilient crop improvement in acidification-prone agroecosystems.





MARSCHNER SESSION **PHOSPHORUS ACQUISITION AND YIELD GAIN IN INTERCROPPING: MECHANISMS AND OUTCOMES**

**Chunjie Li (China)¹; Ellis Hoffland (Netherlands)²; Thomas W. Kuyper (Netherlands)²;
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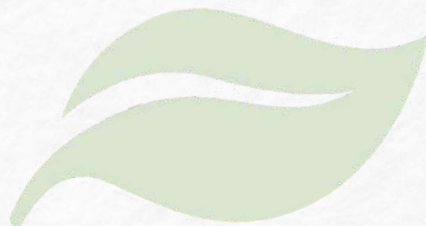
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Intercropping, growing two or more crop species in the same field, has been shown to increase productivity in low phosphorus (P) soils compared to sole crops. The ecological mechanisms underlying these benefits mainly include complementarity and facilitation with respect to resource acquisition. The contribution of these mechanisms to the yield benefit of intercropping probably depends on crop species traits, soil nutrient availability and agronomic practices. We aimed to design intercropping systems for improved P acquisition and yield gain by testing the resource partitioning hypothesis, and by quantifying the absolute yield gain of intercrops and the effect of agronomic practices.

In a pot experiment with sand, we tested the dissimilar abilities of crop species to access the sparingly soluble Ca-bound P, phytate P, P-coated Fe(hydr)oxide. In a pot experiment with low P soils containing a mixture of organic and inorganic P sources, complementarity and facilitation did not result in increased P uptake by species mixtures, because P uptake was also affected by the competitive equality of the intercropped species. In a field experiment on a low P soil, complementarity and facilitation with respect to P uptake occurred in millet/chickpea relay strip intercropping, but they were not the main drivers for overyielding. In a subsequent meta-analysis on intercropping at the field level, the absolute yield gain of intercropping was mainly attributed to a positive complementarity effect, an outcome of any mechanism reducing competition. This positive complementarity effect was related to the temporal complementarity in using resources, which plays an important role in competitive relaxation and hence overyielding. On a global level, there was a set of coordinated management factors rather than a single factor that drove the yield gain of intercropping, resulting in two contrasting syndromes of production. The first syndrome was a high input - high output strategy that is maize-based with species arranged in relay strips and with high fertilizer input. The second syndrome was a low input - low output strategy that is legume-based and arranged in simultaneous full mixtures or alternate row intercrops with low fertilizer input. Both intercropping strategies saved 16-29% land and 19-36% fertilizer compared to monocultures.

To conclude, the conditions under which the P resource partitioning hypothesis can be tested are limited. Designing intercropping systems could consider a set of management strategies such as using strip intercropping, a relatively short co-growth period of the two crop species, and including species with high productivity (e.g., maize).





MARSCHNER SESSION **UNLOCKING THE NUTRITIONAL VALUE OF COMMON BEAN IN THE PORTUGUESE AGRI-FOOD SCENARIO**

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Common bean (*Phaseolus vulgaris* L.) is the most widely produced and consumed legume in Portugal, with an average national production of approximately 2397 tons spread across about 3547 hectares of production area, according to FAOSTAT's 2017 data. Despite the considerable level of genetic diversity in the national germplasm collections, the national catalogue has 17 registered varieties. The National Germplasm Bank is currently carrying out phenotyping studies to characterise this diversity in terms of morphological traits, but little effort has been placed into profiling the seeds' nutritional quality. Consequently, these accessions are not being utilised to their full potential in breeding programs, resulting in their underutilisation. The nutritional composition of grains is known to be an important factor in determining their overall quality and value, but it has historically been overlooked in crop selection. Therefore, considering the increasing global population and the need to ensure food and nutrition security, it urges prioritising the production of high-quality grains that meet nutritional requirements.

Herein, the efforts dedicated to valorising a collection of more than 250 common bean accessions, conserved in the National Germplasm Bank, will be described. This includes the screening for minerals, protein, phytic acid, starch, total phenolics, saponins, and antioxidant activity and an integrated approach to correlate these with the known morphological traits. The results show that, from a nutritional standpoint, this is a highly biodiverse collection as well. For the mineral analysis, the concentration of the micronutrient Zn ranged from 25.09 to 117.5 µg/g and of Fe from 35.88 to 110.2 µg/g, corresponding to a coefficient of variation (CV) of 29% and 21%, respectively. In regards to the concentration of the macronutrients, P ranged from 2.5 to 7.2 mg/g (CV of 17.5%), K ranged from 8.5 to 20.9 mg/g (CV of 11%), Ca ranged from 0.1 and 8 mg/g (CV of 31%), and Mg ranged from 0.4 to 7.3 mg/g (CV of 40%). Protein percentage ranged from 16.6 to 31.0 % (CV of 13%), phytic acid concentration ranged from 2.25 to 5.90 mg/g (CV of 26%) and starch concentration ranged from 11.5 to 44.0 mg/g (CV of 25%). The parameters that varied the most amongst bean accessions were Zn, Ca and Mg concentration and can help to explain the variation within the collection. Further nutritional traits are under analysis to perform a complete profiling of the collection and contribute important knowledge for future breeding programs and agro-environmental practices.





MARSCHNER SESSION **PLANT-BASED DIETARY INTERVENTION FOR GLYCAEMIC CONTROL IN INDIVIDUALS WITH TYPE 2 DIABETES**

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Plant-based dietary choices are crucial in improving metabolic health and managing chronic diseases. Diabetes mellitus (DM) is a chronic metabolic disorder affecting millions of people worldwide, leading to significant health complications and significantly contributing to morbidity and mortality. Dietary habits influence glycaemic control, with refined carbohydrate intake contributing to postprandial hyperglycaemia. Replacing conventional carbohydrate sources with nutrient-dense, plant-based alternatives is a promising strategy for diabetes management. Lentils, rich in fibre, protein, and bioactive compounds, have been associated with improved glycaemic response and overall metabolic health. This study investigates the impact of replacing bread with a lentil-based muffin on glucose metabolism in Portuguese individuals with type 2 diabetes (T2DM) aged between 45 and 75 years old. A two-week crossover clinical trial was conducted with these patients.

In the first week, participants consumed a standard breakfast and afternoon snack of bread with yoghurt or milk. In the second week, the bread was substituted with a lentil-based muffin, formulated without added sugar, while maintaining a similar macronutrient composition. Throughout the study, participants used the FreeStyle Libre system to monitor interstitial glucose levels continuously. Saliva, urine, and blood were collected at the end of each intervention period (after week one and at the end of week 2) to assess metabolic responses. Replacing bread with the lentil-based muffin significantly improved glucose control and led to a significant reduction in blood glucose levels during breakfast, as recorded by the FreeStyle Libre system. These dietary changes not only influenced interstitial glucose levels during breakfast but also had an effect throughout the day, leading to better glucose control. No significant differences were observed in blood clinical analyses. However, insulin levels showed a decreasing tendency after the muffin intervention. Additionally, participants reported reduced hunger levels during the muffin consumption week, suggesting enhanced satiety. These results highlight the potential of a simple plant-based dietary modification in diabetes management. Replacing refined carbohydrate sources, a typical Portuguese breakfast, with fibre- and protein-rich plant-based alternatives, such as lentil-based muffins, may contribute to better glycaemic control and appetite regulation. These findings reinforce the importance of dietary strategies in improving metabolic outcomes for individuals with T2DM and underscore the challenge of dietary habit changes in long-term disease management.





MARSCHNER SESSION **PLANT ORGANIC NITROGEN NUTRITION: COSTS, BENEFITS, AND CARBON USE EFFICIENCY**

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Introduction: Nitrogen (N) availability and form significantly impact plant growth and metabolism. While inorganic N forms like nitrate (NO_3^-) are commonly studied, organic N sources, such as L-glutamine (L-Gln), contribute to plant nutrition in natural ecosystems. The costs, benefits, and carbon use efficiency (CUE) associated with organic N uptake remain poorly understood.

Purpose and Aims: This study investigates plant responses to organic versus inorganic N nutrition, focusing on phenotypic plasticity, N acquisition efficiency, and carbon dynamics. We assess whether organic N uptake leads to specific morphological and physiological adaptations optimizing plant performance.

Methods: Arabidopsis plants were cultivated in a split-root system with stable isotope labeling to track C and N assimilation from L-Gln and NO_3^- . Biomass partitioning, root morphology, and CUE were analyzed to evaluate plant adaptations to different N sources.

Results: Stable isotope analyses revealed that 40–48% of C from L-Gln was retained in plants, contributing 7–8% to total C in both shoots and roots. Plants supplied with L-Gln exhibited increased root mass fraction, enhanced root hair length, and lower N uptake rates per unit root biomass. However, these plants demonstrated significantly higher CUE compared to those grown on NO_3^- .

Conclusions: Our findings suggest that organic N nutrition induces a distinct root phenotype characterized by extensive root and root hair development, optimizing acquisition of less mobile N forms. Enhanced CUE and reduced N uptake per unit root biomass highlight key advantages of organic N-based nutrition, shedding light on adaptive plant strategies in low-N environments.





6

CHAPTER

POSTERS

Theme 1 – Page 108 / 120

Underutilized Crops, Crop Wild Relatives, and Forgotten Foods for Better Nutrition

Theme 2 – Page 121 / 125

Breeding and Genetics for Nutrition and Quality

Theme 3 – Page 126 / 194

Nutrient Uptake, Transport and Homeostasis

Theme 4 – Page 195 / 207

Plant Nutrition Challenges in the Mediterranean Climates – Australia, Europe, and others

Theme 5 – Page 208 / 211

Beneficial Elements (A Tribute to Epstein)

Theme 6 – Page 212 / 232

Plant nutrition challenges towards nutritional Sustainability – Africa

Theme 7 – Page 233 / 243

Plant-based Foods for Human Health

Theme 8 – Page 244 / 250

Abiotic & Biotic Stresses and Plant Nutrition

Theme 9 – Page 251 / 317

Nanonutrition & nano-fertilizers

Theme 10 – Page 318 / 322

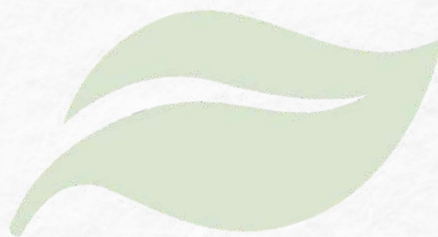
Advances in Potassium Research and Management

Theme 11 – Page 323 / 334

Plant Mineral Nutrition, from the Genes to the Harvest (A tribute to Phillip White)

Theme 12 – Page 335 / 347

Novel Technologies



PO1_1 CHARACTERIZATION OF ANISE GERMPLASM FOR AGRONOMIC PERFORMANCE AND ESSENTIAL OIL CONTENT

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Anise (*Pimpinella anisum* L.) is an annual crop whose seeds (aniseeds), are highly valued for their culinary applications. Its essential oils are used in the food, medicine, cosmetics, pharmaceutical, liquor and perfumery industries. Although the demand for aniseed products has increased in recent decades, there are few registered aniseed varieties. Anise production is still mainly carried out using landraces of uncertain origin, exchanged between farmers in different regions, which do not always offer standard quality due to the mixed nature of these populations. Therefore, breeding programs should be reinforced, focusing on selecting cultivars adapted to local conditions, with an emphasis on traits that allow for mechanical harvesting, as well as seeds quality and essential oil composition.

The aim of this study was to address this gap, investigating the seed yield and essential oil content within a set of 50 anise accessions from worldwide origin. Results showed sufficient variation in agronomic and quality traits, allowing selection of superior germplasm and opening the doors for development of superior cultivars. Accessions PA21, PA47, PA75 and PA87 were selected for their higher seed yield (>3.000 kg/ha). Essential oil (EO) content varied between 0.8% and 5.7% across different genotypes, with 12 accessions exhibited high EO content higher than 5%. Notably, accessions PA1, PA54 and PA55 outstand for 5.7% EO. Still, as the most valuable marketable product is EO, "EO yield" was expressed as kg of EO ha⁻¹, highlighting accessions PA1, PA21, PA26 and PA47 with > 150 kg EO ha⁻¹.

These insights provide a robust foundation for future anise breeding focused on enhancing yield and quality.

ACKNOWLEDGMENTS

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PO1_2 SYNERGISTIC EFFECT OF NICKEL AND MELATONIN ON DROUGHT TOLERANCE IN PEA (PISUM SATIVUM)

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Introduction - The intensification of drought events due to climate change threatens global food security. Pea (*Pisum sativum*) is a key legume for sustainable agriculture, as it fixes nitrogen, improves soil fertility, and has high nutritional value. However, it is highly sensitive to water stress. Nickel (Ni) is an essential micronutrient in nitrogen metabolism, while melatonin (MEL) regulates oxidative stress. The synergy between Ni and MEL may represent an innovative approach to enhancing legume resilience under adverse conditions.

Objective - To evaluate the isolated and combined effects of Ni and MEL on the physiological, biochemical, and productive responses of pea plants under drought stress.

Methodology - The experiment was conducted with *Pisum sativum* cv. "Tom Thumb" grown in pots under two field capacity (F.C.) conditions: well-watered (70-80% F.C.) and drought-stressed (20% F.C.). Ni (45 mg kg⁻¹; 20 g ha⁻¹) and MEL (10 µM and 100 µM) were applied at the TS and V4 stages. Biomass, nodule number, SPAD, pigment and protein content, MDA, H₂O₂, antioxidant activity, and yield components were evaluated. Molecular analyses and mineral composition (ICP-OES) are ongoing.

Results - The combined application of Ni and MEL in drought-stressed plants promoted an increase in aerial and root biomass (+27%) and in nodule number (+27%), indicating greater nitrogen fixation efficiency. In addition, chlorophyll degradation was reduced (+15% SPAD), while antioxidant activity was enhanced, correlating with a reduction in H₂O₂ (-45%) and lipid peroxidation (-38% MDA), suggesting lower oxidative stress. Protein content in roots, leaves, and seeds increased and the number of pods per plant (+33%) and grain biomass (+21%) also improved.

Conclusion - Results indicate Ni and MEL synergy improves nutrition, strengthens antioxidant defences, and maintains cellular integrity, leading to higher productivity under drought stress. This approach may enhance legume resilience to climate change, promoting sustainable agricultural systems.





PO1_3 EVALUATION OF MICRONUTRIENT AND PHYTOCHEMICAL CONCENTRATIONS OF SPROUTED CHICKPEAS SUBJECTED TO ULTRASOUND-ASSISTED COLD WATER SOAKING WITH VARYING TIME-AMPLITUDE COMBINATIONS

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Introduction - Thermosonication, also known as ultrasound-assisted thermal or sono-thermal processing, has emerged as a popular food processing technique for reducing food microbial contamination. Legume sprouts- germinated seeds to be eaten raw or cooked, are a common ingredient worldwide. Chickpeas (*Cicer arietium* L.), are essential legumes for human consumption, and chickpea sprouts may be an engaging format for increasing consumption of both Desi and Kabuli types. However, cold water sonication and sprouting may induce changes in micronutrient and phytochemical composition of chickpeas, and these effects remain underexplored.

Methods - This study examined Desi and Kabuli chickpea seeds and sprouts subjected to sonication pre- treatment (20 kHz, 15 ± 5°C) at varying amplitudes (20%, 40%, 100%) and durations (5, 10, 15 min), and non-sonicated chickpeas (soaked for 10 min in deionized water). After 96 hours of germination, sprouts and dry seeds were analyzed for proteins, phenolics, tannins, DPPH activity, and micronutrients.

Results - Results showed a significant variation ($p < 0.05$) between Desi and Kabuli types in phytochemical and micronutrient concentrations. While sonication did not show significant alterations, germination significantly increased total phenolics in both genotypes ($p < 0.05$), where total phenolics in Desi dry seeds and sprouts were (57 ± 3 mg GA/100g DW) and (68 ± 6 mg GA/ 100g DW) respectively and total phenolics concentrations in Kabuli dry seeds and sprouts were (51 ± 1 mg GA/100g DW) and (74 ± 5 mg GA/100g DW) respectively. The total protein concentrations followed a similar trend: Desi seeds and sprouts had 11% and 13% respectively, and Kabuli seeds and sprouts had concentrations of 15% and 16% respectively. Iron (Fe) levels declined substantially upon germination for both genotypes, accounting for a 23% (in Desi) and 55% (in Kabuli) reduction.

No significant differences were observed in condensed tannins and DPPH activity in Desi and Kabuli, regardless of treated or untreated seeds. Moreover, zinc (Zn), copper (Cu) concentrations did not alter for dry seeds, sonicated sprouts, and un-sonicated sprouts. Manganese (Mn) concentrations remained unchanged in Kabuli but decreased by 5% in sonicated Desi sprouts compared to dry seeds.

Conclusions - Ultrasonication and sprouting of chickpeas is gaining recognition as a novel processing tool in the food industry. This study can aid future research in using sonication to optimize seed priming processes or streamlining industrial processes for removing physical, microbial, or chemical residues in chickpea seeds while ensuring nutrient retention in fresh chickpea sprouts.





PO1_4 ANTI-INFLAMMATORY AND METABOLIC EFFECTS OF LENTIL PHENOLIC COMPOUNDS

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Lentils (*Lens culinaris* L.) are nutrient-dense legumes with a low glycemic index, high phenolic content, and antioxidant properties. Epidemiological data suggests their potential in preventing metabolic disorders, largely due to their bioactive compounds. However, the mechanisms by which lentil phenolic extracts influence inflammatory pathways and metabolic regulation remain poorly understood. This study aimed to identify the lentil variety with the highest phenolic and flavonoid content, characterize the phenolic profile, and evaluate its immunomodulatory and gene expression effects in an in vitro model of intestinal inflammation.

Four *Lens culinaris* L. varieties, distinguished by seed colour- green (Len01, Len02), brown (Len03), and red (Len04)-were analyzed in both raw and cooked forms for their phenolic and flavonoid contents. The variety Len01, exhibited the highest levels of phenolics and flavonoids, and as such it was selected for further analysis. The phenolic profile analysis revealed that raw Len01 had higher concentrations of (epi)catechin, procyanidins, and kaempferol derivatives than other varieties. Cooking reduced certain phenolic compounds, particularly (epi)catechin and procyanidin derivatives, but kaempferol glycosides remained relatively stable. Phenolic extracts from Len01 were then tested on Caco-2 cells, a human colorectal adenocarcinoma cell line with inflammation induced by the pro-inflammatory cytokine interleukin-1 beta (IL-1 β). The secretion of inflammatory markers IL-6 and IL-8 was quantified through ELISA. Results showed that Len01 phenolic extracts significantly reduced IL-6 and IL-8 secretion in IL-1 β -stimulated Caco-2 cells, indicating anti-inflammatory properties. Finally, expression of genes related to inflammation (IL-8, IL-6, IL-1 β , TGF β , TGF β receptor 1), glucose transport (SGLUT1, GLUT2), barrier integrity (Occludin, CDH1), glucose and lipid metabolism (ACAT, PPARY), oxidative stress (HO1) and multi-substrate deacetylase (SIRT1) was assessed using quantitative real-time PCR. It showed that Len01 phenolic extracts modulated mRNA expression by downregulating inflammatory genes while upregulating genes involved in barrier integrity. This suggests a role for lentil phenolics in strengthening epithelial tight junctions and influencing those molecules related to glucose transport and lipid metabolism.

These findings highlight the potent anti-inflammatory effects of lentil phenolic extracts, which attenuated inflammatory responses in vitro and regulated key genes involved in intestinal barrier function and metabolic processes. This study underscores the potential of lentil-derived phenolic compounds as functional ingredients or therapeutic agents for managing inflammation and metabolic disorders.





PO1_6 WEED-BASED BIOSTIMULANT APPLICATION AS A SUSTAINABLE STRATEGY TO IMPROVE DROUGHT RESILIENCE IN BRASSICA JUNCEA

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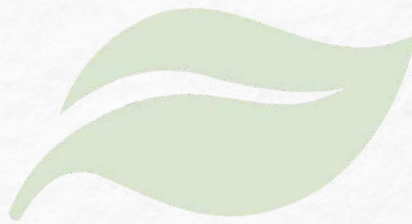
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The efficacy of biostimulants can vary depending on the dosage and plant species. This study aimed to evaluate the physiological and biochemical responses of *Brassica juncea* grown under well-watered and drought-stressed conditions, treated with a novel weed-based biostimulant produced on Terceira Island (Azores). The biostimulant was applied in a range of dilutions (4:1, 1:4, and 1:3 biostimulant to water) across three separate trials in which different traits were measured. Subsequently, growth performance, pigment composition, physiological characteristics, and metabolic indicators were assessed. The biostimulant was made from five weeds, that are common to Terceira Island, which include Common Comfrey (*Symphytum officinale*), Field Horsetail (*Equisetum arvense*), Sorrel (*Rumex acetosa*), Broadleaf Plantain (*Plantago major*), and Ribwort Plantain (*Plantago lanceolata*). Out of eleven kilograms of weed biomass, around four kilograms of biostimulant liquid was produced, which was diluted according to each trial.

Physiological analyses revealed that the highest benefits are in Trial 1 with a 4:1 biostimulant application. This treatment resulted in significantly greater anthocyanin, chlorophyll, and flavonoid content - with total anthocyanins averaging ± 0.3 mg/g, chlorophylls ± 0.9 mg/g - and flavonoids ± 40 mg/g levels. Root length in plants treated with the biostimulant was not significantly different from the control. In Trial 2, biostimulant-treated groups had higher fresh weight and soluble sugar concentrations in both well-watered and drought-stressed conditions.

Although not significantly, dry weight and leaf count were improved in the water-stressed biostimulant-treated groups compared to those of the control. Shoot length, total chlorophylls, anthocyanins, carotenoids, and soluble polyphenol content remained unaffected across all treatments. In Trial 3, biostimulant application resulted in significantly greater plant fresh weight and dry weight under drought stress, indicating improved stress tolerance. Photosystem II (PSII) efficiency, measured by PSII yield, was also significantly higher in biostimulant-treated plants under both well-watered and drought-stressed conditions, suggesting enhanced photosynthetic performance. The electron transport rate (ETR) was highest in the well-watered controls but lowest in their biostimulant-treated counterparts. Leaf temperature was more stable under well-watered conditions in both treated and control groups. Maximum quantum yield of PSII (Fv/Fm) remained constant across treatments, even while minimum fluorescence (Fo) and maximum fluorescence (Fm) were significantly reduced under drought stress, indicating that the biostimulant helped maintain a stable photosynthetic performance. Overall, these results demonstrate that this novel weed-based biostimulant can mitigate drought stress and improve photosynthetic activity and growth performance in *Brassica juncea*, especially when applied at higher dilutions, offering a promising sustainable tool for stress-prone agricultural systems.





PO1_7 DOUBLE-UP LEGUMES: EXPLORING THE IMPACT OF LEGUME-LEGUME INTERCROPPING ON PLANT PERFORMANCE, SOIL FUNCTION, AND PHENOLIC PROFILES

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Legume-legume intercropping provides ecosystem benefits beyond biological nitrogen fixation. Here we report upon interactions mediated by secondary metabolites, particularly phenolics, that influence plant-microbe interactions, allelopathy, and stress adaptation. Yet, as they are regarded as antifeedants by some major animal-feed sectors, phenolics are targets for elimination by crop breeders. Also, their ecological role and potential in cropped systems, including via intercropping, remains to be fully elucidated. This study investigates how novel legume-legume intercrops, and with contrasting phenolic compositions, affects yield, yield qualities, plus soil-provisioning and -functions. A field experiment was conducted to compare intercropping and monocropping of high- and low-phenolic commercial and heritage cultivars of pea (*Pisum sativum* L.) and faba bean (*Vicia faba* L.). The trial was arranged in a randomised block design with consistent plant densities across treatments to ensure comparability. Plant biomass including whole crop- and grain-yield components, plus phenolic profiles, were assessed to determine potential interactions between crop-species and -genotypes (varieties). Soil samples were analysed for nitrogen availability, microbial activity, and microbiome composition. Preliminary results indicate that intercropping affected plant production and soil-residue contributions, with implications for nutrient cycling. Genotype-specific phenolic composition was altered, affecting phenolic content, mineral composition, and overall forage quality. Intercropping also enhanced soil labile organic matter and soil microbial activity, as assessed using the fumigation-extraction method, suggesting shifts in microbial community diversity and soil processes. These microbial changes are hypothesised to influence nitrogen mineralization and retention, as a significant increase in soil nitrogen availability was observed between intercropped and monoculture plots. Depending on the interaction between phenolic compounds and microbial activity, intercropping has either enhanced nitrogen cycling efficiency or slowed it through immobilization, influencing plant nutrient uptake and overall biomass productivity. The results highlight the potential of phytochemically diverse legume-legume intercropping to enhance plant nutritional profile and ecosystem services. Selecting genotypes with contrasting phenolic profiles has provided valuable insights into the role of secondary metabolites in agroecosystems and soil nutrient cycling, emphasizing the need to rethink pulse breeding targets. Further research is needed to refine intercropping strategies for resilient and sustainable agriculture, food, and feed systems.





PO1_8 PHOSPHATE FERTILIZERS IN SOIL PHOSPHORUS DYNAMICS AND THEIR IMPACT ON SUGARCANE YIELD

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This study aims to evaluate the effects of phosphate fertilization in sugarcane ratoons and its impact on phosphorus dynamics in tropical soils. Specifically, it investigates whether different phosphate fertilizers influence phosphorus availability, soil fertility, and sugarcane productivity. The research hypothesizes that various phosphorus sources and their interactions with soil components, such as calcium, iron, and aluminum, affect phosphorus solubility and plant uptake. By exploring fertilizer formulations and their role in enhancing phosphorus efficiency, the study seeks to improve the understanding of nutrient management in sugarcane cultivation and optimize the use of phosphate fertilizers in tropical soils. The study evaluated two successive sugarcane ratoon crops with phosphorus fertilization treatments, including different sources of P. Soil samples were collected at depths of 0-5, 5-10, and 10-20 cm for phosphorus fractionation, following the method of Hedley et al. (1982). Statistical analyses were performed using Tukey's test, and the interaction between fertilizer source and phosphorus reapplication was assessed. The application of monoammonium phosphate (MAP, MAPH, MAPS) fertilizers significantly increased labile P fractions (P-resin) in the 0-5 cm soil layer, compared to control treatments. In contrast, rock phosphate compost (PCOM) had minimal impact on available P, likely due to insufficient microbial activity during composting. Despite variations in fertilizer sources, no significant differences were observed in other P fractions (e.g., P-HCl, organic P fractions) across treatments. The phosphorus fractions most altered by phosphate fertilization are those extracted with an anion exchange resin and phosphorus extractable with NaOH 0.1 mol L⁻¹, which are called labile and moderately labile. However, these effects were only observed after the reapplication of phosphate fertilizers in the second crop season evaluated. This experiment also demonstrated synergy between these fractions. Additionally, phosphorus movement was limited to the topsoil layers, with no detectable changes at deeper layers. The study suggests that P availability in soil is influenced by the fertilizer type, with ammonium-based phosphates promoting higher labile P concentrations. However, the overall phosphorus distribution in the soil was complex and influenced by both the fertilizer's chemical properties and the interaction with organic materials. Polifosfato behaved similarly to TSP in altering phosphorus fractions. Despite increasing available phosphorus, fertilization did not improve the growth of sugarcane ratoons, even with reapplication in the third ratoon. This indicates limited benefits of phosphorus fertilization for this particular cane variety under the studied field conditions.





PO1_9 REVITALIZING UNDERUTILIZED CROPS FOR A SUSTAINABLE AND NUTRITIOUS FOOD SYSTEM IN EUROPE

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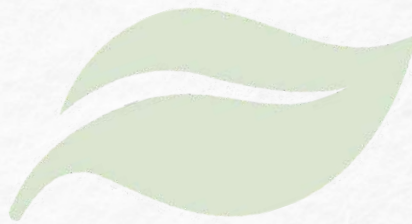
Introduction: The demand for nutritious and environmentally sustainable crops has become increasingly urgent amid growing concerns over food security, agricultural sustainability, and climate resilience. Despite their historical importance and adaptability, many nutrient-rich crops remain underutilized in Europe. The Diversicrop and BioValue projects seek to bridge this gap by promoting stress-resilient crops such as rye, buckwheat, legumes, and selected vegetables, which provide essential nutrients, require fewer agricultural inputs, and support more sustainable food systems.

Methods: Diversicrop integrates historical, genetic, and agronomic research to explore the adaptation of these crops to changing environments and their role in enhancing dietary diversity. It examines historical cultivation practices to inform modern agriculture, assesses genetic diversity for improved climate resilience, and evaluates nutritional value and their potential to mitigate diet-related diseases. The BioValue project develops a dynamic and modular agent-based simulation tool to analyze the interactions between biodiversity, the agri-food value chain, the environment, consumer preferences, and health outcomes. This tool integrates multi-source data, models various stakeholders' behaviors, simulates policy-driven scenarios, and serves as a decision-support system for sustainable agri-food policies.

Results: Reintroducing underutilized crops faces production, market acceptance, and consumer awareness challenges. Diversicrop collaborates with policymakers, farmers, processors, and retailers to develop strategies that enhance cultivation and consumption, aligning with the European Green Deal's Farm to Fork and Biodiversity strategies. The project provides actionable strategies that balance agricultural sustainability with human nutrition by harmonizing fragmented data. The BioValue project reintegrates underutilized crops into the European agri-food value chain through agent-based modeling, participatory breeding, and collaboration with nutritionists and chefs. Certification and traceability systems enhance transparency, promoting seven crops across fourteen countries. By addressing environmental challenges, BioValue supports sustainable agriculture and healthier diets.

Conclusion: By leveraging insights from both Diversicrop and BioValue, future initiatives should explore plant-based alternatives, functional foods, and innovative food technologies leveraging underutilized crops. Addressing environmental, economic, and health challenges will support the European Green Deal and UN Sustainable Development Goals. Moving beyond these projects, the goal is to establish a robust, diverse, and sustainable food system where underutilized crops are fully integrated into modern agriculture and daily diets, ensuring long-term benefits for both people and the planet.

Acknowledgments: This research was funded by the BioValue project (EU Horizon 2020, GA 101000499), COST Action DIVERSICROP (CA22146), and the Ministry of Science, Technological Development, and Innovation of Serbia (Grant No. 451-03-66/2024-03/200015).



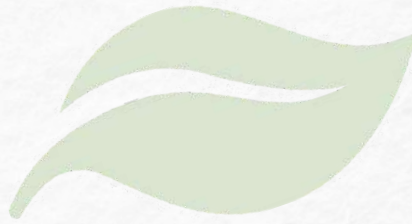
PO1_12 TISSUE-SPECIFIC ELEMENT PROFILES IN SEEDS AND GRAINS OF UNDERUTILIZED CROPS

Paula Pongrac (Slovenia)¹; Ela Vavpetič (Slovenia)¹; Neža Kokalj (Slovenia)¹; Aleš Kladnik (Slovenia)¹; Maja Kajin (Slovenia)¹; 3; Primož Vavpetič (Slovenia)²; Mitja Kelemen (Slovenia)²; Blaž Režonja (Slovenia)¹

1 - Biotechnical Faculty, University of Ljubljana; 2 - Jožef Stefan Institute, Ljubljana; 3 - Department of Ecology, Rio de Janeiro State University

Differences in element composition of staple seeds and grains are the basis of diverse diets, which are best suited to satisfy adequate element requirements in a healthy individual. Often, only selected tissues of seeds and grains are consumed, e.g. when cereal grain is processed (dehusked, milled and/or polished) to obtain desired fraction(s). Therefore, to assess the amounts lost due to processing and to acquire background values in edible portions, element profiles of seed and grain tissues should be compiled. Because manual dissection of seeds and grains is tedious, and mechanical fractionation may be too coarse, an in-situ analysis of element composition of seed and grain at tissue level should be performed. Available techniques are either X-ray fluorescence-based or ICP-MS-based and allow imaging distribution of elements at tissue, cell-type and subcellular levels. In this study we captured tissue-specific profiles in seeds and grains of eight underutilized crops, namely flax (*Linum usitatissimum*), chia (*Salvia hispanica*), poppy (*Papaver somniferum*), caraway (*Carum carvi*), oilseed rape (*Brassica napus*), quinoa (*Chenopodium quinoa*), Tartary buckwheat (*Fagopyrum tataricum*) and proso millet (*Panicum miliaceum*). A non-destructive, multielemental and quantitative technique micro-particle-induced X-ray emission (micro-PIXE) with imaging resolution of below 5 μm (allowing tissue-level analysis) was used. To identify tissues, sections were first imaged using bright field and autofluorescence microscopy, followed by mapping of P, S, Cl, K, Ca, Mn, Fe and Zn allocation in seeds and grains. Example of micrographs, distribution of P, K and Ca in longitudinal section, and distribution of Mn, Fe and Zn in transverse section of caraway is shown in Figure 1. In post-measurement evaluation, image analysis allows extraction of element concentrations in selected seed and grain tissues. Tissue-specific element profiles in caraway are shown in Figure 2, where values are in mg kg^{-1} dry matter. Element distributions and tissue-specific element profiles in analysed underutilized crops will be presented and discussed.





PO1_14 CHLORIDE-DEPENDENT PLASMA MEMBRANE HYPERPOLARIZATION CONFERS SUPERIOR SALINITY TISSUE TOLERANCE IN WILD RICE ORYZA COARCTATA

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¹ - School of Biological Sciences, University of Western Australia

Salinity tissue tolerance is a key trait that confers the adaptive potential of halophyte species. The aim of this study was to understand the mechanistic basis of salinity tissue tolerance in the *Oryza coarctata*, a halophytic wild relative of cultivated rice *Oryza sativa*, to be then used as novel targets for improving its salinity stress tolerance. Salinity induced ~ 80% decline in the mesophyll cell viability in cultivated rice, whereas only 15% reduction was observed in the wild rice. In response to NaCl treatments, mesophyll cells of *O. coarctata* possessed less Na⁺ uptake and better K⁺ retention than cultivated rice. Pharmacological experiments suggested that salinity-induced Na⁺ uptake and K⁺ loss in *O. coarctata* were mediated by non-selective cation channels (NSCCs). While in cultivated rice K⁺ loss was mediated predominantly by GORK (guard cell outward-rectifying K⁺) channel. Salt treatment resulted in a depolarization of the plasma membrane (PM) in *O. sativa*. In contrast, *O. coarctata* had NaCl dose-dependent hyperpolarization in the mesophyll cells, due to its higher preference for Cl⁻ uptake. This difference in plant ionic relations was partially attributed to the difference in transcriptional changes in AKT1, SOS1, HKT1, and CLC1 transporters. It is concluded that *O. coarctata* possesses a strong ability to discriminate between Cl⁻ and Na⁺ uptake (a trait lacking in the cultivated rice) and use it to maintain negative membrane potential (MP) values without activating H⁺-ATPase, thus enabling more efficient K⁺ retention in mesophyll at no energy cost. The above traits should be considered as potential targets in the rice breeding program for salt tolerance enhancement.





PO1_15 HARNESSING AEGILOPS TAUSCHII DIVERSITY FOR FE-BIOFORTIFIED AND - DEFICIENCY TOLERATED BREAD WHEAT

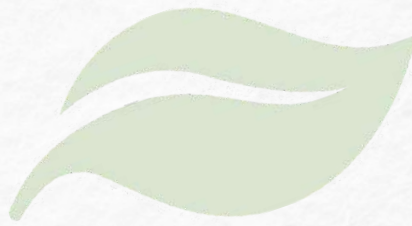
Tomoko Nozoye (Japan)1; Yuta Nagai (Japan)2; Yoshihiro Koyama (Japan)3; Tomoki Okamura (Japan)4; Yusei Hiraki (Japan)5; Hiromi Nakanishi (Japan)2; Yoshihiro Matsuoka (Japan)3; Seiji Nagasaka (Japan)4; Atsushi Ishihara (Japan)5; Takayoshi Ishii (Japan)6; 7; Hisashi Tsujimoto (Japan)6; 7

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Bread wheat (*Triticum aestivum* L. subsp. *aestivum*) is an important crop for global food security. Bread wheat is produced on more land than any other crops and provides a fifth of all calories consumed by humans. It was pointed out that inadequate irrigation in the dryland progressed to the accumulation of salts, increasing soil pH. Irrigated salt-affected soils were estimated between 20-50 % of the irrigated area. In these drylands, iron (Fe) deficiency of plants is one of the agronomical problems. It was expected that the generation of Fe deficiency tolerate and/or Fe biofortified bread wheat would contribute to global food security. Bread wheat originated through a few events of natural hybridization between durum wheat (*T. turgidum* L. subsp. *durum*) and *Aegilops tauschii* Coss. (*Ae. squarrosa* auct. Non L.). *Ae. tauschii* is a wild diploid self-pollinating species ($2n = 2x = 14$, DD), and has been a donor of the D genome to the hexaploid genome of bread wheat ($2n = 6x = 42$, AABBDD). Since there are numerous *Ae. tauschii* accessions available in genebanks, it is speculated that there remain many useful genes that can improve the yields and qualities when transferred to bread wheat. The physiological analysis combined with the genetic analysis of *Ae. tauschii* accessions might find the new key components that contribute to the efficient uptake and translocation of Fe.

Previous research showed that there were diversities in all physiological traits examined in 42 of *Ae. tauschii* accessions and several candidate genes were extracted by Genome-Wide Association Study (GWAS) analysis (Nozoye et al., 2023). This study analyzed physiological traits in 209 accessions of *Ae. tauschii*, involving Fe homeostasis, i.e., mugineic acid family phytosiderophores (MAs), phenylamides, SPAD values, and metal concentrations to further identify the candidate genes. The SPAD values were negatively correlated to the 2'-deoxymugineic acid (DMA), one of MAs, consisting to the previous study. The Fe concentrations in both shoots and roots were correlated to the zinc, copper and manganese concentrations. Principal component analysis suggested coumaroylputrescine among analyzed phenylamides has possibility to be involved in Fe homeostasis in *Ae. tauschii*. Furthermore, GWAS analysis with 209 accessions extract the candidate genes with strongly connected to the variations in each physiological trait analyzed in this study. We believe that further analysis could generate Fe deficiency tolerate and/or Fe biofortified wheat to contribute food production in the drylands.





PO1_17 **CAN QUINOA (CHENOPODIUM QUINOA) REPLACE TRADITIONAL CEREALS UNDER CURRENT CLIMATE SCENARIOS?**

Sergey Shabala (Australia)¹; Hongju Sun (China)^{3; 4}; Waqas ud Din Khan (China)⁵; Michael Palmgren (Denmark)⁶

1 - University of Western Australia, Australia; 2 - Foshan University, China; 3 - Inner Mongolia University, Hohhot, China; 4 - Ministry of Education, Hohhot, Inner Mongolia; 5 - Xinjiang Institute of Ecology and Geography, China; 6 - University of Copenhagen, Denmark

Agricultural production is hampered by climate extremes such as heat, drought, waterlogging, and salinity, affecting soil health, water availability, and crop performance. Not only it cost growers over US\$170Bln in lost production but also has major implications for the global food security. Using wild crops to regain the abiotic stress tolerance that was lost or weakened during domestication is fundamental to achieving global food security and sustainable agricultural production in the face of climate change. The progress in the field could be achieved by introducing genes from wild relatives, but the lack of understanding of the operation of specific genes in planta remains a major hurdle in breeding programs, calling for broader use of cell-based phenotyping platforms. An alternative solution is to engage in direct domestication of wild relatives that already have the genes required for abiotic stress tolerance. In this talk, we argue that under current climate scenarios, agriculture in the 21st century will become saline, severely limiting (or even making impossible) the use of traditional cereal crops for human calorie intake. As regaining the lost abiotic stress tolerance can only be done using modern gene editing technologies and given uncertainties on when and to what extent the public will embracing such new technologies, de novo domestication of already tolerant wild species or semi-domesticated "orphan" species is arguably the most efficient way to proceed. One of them is quinoa (*Chenopodium quinoa*), a pseudo-cereal crop with exceptional nutritional qualities. Accordingly, we comprehensively evaluate nutritional qualities of quinoa and discuss the benefits of using quinoa as a viable alternative to traditional cereals, from both agronomical and nutritional point of view. We also highlight the existing gaps in the knowledge and next steps required to assure public acceptance of quinoa in a daily diet, alongside (or instead of) traditional cereals such as wheat or rice.





PO1_18 OPTIMIZING LEGUME RESIDUE INPUTS FOR SOIL AND CROP HEALTH

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1 - Universidade Católica Portuguesa, CBQF - Centro de Biotecnologia e Química Fina – Laboratório Associado, Escola Superior de Biotecnologia, Rua Diogo Botelho 1327, 4169-005 Porto; 2 - Ecological Sciences, James Hutton Institute, Invergowrie, Dundee, Scotland DD2 5DA, UK

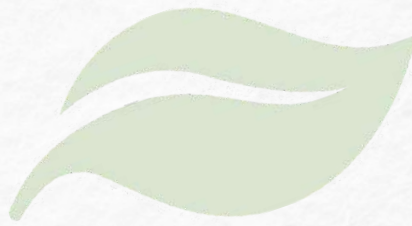
Objectives As sustainable agriculture increasingly relies on organic inputs, incorporating residues into soil, legumes in particular, is recognised for its potential to recycle nutrients and support soil health. However, the effects of residue composition (such as phenolics) and application rate remains insufficiently characterized. This study investigated how two incorporation rates of faba bean and pea residues, differing in phenolic composition, influenced soil nitrogen dynamics, microbial activity, CO₂ emissions, and the growth of spring barley.

Methods A sandy loam arable soil from Invergowrie, Scotland, with no history of legume cultivation in the preceding decade, was used to establish a mesocosm experiment. Soil was packed into pots following the standard protocol of Paterson et al. (2008) and planted with spring barley. The experimental design was a randomized block with three treatments: (i) unamended control, (ii) mineral N fertiliser, and (iii) legume residue amendments at rates equivalent to 5 and 20 t ha⁻¹ (dry weight). Residue chemical composition was characterized prior to incorporation. Each treatment had six replicates. Microcosms were maintained under controlled glasshouse conditions, and CO₂ flux was measured periodically over an eight-week period. At harvest, aboveground barley biomass was collected, and soil was sampled for nutrient and microbial analyses.

Results Residue addition significantly increased soil CO₂ emissions, peaking in the first week post-incorporation. The 5 t ha⁻¹ treatment increased soil respiration by 2.2-fold, while the 20 t ha⁻¹ treatment led to the higher increase (4.2-fold) relative to the control. Despite increased respiration, microbial biomass declined, suggesting elevated microbial turnover. High residue rates led to reduced plant-available nitrogen due to immobilisation, resulting in an accentuated decline in barley biomass. In contrast, the lower dose maintained N availability and enhanced plant growth, with faba bean residues increasing biomass by up to 32% over the unamended control. Residue quality further modulated effects: low-phenolic faba bean residues supported the highest biomass due to more rapid decomposition, whereas high-phenolic residues (with 21% more lignin, a recalcitrant compound) decomposed slowly and had minimal immediate benefit, though they may support nutrient release over time.

Conclusion This study demonstrates that both the quantity and quality of legume residues critically affects soil nutrient dynamics, microbial processes, and crop productivity. Incorporating moderate quantities of low-phenolic residues can improve short-term plant performance, while high-phenolic inputs may offer longer-term benefits through gradual nutrient release. These findings highlight the potential to tailor residue management strategies to enhance soil health and plant performance.





PO2_2 GENOME-WIDE ASSOCIATION STUDIES OF MINERAL CONTENT IN PEA

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1 - CBQF - Centro de Biotecnologia e Química Fina – Laboratório Associado, Escola Superior de Biotecnologia, Universidade Católica Portuguesa, Rua Diogo Botelho 1327, 4169-005, Porto, Portugal; 2 - Institute for Sustainable Agriculture, CSIC, 14080 Córdoba, Spain

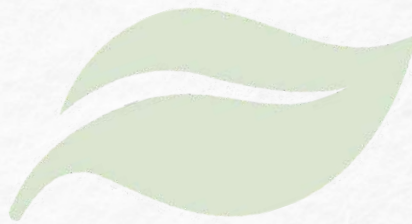
Pea (*Pisum sativum*) is a nutrient-dense crop, serving as an important source of essential micro- and macronutrients, making it a valuable component of a balanced diet. Its seeds provide significant amounts of minerals, including phosphorus, calcium, magnesium, potassium, iron, zinc, manganese, and copper, all of which play crucial roles in human health. Enhancing the mineral composition of pea through genetic improvement can further increase its nutritional value, contributing to global food security and addressing micronutrient deficiencies.

The present study aimed to investigate the genetic basis of mineral accumulation in pea seeds. To achieve this, a genome-wide association study (GWAS) was conducted on a diverse *Pisum* germplasm collection comprising 325 previously genotyped accessions. The mineral content of the seeds was assessed using Inductively Coupled Plasma (ICP) Spectroscopy. Genotyping was performed using the Illumina Infinium® BeadChip, generating data for 11,366 single-nucleotide polymorphism (SNP) markers distributed across the genome.

The GWAS identified multiple significant SNPs associated with mineral content across different chromosomes. A total of 23 SNPs were significantly associated with iron content, while 18 SNPs were linked to magnesium content, both spanning chromosomes from Ps01 to Ps07. In the case of copper, 17 SNPs were identified on chromosomes Ps01, Ps02, Ps03, Ps04, Ps05, and Ps06. Similarly, 16 SNPs were found to be significantly associated with potassium content, distributed across chromosomes Ps01, Ps03, Ps04, Ps05, Ps06, and Ps07. For manganese content, 11 SNPs were detected on chromosomes Ps02, Ps03, Ps04, Ps05, and Ps06. The analysis also revealed five SNPs associated with phosphorus content on chromosomes Ps01, Ps04, Ps05, and Ps06, while six SNPs were linked to calcium content on chromosomes Ps03, Ps04, Ps05, and Ps06. Lastly, five SNPs significantly correlated with zinc content were located on chromosomes Ps01 and Ps05.

The identified genomic regions provide valuable insights into the genetic control of nutrient accumulation and serve as potential targets for breeding programs aimed at improving the nutritional quality of pea seeds. This knowledge can be utilized in genomics-assisted breeding to develop biofortified pea varieties with enhanced mineral content, ultimately benefiting both agriculture and human health.





PO2_3 UNRAVELING THE IMPACT OF DROUGHT STRESS ON NUTRITIONAL PARAMETERS AND DEFENSE RESPONSE OF PEA GENOTYPES

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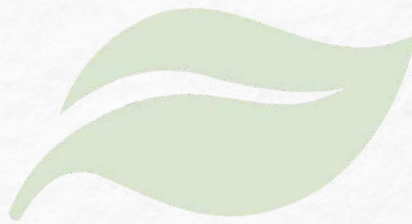
Drought stress negatively affects plant growth, triggering morphological, physiological, and biochemical changes that reduce productivity. Identifying drought-tolerant cultivars is essential for enhancing agricultural resilience and ensuring food security.

This study evaluated the drought tolerance of three pea genotypes: *Pisum sativum* var. *humile* (accession #196), *P. sativum* var. *arvense* (accession #222), and *P. fulvum* (accession # 312). Two irrigation treatments were applied: control (70% field capacity) and drought stress (30% field capacity) for 20 days during the vegetative phase. Each plant was grown individually in a pot, with pots randomly placed in a growth chamber (day temperature: 22°C, night: 18°C, relative humidity: 60%). After the experiment, plant height, fresh weight (FW), and dry weight (DW) were recorded. Additionally, protein content, polyphenols, tannins, antioxidant activity, and pigments (chlorophyll, anthocyanins, carotenoids) were analyzed using spectrophotometry.

Drought stress significantly reduced plant height (30%), FW (60%), and DW (35%) in *P. sativum* var. *arvense*, while *P. fulvum* and *P. sativum* var. *humile* showed no major growth reductions. Under drought conditions, antioxidant activity in *P. sativum* var. *arvense* was 34% lower than in the other two genotypes. Polyphenol content increased in all three genotypes under drought, with *P. fulvum* exhibiting the highest levels (410 mg GAE/100 g DW). Tannin content decreased in *P. sativum* var. *arvense* (6.5%) and *P. sativum* var. *humile* (2.8%) but increased by 2.9% in *P. fulvum*. Protein content declined in *P. fulvum* (7.5%) and *P. sativum* var. *arvense* (15.3%) but increased by 1.5% in *P. sativum* var. *humile*. Anthocyanin content rose by 38% in *P. sativum* var. *humile* and 24% in *P. fulvum*, while it dropped by 20% in *P. sativum* var. *arvense*. Total chlorophyll and carotenoid content remained stable across all genotypes.

The results suggest that genotype plays a significant role in drought tolerance. *P. fulvum* and *P. sativum* var. *humile* maintained growth under drought conditions, while *P. sativum* var. *arvense* experienced severe reductions in growth and antioxidant capacity. *P. sativum* var. *humile* exhibited protective biochemical responses, increasing polyphenol and anthocyanin levels. *P. fulvum* uniquely increased tannin content, while *P. sativum* var. *humile* increased proteins. Among the genotypes studied, *P. sativum* var. *arvense* was the most drought-sensitive, whereas *P. fulvum* and *P. sativum* var. *humile* demonstrated strong drought tolerance by maintaining growth and activating biochemical defense mechanisms.





PO2_5 DEVELOPMENT OF FE AND ZN-ENRICHED RICE THROUGH MARKER-ASSISTED SELECTION

Takehiro Kamiya (Japan)¹; Shihab Uddin (Japan)¹; Toru Fujiwara (Japan)¹

¹ - University of Tokyo

Hidden hunger, a deficiency of micronutrients in humans, is a widespread issue, particularly in populations that rely heavily on their primary caloric source on cereals, since cereals naturally contain small amounts of micronutrients. Fe and Zn are one of the micronutrients whose deficiency causes hidden hunger.

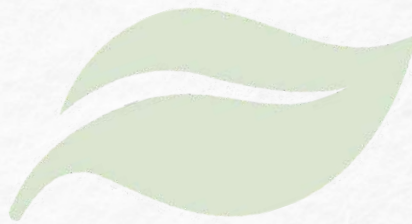
Bangladesh has the highest per capita rice consumption in the world, which exacerbates Fe and Zn in its population. One strategy to tackle hidden hunger is the development of nutrient-rich (biofortified) rice varieties. However, conventional breeding of biofortified rice is time-consuming due to the labor-intensive selection process, which involves growing and harvesting a large number of plants followed by the measurement of grain element concentrations.

Here, we developed DNA markers for a high-Fe and high-Zn rice mutant previously identified in our research and introduced the mutation responsible for this phenotype into Bangladesh rice cultivars by marker-assisted selection. The mutant, named 1095_k (Japonica rice background), has a nonsense mutation in Vacuolar Iron Transporter 2 (OsVIT2) and accumulates high Fe and Zn in grain without compromising plant growth (Kandwal et al. Front. Plant Sci. 2022).

To perform marker-assisted selection, we generated DNA markers: dCAPS marker and a marker that does not require a restriction enzyme. Using these markers, we backcrossed Bangladeshi rice cultivar, BRRI dhan48, with 1095_k, and performed marker selection. At BC5F1 generation, genome sequencing was performed to determine the genomic region retaining the Japonica background. The analysis revealed that a 10 Mb region of chromosome 9, where the OsVIT2 mutation is located, retains the Japonica background.

For further selection, we developed additional markers and selected BC5F2 plants with minimal Japonica background. At BC5F3 generation, we fixed the OsVIT2 mutation as homozygous and harvested seeds. Notably, in BC5F3, only 192 kbp region differs from BRRI dhan48, resulting in a single amino acid difference. The phenotypes, including grain shape and plant morphologies, of BC5F2 were not different from the BRRI dhan48. Currently, we are growing BC5F3 and determining the grain Fe and Zn concentrations.





PO2_6 IN SEARCH OF ZINC, IRON TRAITS IN POACEAE: GENOME IONOME VARIATIONS FOR ADVANCING FUTURE FOOD SECURITY

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Poaceae family (corn, rice, wheat, barley, oats, rye) contains some of the most important staple crops to address the micronutrient malnutrition also known as “Hidden Hunger” affects 2 billion people globally. The genetics underlying seed ionome in plants remains largely unexplored. Therefore, we conducted a comprehensive study to dissect the wheat ionome genes and proteins. This study will provide important insights on the ionome variations in wheat, on the bioinformatics basis of the genome-ionome variations and linkages. Zinc (Zn) and iron (Fe) are essential micronutrients for plant growth and development. Identifying ionome gene products contributing genomic regions helps to dissect the genetic architecture of ionomic traits for use in biofortification. As sequenced plant genomes growing, they increasingly require comprehensive gene / protein experimental structural, and functional annotation, and therefore useful biological information. With the future goal of plant nutrition in mind, here we took a comprehensive annotation approach to create a list of Poaceae ionomics associated genes and proteins. Preliminary characterization of identified mineral nutrient gene families and proteins from published data sets will be presented. Genomic regions governing seed Zn, Fe, and other mineral nutrients were investigated in Poaceae family crops via reviewing gene models and curation. This research could provide information for cereal breeders and biofortification researchers to develop/ select crop cultivars with high seed mineral content in their programs. Overall, our study provides crucial insights into the genetic basis of ionomic variations in wheat and will facilitate improvement in breeding for seed zinc and iron mineral content. The current status of this project will be presented including the further research results.





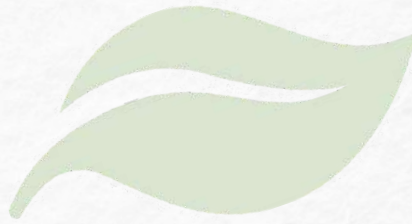
PO2_7 COMPREHENSIVE EVALUATION OF ACID TOLERANCES OF THE MAIZE HYBRIDS BY USING MULTIVARIATE ANALYSIS

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Acidic soils, characterized by nutrient deficiencies and metal ion toxicity, pose significant constraints to maize productivity. The cultivation of acid-tolerant varieties represents a promising strategy to mitigate these challenges. In this study, we evaluated the response of 50 maize hybrids to acid stress (AS) and control conditions (CK) through a pot experiment, measuring 15 traits at the V5 stage. Multivariate analysis was employed to identify key indices for assessing acid tolerance, and the findings were further validated in field trials using four selected varieties. The results revealed that the majority of maize varieties exhibited sensitivity to acid stress, with significant variability observed across the measured indicators. Cluster analysis categorized the 50 hybrids into five distinct groups based on their acid tolerance levels. Stepwise regression analysis identified six critical traits—plant height, fresh weight, stem diameter, leaf area, total nitrogen accumulation, and total potassium accumulation—along with three antioxidant enzymes (POD, APX, CAT) and reactive oxygen species (ROS) levels (O_2^- , H_2O_2) as key parameters for screening acid-tolerant varieties ($R^2 = 0.95$). Notably, acid-sensitive (HAS) varieties expended more energy on antioxidant enzyme activities to counteract stress, whereas highly acid-tolerant (HAT) varieties allocated greater energy toward nutrient uptake, growth, and enhanced stress adaptation. Field validation confirmed the reliability of the multivariate analysis in identifying acid-tolerant genotypes. This study provides a comprehensive framework for evaluating maize acid tolerance and highlights the potential for improving yields on acidic soils through the deployment of suitable germplasm. The findings offer valuable insights for breeding programs aimed at developing resilient maize varieties for stress-prone environments.





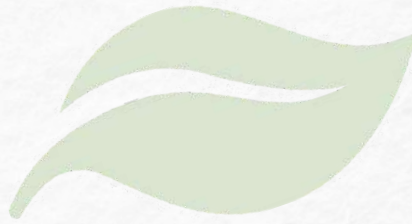
PO3_2 MUTATION OF STRIGOLACTONE BIOSYNTHETIC GENE DWARF 17 IMPAIRS THE RESPONSES OF RICE TILLERING TO N SUPPLY

Le Luo (China)¹; Guohua Xu (China)¹

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Tiller number is one important parameter for rice yield and is influenced by both strigolactone (SL) and nitrogen (N). However, how SL and N interact to regulate the tiller outgrowth in rice is unclear. In this study, we isolated a multi-tillering mutant, tin, from an ethyl methanesulfonate (EMS)-mutagenized population of Wuyunjing 7, a japonica cultivar. The tin mutant exhibited low sensitivity to varying N concentrations during the tiller development. Through bulk segregation analysis (BSA), we identified a missense mutation located in the exon of DWARF 17 (D17), a key gene involved in SL biosynthesis. Complementation experiments confirmed that D17 is responsible for the tin tiller phenotype, and exogenous application of the SL analogue GR24 restored the tiller response of tin to N. Transcriptome analysis further revealed that D17 and SL regulate the tiller response to N by modulating the expression of SQUAMOSA PROMOTER BINDING PROTEIN-LIKE (SPL) genes and ammonium transporter genes. These findings elucidate the mechanism by which SL and N coordinate to regulate rice tillering growth, providing valuable insights for optimizing rice plant architecture to enhance yield potential.





PO3_3 OSNLP3 AND OSPHR2 ORCHESTRATE DIRECT AND MYCORRHIZAL PATHWAYS FOR NITRATE UPTAKE BY REGULATING NAR2.1-NRT2S COMPLEXES IN RICE

Shuangshuang Wang (China)¹; Hanghang Ye (China)¹; Congfan Yang (China)¹; Yan Zhang (China)¹; Jiawen Pu (China)¹; Yuhang Ren (China)¹; Kun Xie (China)¹; Lingxiao Wang (China)¹; Dechao Zeng (China)¹; Haoqiang He (China)¹; Haoyan Ji (China)¹; Luis Rafael Herrera-Estrella (United States)¹; Guohua Xu (China)¹; Aiqun Chen (China)¹

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Nitrogen (N) is the most important essential nutrient required by plants. Most land plants have evolved two N uptake pathways, a direct root pathway and a symbiotic pathway, via association with arbuscular mycorrhizal (AM) fungi. However, the interaction between the two pathways is ambiguous. Here, we report that OsNAR2.1-OsNRT2s, the nitrate transporter complexes with crucial roles in direct nitrate uptake, are also recruited for symbiotic nitrate uptake. OsNAR2.1 and OsNRT2.1/2.2 are coregulated by NIN-like protein 3 (OsNLP3), a key regulator in nitrate signaling, and OsPHR2, a major regulator of phosphate starvation responses. More importantly, AM symbiosis induces expression of OsNAR2.1-OsNRT2s, OsNLP3, and OsSPX4, encoding an intracellular Pi sensor, in arbuscular-containing cells, but weakens their expression in the epidermis. OsNAR2.1 and OsNLP3 can activate both mycorrhizal nitrate uptake and mycorrhization efficiency. Overall, we demonstrate that OsNLP3 and OsPHR2 orchestrate the direct and mycorrhizal nitrate uptake pathways by regulating the NAR2.1-NRT2s complexes in rice.





PO3_4 UNCOVERING RHIZODEPOSITION AND ROOT DEPTH IN BARLEY GENOTYPES USING ^{13}C LABELLING: IMPACTS ON CARBON SEQUESTRATION AND NUTRIENT UPTAKE

Babak Malekian (Austria)¹; Rebecca Hood-Nowotny (Austria)²; Katharina Schott (Austria)²; Mette Vestergård (Denmark)³; Mogens Nicolaisen (Denmark)³; Katarzyna Retzer (Austria)¹

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Rhizodeposition, the transfer of carbon from roots into the surrounding soil, is a critical process linking plant physiology to soil microbial dynamics and nutrient cycling. Understanding genotypic differences in rhizodeposition is essential for designing crops that support more sustainable nutrient acquisition and improved soil health. This work was conducted within the EU-funded BarleyMicroBreed project, which seeks to improve crop performance through root and microbiome-related traits. We investigated rhizodeposition and root distribution in four spring barley (*Hordeum vulgare*) genotypes including Morex, Morex1HL32, Taffa, and Anakin, grown under field conditions in Rassdorf, Austria. Plants were labelled repeatedly with $^{13}\text{CO}_2$ using a bicarbonate-based pulse-labelling system applied to field-installed cylinders throughout the 2024 growing season. At harvest, soil and root samples were collected down to 1 m depth and analyzed for total carbon, nitrogen, and ^{13}C enrichment using elemental analysis–isotope ratio mass spectrometry (EA-IRMS). Roots were separated into macro and cryptic fractions to distinguish biomass from rhizodeposit-derived carbon. We also evaluated the effect on rhizodeposition on NPK uptake of different barley varieties.

On average, 70% of total root biomass was found in the top 15 cm of soil across genotypes, with Anakin producing the highest total root mass (not statistically significant). Taffa and Anakin exhibited deeper root distribution compared to the Morex lines, whose biomass was mostly concentrated near the surface. All recovered root and rhizodeposit fractions were isotopically enriched above natural abundance thresholds, confirming successful labelling. Rhizodeposition was significantly higher in the topsoil (0-15 cm, $p < 0.001$) than in deeper layers, with Anakin and Morex1HL32 exhibiting nearly double the carbon inputs in the surface layer compared to the other two genotypes. Although differences between varieties were not statistically significant overall, the observed trends indicate genotypic influence on rhizodeposition dynamics.

Our findings show that while total root biomass and rhizodeposition differences were not significant, genotypic trends in root depth and carbon input were observed. Anakin and Morex1HL32 had higher rhizodeposition in the topsoil, while Taffa and Anakin had deeper roots, indicating varietal effects on belowground carbon allocation. These traits could influence soil microbial communities and nutrient dynamics, offering targets for breeding barley varieties with improved nutrient uptake efficiency and sustainable soil carbon management.





PO3_5 **EXPRESSION PATTERNS OF ARABIDOPSIS BZIP19 AND BZIP23 ELUCIDATE THEIR INDIVIDUAL CONTRIBUTION TO THE REGULATION OF THE ZN DEFICIENCY RESPONSE**

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Abstract

Micronutrients are required by plants, at adequate concentrations, for optimal growth. In order to avoid deficiency or excess, plants rely on a tightly regulated micronutrient homeostasis network. The prevalence of micronutrient deficiencies in cultivated soils and plants are a global problem that negatively affect crop production and plant nutritional value, as well as human health and well-being (Assunção et al. 2022).

In *Arabidopsis thaliana*, the transcription factors bZIP19 and bZIP23 regulate the homeostasis of the micronutrient Zn, acting as the key regulators of the Zn deficiency response and also as sensors of cellular Zn status (Lilay et al., 2021). Although there is a degree of functional redundancy between bZIP19 and bZIP23, their individual contributions in this regulatory process are not yet understood.

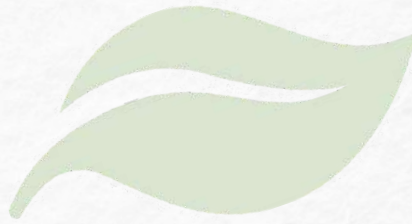
To gain insight on the individual contributions of bZIP19 and bZIP23, here we analysed the phenotypes of bzip19, bzip23 and bzip19bzip23 single and double mutants in response to Zn deficiency, and histochemical GUS staining in pbZIP19::GUS and pbZIP23::GUS lines.

Analysis of mutant phenotypes indicated unequal redundancy between bZIP19 and bZIP23. GUS expression in pbZIP19::GUS was observed throughout the plant, in differentiated cells and tissues, including those involved in transport pathways, whereas in pbZIP23::GUS was observed mostly in meristematic tissue. These results indicate that bZIP19 and bZIP23 have different expression patterns across plant tissues, which may explain the unequal redundancy between bZIP19 and bZIP23, and also their evolutionary retention as paralogs.

Future research should further address bZIP19 and bZIP23 individual regulatory activities. This knowledge has implications for the mechanistic understanding of the Zn sensing and deficiency response in *Arabidopsis*, and for improving Zn nutritional value and use-efficiency in crops.

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- Lilay, Persson D.P., Castro P.H., Liao F., Alexander R.D., Aarts M.G.M., Assunção A.G.L. (2021) *Arabidopsis* bZIP19 and bZIP23 act as zinc sensors to control plant zinc status. *Nature Plants* 7:137–143.



PO3_6 FUNCTION OF OSCAX1A AS A KEY REGULATOR OF NITROGEN UPTAKE EFFICIENCY AND GRAIN YIELD IN RICE

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Elucidating the molecular regulatory mechanisms of nitrogen absorption and utilization in crops, exploring nitrogen-efficient germplasm resources, and breeding novel nitrogen-efficient crop varieties represent urgent demands for the sustainable agriculture. In flooded paddy fields, ammonium serves as the primary nitrogen form absorbed and utilized by rice roots, with substantial genetic variations observed in its uptake efficiency, indicating significant potential for genetic improvement. This project utilized root ammonium uptake activity as a physiological readout in a natural rice variation population and identified a key genetic locus regulating ammonium uptake efficiency through genome-wide association study (GWAS). This locus encodes a rice calcium/proton exchanger OsCAX1a, which modulates root ammonium uptake efficiency by controlling cellular calcium homeostasis. Focusing on two crucial agronomic traits, nutrient efficiency and high yield, this research integrates multidisciplinary approaches including genetics, plant nutrition, and cell biology to decipher the biological mechanisms by which OsCAX1a regulates calcium homeostasis, nitrogen uptake efficiency, and yield traits in rice. Furthermore, we aim to mine superior OsCAX1a allelic variations with potential breeding value from natural rice populations, thereby providing candidate genes and germplasm resources for developing novel rice varieties characterized by high nutrient efficiency, superior yield, and quality.





PO3_7 PHOSPHORUS DEFICIENCY AFFECTS THE RATE OF UPTAKE OF FOLIAR PHOSPHORUS FERTILISERS

Victoria Fernández (Spain)¹; Gabriel Sgarbiero Montanha (Brazil)³; Tamara González-Illanes (Spain)¹; 4; Héctor A. Bahamonde (Argentina)⁵; Enrique Rodríguez Cañas (Spain)⁶; Hiram Castillo-Michel (France)⁷; Clement Hole (France)⁷; Hudson W. P. Carvalho (Brazil)³; 8

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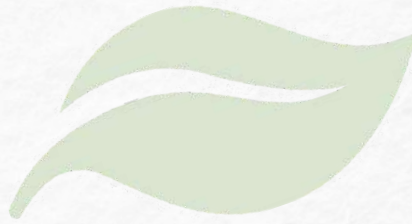
Introduction Phosphorus (P) deficiency is a common nutritional disorder affecting crop plants. The supply of foliar P sprays can alleviate P deficiency symptoms, but many factors associated with the efficacy of foliar P treatments remain unclear.

Purpose and aims This study aimed at evaluating the foliar absorption rate of a hygroscopic and a non-hygroscopic P salt supplied to P-sufficient and P-deficient wheat leaves (*Triticum Aestivum* L var. Aneto), under greenhouse conditions.

Methods Wheat seeds were germinated in pots containing calcareous soil and were irrigated with a complete nutrient solution with or without P, including potassium (K) silicate. After 7 weeks of growth when the flag leaf was developed, plants were transported to the European Synchrotron Research Facilities (ESRF) to carry out a foliar P application experiment. Leaves were treated with a hygroscopic (K_2HPO_4) and a non-hygroscopic (KH_2PO_4) 200 mM P salt plus 0.1% surfactant. After one day, leaves were cryosectioned and observed by Micro X-ray Fluorescence (ID21 beamline of the ESRF) on a cryostage. Additionally, the wettability, surface free energy, stomatal conductance, biomass, pigment content and elemental concentration of P-deficient and P-sufficient leaves were estimated. Leaf anatomy with focus on the ultra-structure of epidermal cells was examined by transmission and scanning electron microscopy, carrying out also Fourier transform infrared spectroscopy analyses of P-sufficient and deficient leaves.

Results Phosphorus-deficient leaves were more unwettable and had a lower surface free energy than P-sufficient ones. Together with the stunted growth observed in P-deficient plants, leaves had a limited stomatal conductance and significantly lower P concentrations, preserving a major area of nano-structured epicuticular waxes. In general, the hygroscopic P salt was absorbed by the foliage at a higher rate compared to KH_2PO_4 . Higher foliar P uptake rates were detected for P-sufficient compared to P-deficient plants.

Conclusion Phosphorus deficiency had a major impact on wheat plant growth and development. Foliar P application to the adaxial leaf side led to increased P concentrations and transport within the leaves. However, many factors affect the response of plants to foliar sprays and more research is required for optimising the efficacy of this fertilisation strategy.



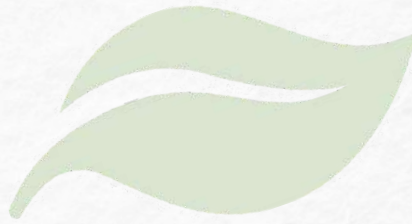
PO3_8 H₂O₂-MEDIATED OXIDATION OF PHOSPHATE STARVATION RESPONSE2 PROMOTES ADAPTATION TO LOW PHOSPHATE IN RICE

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Phosphorus (P) is an essential macro-nutrient for plant growth and development. It is preferentially taken as inorganic phosphate (Pi), an anion that is easily fixed in the soil, making Pi acquisition challenging for plants in most soils. Plants have evolved elaborate mechanisms to adapt to low Pi (LP) conditions through activating Pi-starvation responses. H₂O₂ is an important signal molecule that has been involved in plant adaption to diverse environmental stresses. However, whether H₂O₂ plays a role in Pi-starvation responses remains unknown. Here, we revealed a mechanism by which H₂O₂ production by the respiratory burst oxidase homologs OsRBOH-D and -H facilitates Pi-starvation responses to promote phosphate uptake and utilization under LP conditions in rice. We showed that LP induces H₂O₂ production and promotes the oxidization of the key phosphate signaling transcription factor PHOSPHATE STARVATION RESPONSE2 (OsPHR2) at its Cys377 residue to trigger its oligomerization, specific DNA binding activity and nuclear translocation, thereby enhancing Pi-starvation responses to adapt to LP conditions. Additionally, our molecular and biochemical data revealed that OsRBOH-D is a direct target gene of OsPHR2. Thus, OsPHR2 and OsRBOH-D form a positive feedback regulatory loop in which H₂O₂ acts as a second messenger to amplify the Pi-starvation response.





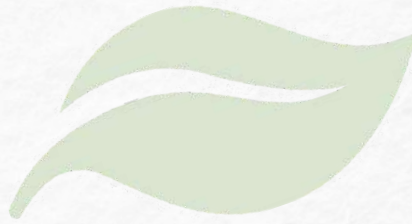
PO3_9 M6A MODIFICATIONS FACILITATE PLANT ADAPTATION TO PI-DEFICIENT STRESS

Zhiye Wang (China)¹

¹ - Zhejiang University

N6-methyladenosine (m6A) is the most prevalent, abundant, conserved internal covalent modification in eukaryotic messenger RNAs (mRNAs). m6A modifications are induced by various stress conditions and post-transcriptionally regulate gene expression. However, how m6A modifications help plants respond to nutrient-deficient stresses remains unclear. Here, we profile high-confidence m6A modifications in Arabidopsis transcriptome-wide under normal and inorganic orthophosphate (Pi)-deficient conditions (-P). Pi starvation induces widespread m6A modifications, mediated by the Pi starvation response (PSR) master regulator PHOSPHATE STARVATION RESPONSE1 (PHR1) and its family members. Many Pi starvation-induced (PSI) m6A modifications occur on PSR-related mRNAs, including PHR1. In addition, PHR1 proteins interact with the m6A writers MRNA ADENOSINE METHYLASE (MTA) and METHYLTRANSFERASE B (MTB) in nuclei under -P conditions. m6A modifications facilitate systemic PSR signaling, as reflected by the reduced Pi content and PSR signaling in a knockdown artificial miRNA line targeting MTA, which shows a global decrease in m6A. Transcriptome-wide mRNA decay analysis reveals that PSI-m6A increases the stability of PSR-related mRNAs, but not through alternative polyadenylation site shifts. Analysis of transgenic plants with mutations in m6A loci demonstrates that m6A stabilizes PHR1 transcripts via a positive feedback loop. Our findings indicate that PSI-m6A modifications facilitate PSR signaling by enhancing the stability of certain mRNAs, shedding new light on the role of m6A modifications in plant nutrient stress responses.





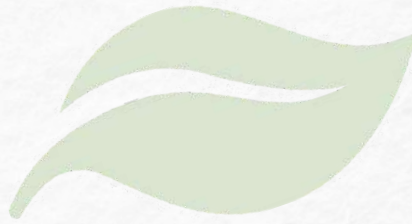
PO3_10 **TRANSCRIPTION FACTOR-CENTERED PATHWAYS COORDINATE ROOT PLASTICITY AND NUTRIENT ACQUISITION IN PLANTS**

Wen Hao Tian (China)¹; Shao Jian Zheng (China)²

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Plant nutrient use efficiency (NUE) is largely determined by the ability of roots to absorb external nutrients, with nutrient availability and distribution subsequently influencing the reprogramming of root system architecture (RSA) to optimize nutrients acquisition. Plant roots exhibit significant plasticity and have evolved mechanisms to optimize RSA, thereby enhancing survival and adaptation to a changing soil environment. Therefore, optimizing RSA is a crucial approach to improving NUE in crops. It is well-established that plants can sense changes in bioavailability of nitrogen (N) and phosphorus (P), and adjust their RSA accordingly to enhance N/P uptake and utilization. We demonstrate that different N forms trigger iron over-accumulation, which in turn generates hydroxy radicals that reshape RSA in response to P deficiency. Under P deficiency, we found that ammonium uptake acidifies the apoplast through proton release, leading to the accumulation of the STOP1 protein, which activates the expression of the malate and citrate transporter genes. As a consequence of rhizosphere acidification and organic acid secretion, insoluble P sources become partially available, improving P nutrition. In addition, STOP1 mediates the feedback repression of ammonium uptake by activating the expression of CIPK23, a protein kinase that inactivates the ammonium transporters AMT1;1 and AMT1;2 via phosphorylation. Furthermore, we will present new data on regulatory genes that can coordinately optimize root growth and nutrient utilization in rice. In summary, elucidating the regulatory mechanisms underlying root development plasticity and nutrient utilization will provide crucial insights for optimizing NUE, achieving fertilizer reduction and sustainable agriculture.





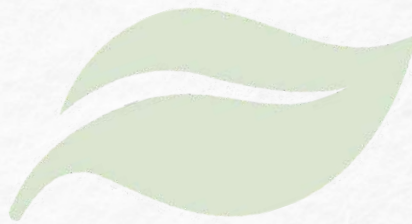
PO3_11 A NOVEL NETWORK CONTROLS ROOT HAIR ELONGATION IN ARABIDOPSIS

Meng Qi Cui (China)¹; Gui Xin Li (China)¹; Zhong Jie Ding (China)¹; Shao Jian Zheng (China)¹

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Root hairs effectively increase the root surface area and are essential for water and nutrient acquisition from the soil. Despite their importance, root hair growth is intrinsically finite. Our previous studies demonstrated that LONG ROOT HAIR (LRH) inhibits the association of eukaryotic translation initiation factor 4Es (eIF4Es) with the mRNA of ROOT HAIR DEFECTIVE6-LIKE4 (RSL4) that encodes the master regulator of root hair growth, thereby repressing RSL4 translation and subsequent root hair elongation. In turn, RSL4 directly transactivates LRH expression to maintain a proper LRH gradient in the trichoblasts. Additionally, we identified another target of RSL4, a novel receptor-like cytoplasmic kinase (RLCK) SRH, as a positive regulator of root hair elongation. We demonstrated that SRH interacts with and phosphorylates ROOT HAIR DEFECTIVE 2 (RHD2) to facilitate reactive oxygen species (ROS) production, therefore promoting root hair growth. Furthermore, SRH is also interacted with and phosphorylated by multiple receptor-like kinases (RLKs) at plasma membrane known to regulate root hair growth. These findings provide compelling evidence for a novel RLKs-SRH-RHD2 signaling pathway that mediates the ROS-dependent regulation of root hair elongation, and bridges upstream signaling events with downstream growth control mechanisms. Overall, the novel network consisted of LRH-RSL4 feedback loop and RLKs-SRH-RHD2 signaling pathway provides new insights into how root hair growth is precisely controlled, and may establish a conceptual framework for molecular design breeding strategies targeting crop varieties with optimized root system architectures.





PO3_12 EFFECT OF PHOSPHORUS FERTILIZER TYPES AND THEIR APPLICATION METHODS ON YIELD AND CALCIUM AVAILABILITY IN CHINESE CABBAGE

Doron Shabtay (Israel)¹; Natalie Toren (Israel)¹; Adi Bier Kushmaro (Israel)¹; Ishai Nahari (Israel)¹; Ran Erel (Israel)¹

1 - Gilat Research Center, Agricultural Research Organization – Volcani Institute; 2 - The Robert H. Smith Faculty of Agriculture, Food and Environment The Hebrew University of Jerusalem

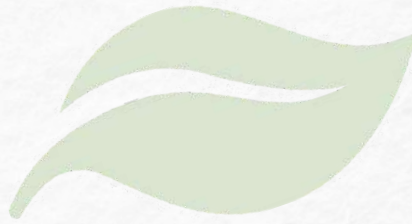
Phosphorus (P) is an essential macronutrient for plant growth, particularly for root development, energy transfer, and photosynthesis. In Israeli field crops, P is mainly applied as a basal fertilizer in the form of orthophosphate (Ortho-P), but its availability depends on soil characteristics. In calcareous soils, common in Israel, P rapidly binds with calcium, forming insoluble compounds that limit plant uptake. Polyphosphate (Poly-P) consists of two or more Ortho-P units chemically linked, creating a slow-release P source. It also has a strong ability to chelate metals, particularly calcium, potentially enhancing nutrient availability. Beyond agriculture, Poly-P is used in the food industry to improve product texture etc. We therefore hypothesized that application of poly-P will be superior over ortho-P, specifically under fertigation that continuously supply fresh P.

A field experiment at Gilat Research Center evaluated the effects of P type and application method on Chinese cabbage. The study included two fertilizer types (Poly-P and Ortho-P) and two fertilization strategies (basal and fertigation), resulting in four treatments. Parameters measured included fresh yield, soil P residuals (Olsen test), mineral composition (ICP), and internal browning incidence—a physiological disorder associated with calcium deficiency.

Fertigation increased yield by 14.57% and calcium concentration by 25.4% compared to basal fertilization. Poly-P fertilization resulted in a 13.22% rise in calcium and an 11.4% increase in P concentration. Calcium levels were 40.7% higher in plants fertigated with Poly-P than in those fertilized with basal Ortho-P. Additionally, Olsen P levels were 21.5% higher in Poly-P-treated plots.

These findings suggest that Poly-P-based fertilization can enhance P and calcium availability, reduce calcium deficiency-related disorders, and improve yield. By improving calcium uptake, this approach may also help mitigate physiological defects associated with calcium deficiency, such as internal browning, thereby enhancing overall crop quality.





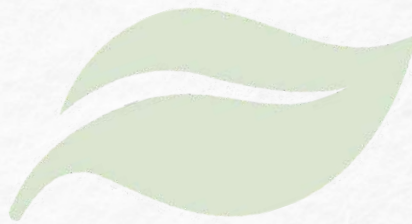
PO3_13 RECIPROCAL REGULATION BETWEEN NHD1 AND GHD7 MEDIATES LOW OR HIGH NITROGEN-TRIGGERED FLOWERING DELAY IN RICE

Shunan Zhang (China)¹; Guanzhong Shou (China)¹; Ying Liu (China)¹; Guohua Xu (China)¹

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Nitrogen (N) -mediated flowering time (heading date in rice) exhibits a U-shape curve (i.e., delay by either limitation or excess of N availability), which affects productivity, resource use efficiency and crop rotation. Our previous study identified an N-dependent flowering regulator, Nhd1 (N-mediated heading date-1), which coordinates N utilization with yield and grain quality. Here, we show that Nhd1 and another flowering repressor, Ghd7 (grain number, plant height, and heading date-7) form a reciprocal regulatory module controlling the N-dependent flowering time under long-day (LD) condition in rice. Nhd1 is epistatic to Ghd7 to promote flowering, while Ghd7 inhibits flowering particularly at low or high N condition in LD. Both genetic and molecular analyses suggest that low-N-triggered delay of flowering is mediated by Ghd7-induced suppression of Nhd1, while high-N delayed flowering relies on Nhd1-activated expression of Ghd7. Furthermore, Heading date-3a (Hd3a) is required for the Nhd1/Ghd7-mediated U-shape response of flowering time to N supplies. Moreover, Nhd1 regulation of flowering time response to N prevails in weak/none function Ghd7 alleles, but not in strong function Ghd7 alleles. The Nhd1-Ghd7-Hd3a regulatory module, thus, orchestrates the flowering time via a seesaw effect for rice adaptation to fluctuating N availabilities.





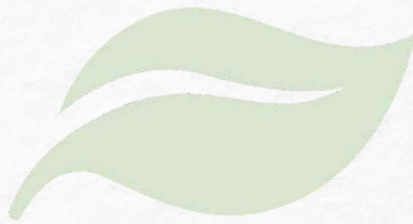
PO3_14 IMPORTIN- α 1 PROMOTES PHOSPHATE UPTAKE THROUGH INTERACTING WITH AND MAINTAINING THE PROTEIN STABILITY OF THE TRANSCRIPTION FACTOR WRKY21 IN RICE

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Due to over-fertilization, many farmland soils are experiencing phosphorus (P) surpluses. Therefore, it is of particular importance to study the phosphate (Pi) uptake mechanisms under Pi-replete conditions. However, much attention has been paid to the mechanisms under Pi-deficient conditions. Previously, we demonstrated that a WRKY transcription factor in rice (*Oryza sativa* L.), WRKY21, promotes Pi uptake under Pi-replete conditions via activating the expression of a Pi transporter gene *PHT1;1* (Zhang et al., 2021, *New Phytol*, 229: 1598-1614). Here, we report an IMPORTIN- α protein, IMPORTIN- α 1 (IM α 1), promoting Pi uptake under Pi-replete conditions. IM α 1 physically interacted with WRKY21, and IM α 1 showed a transcriptional response similar to that of WRKY21, namely induced by Pi supply. Overexpression of IM α 1 led to suppressed plant growth and increased Pi accumulation, accompanied by enhanced expression of *PHT1;1*, mimicking the phenotype of WRKY21-overexpression plants. Knockout of IM α 1 in the background of WRKY21-overexpression lines counteracted the over-accumulation of Pi. Furthermore, WRKY21 protein was largely degraded upon IM α 1 mutation. Our findings represent a novel pathway (IM α 1-WRKY21-PHT1;1) involving both post-translational and transcriptional regulations for maintaining Pi uptake under Pi-replete conditions.





PO3_15 FUNNELIFORMIS MOSSEAE IMPROVES WHEAT GROWTH/NUTRIENT ACCUMULATION BY FACILITATING SOIL NUTRIENT UPTAKE UNDER DAYTIME-ECO₂, NOT NIGHTTIME-ECO₂

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Almost all reports of plant responses to elevated CO₂ (eCO₂) concentrations have been executed under equal CO₂ concentrations over daytime and nighttime, while ambient CO₂ (ACO₂) can be 10-20 % greater during nighttime than during daytime. A simulation of currently atmosphere daytime or nighttime CO₂ concentrations would provide a closer observation on how plants could respond to forthcoming CO₂ rising. Arbuscular mycorrhizal fungus (AMF) always improves plant nutrient absorption and growth. However, interactive effects of eCO₂ and AMF on accumulations of carbon (C), nitrogen (N), phosphorus (P) and potassium (K) in plant and soil, and thus plant growth are rarely elucidated. To understand mechanisms of eCO₂ plus AMF on crop growth and soil fertility, wheat (*Triticum aestivum* cv. Yunmai) were grown over 12-weeks under plus or minus AMF (*Funneliformis mosseae*) inoculation and four CO₂ concentrations, i.e. (1) daytime/nighttime ACO₂ (410/460 ppm), (2) sole daytime eCO₂ (DeCO₂, 550/460 ppm), (3) sole nighttime eCO₂ (NeCO₂, 410/610 ppm), and (4) dual daytime+nighttime eCO₂ ((D+N)eCO₂, 550/610 ppm). Biomass of shoot and root, accumulations of plant C, N, P and K, activities of soil invertase and urease generally significantly enhanced, while concentrations of shoot and root N, P and K, and soil available N, P and K decreased under DeCO₂, NeCO₂ and (D+N)eCO₂. Compared with non-AMF control, effects of *F. mosseae* on above-mentioned characteristics were significantly positive under ACO₂, DeCO₂ and (D+N)eCO₂, while on accumulations of plant biomass, C, N, P and K were negative under NeCO₂. *F. mosseae* association generally mitigated soil nutrient restraints on wheat's response to DeCO₂, while NeCO₂ reduced AMF's positive effects on wheat. These results demonstrated that integrations of AMF's benefits to crops growing under natural habitats of DeCO₂ and/or NeCO₂ are vital in managing potential long-term consequences of forthcoming CO₂ rising on worldwide farming systems.





PO3_16 CHARACTERIZATION OF CUCUMBER RESPONSE TO IRON AND PHOSPHOROUS DEFICIENCY

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In alkaline condition, both Iron (Fe) and Phosphorus (P) are scarcely available for plant acquisition leading to nutritional stresses in crops. In recent years, strong cross-connections between plant responses induced by Fe and/or P deficiency have been reported in the literature, suggesting a close interplay in the regulation and functionality of Fe- and P-acquisition mechanisms. Indeed, some genes induced in response to low-available P are also upregulated in low-Fe conditions and conversely, some components of the P acquisition are enhanced in Fe deficiency. This synergism between Fe- and P-deficiency responses might be taken advantage to improve the acquisition of these poorly bioavailable nutrients. To investigate the interplay between Fe- and P-nutritional pathway *Cucumis sativum* plants were hydroponically grown under Fe and/or P deficiency (+Fe+P, +Fe-P, -Fe+P, -Fe-P; for three weeks). In roots, the transcriptomic profiles indicated that when plants were exposed to -Fe-P, more than 5500 genes were differentially modulated compared to +Fe+P of which about 17% exclusively modulated by -Fe-P and not shared with -Fe+P or +Fe-P. Metabolomic analyses showed also an induction of secondary metabolites' and amino acids' and hormone synthesis. Using hyperspectral imaging analysis, we discriminate between Fe deficiency and P deficiency focusing on reflection intensity changes in specific wavelength bands. Key wavelength bands were selected using Competitive Adaptive Reweighted Sampling (CARS) algorithm. Using these wavelengths and two different classification algorithms, Support Vector Machine (SVM) and Linear Discriminant Analysis (LDA), it was possible to develop a classification model to discriminate between the two deficiencies with an accuracy of the model up to 100% of the test data. Next soluble form of either Fe or P were resupplied, first results indicated that -P and -Fe-P plants exhibited an enhanced accumulation of Fe, and the reciprocal is also enhanced (P in -Fe and -Fe-P). These findings confirm that there is a significant interplay between the responses of the plant to Fe and P deficiency. Furthermore, the transcriptomic data suggest that the double deficient plants have a specific response that it is not display by either single deficient plant. Fundings CEDRIC project is funded by Interreg Italia Austria, DM1062/2021-Tomasi, DM737/2021-Tomasi and Agritech National Research Center are funded by European Union Next-GenerationEU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR)-MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.4-D.D. 1032 17/06/2022, CN00000022) and the Departmental Strategic Plan (PSD) of the University of Udine - Interdepartmental Project on Artificial Intelligence (2020-25)





PO3_17 GOOD NEIGHBOURS – CURRENT-YEAR NEEDLES IN NORMAN FIR (ABIES NORDMANNIANA) RELY ON THEIR 1-YEAR OLD NEIGHBOURING NEEDLES FOR ADEQUATE NUTRIENT SUPPLY

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The distribution patterns of nutrients in evergreen conifers differ substantially from that of annual herbaceous plants. Previous studies have indicated that particularly cations like calcium (Ca) and magnesium (Mg) follow a gradual and seasonal ascent towards the new growth of the trees, but these processes are not fully understood. Both in commercial production of trees and in forest management, these knowledge gaps impose uncertainties with respect to the nutritional status of trees and on how to design fertilization strategies, if needed.

Our experimental data from young Norman fir trees (*Abies nordmanniana*) show that Mg and Ca, added as stable isotopes, remain in the roots and lower parts of the stem during the whole growth season. This finding suggests that remobilization of nutrients is crucial, particularly during and after budbreak, due to the high nutritional demand during new growth. By analyzing old and current-year needles throughout the growth season, we found a distinct decrease in Mg and Ca in the 1-year needles during budbreak, which correlated with an increase in the current-year needles from the same branch. These data therefore suggest a flow of Ca and Mg from the 1-year needles to the current-year ones. By utilizing a novel combination of advanced microscopy, immunohistochemistry and element bioimaging (Laser Ablation ICP-MS), we show that the one-year old needles alter their cell wall pectin, and thereby liberates a fraction of the cell wall bound Ca for remobilization to the emerging current-year needles. This process has the feature of a pulse, lasting only a few days, and involves a dramatic alteration in pectin esterification. Our results pave the way for timely foliar fertilization strategies that can mitigate these deficiencies.





PO3_18 A PROTEIN INTERACTING WITH MEDICAGO TRUNCATULA NODULE IRON TRANSPORTER VTL8 IS REQUIRED FOR SYMBIOTIC NITROGEN FIXATION

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Introduction Iron (Fe) homeostasis plays a critical role in symbiotic nitrogen fixation (SNF) in legumes, yet the molecular mechanisms of Fe delivery to symbiosomes remain insufficiently understood. Nodule-specific Fe transporters like VTL8 and FPN2 facilitate Fe transport across symbiotic membranes to bacteroids. However, the Fe chaperones that mediate cytosolic Fe trafficking to these transporters remain unidentified, despite analogous proteins being characterized in humans and mammals. Addressing this gap is crucial for understanding Fe sorting in nodules and optimizing SNF.

Purposes and aims This study aimed to identify and characterize proteins involved in Fe trafficking within nodule cells and their interaction with specific Fe transporters. Using *Medicago truncatula* as a model system, we determined those proteins interacting with VTL8. After validating their interactions, we assessed their functional roles in SNF. **Methods and Results** A combination of genetic, molecular, and biochemical approaches was used to validate the protein interaction between VTL8 and M90, as well as to determine the physiological function of M90 in plants. Using VTL8 as bait, we identified M90 as a putative interactor in a split-ubiquitin yeast two hybrid assay. The interaction between M90 and MtVTL8 was validated using BiFC. Furthermore, M90-C-Strep protein was transformed into *E. coli* BL21 cells and purified using a Strep-Tactin affinity column. Subsequent experiments demonstrated that the purified M90 protein binds ferrous ions in a 1:1 molecular ratio. Phenotyping studies using RNA interference (RNAi) and CRISPR-Cas9 techniques demonstrated that M90 plays an essential role in SNF, as altering m90 expression levels led to reduced nitrogen fixation capacity. Promoter-GUS staining and immunolocalization confirmed M90 expression in specific nodule zones and association with plasma and symbiosome membranes.

Conclusions This work bridges a key knowledge gap by demonstrating how Fe-transporters interact with other proteins, maybe Fe chaperones, to support SNF, providing novel insights into the molecular mechanisms of Fe homeostasis in legumes. Optimizing Fe delivery processes in legumes may lead to more efficient nitrogen fixation, reducing dependence on synthetic fertilizers and contributing to environmentally friendly farming practices. Future efforts will focus on the validation of Fe transfer between M90 and VTL8 to confirm whether it is an Fe chaperone.

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PO3_20 UNCOVERING THE MOLECULAR MECHANISMS FOR IODINE CONTENT BALANCE IN PLANTS

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Iodine is widely recognized for its essential role as a nutrient in human health. In plants, iodine function is understudied and, nonetheless, considered a beneficial element that, in the proper doses, can enhance plant production and tolerance to environmental stresses. Excessive doses in soil, resulting from anthropogenic actions or in specific ecosystems, can harm plants, known as Reclamation Akagare disease. Therefore, iodine levels should be tightly balanced inside the plant. Plants have developed efficient strategies to balance the iodine content to avoid toxicity. One strategy is the iodine volatilization performed by halide methyltransferase (HMT) enzymes. These enzymes have the ability to methylate iodide, making it possible to release it into the atmosphere. For that reason, HMT enzymes are essential molecular players in the homeostatic regulation of iodine, being considered an important mechanism for iodine detoxification in plants. In the present work, we studied the conservation of the HMT gene family in plants. The phylogenetic overview of this gene family highlighted the high degree of conservation in plants. For a functional genomics analysis, Arabidopsis T-DNA insertion mutants, overexpression, and complementation lines were established and subjected to varying concentrations of iodide salts. The impact of these treatments was studied through the analysis of morphology/physiology parameters, and the iodine content of the different lines was quantified. With the promoter::GFP report assays, we establish the spatial expression patterns and response to iodine treatments. Importantly, transcriptomics analysis of plants treated with iodine revealed how plants react against unbalanced levels of iodine anchored on the activity of HMT genes. The current study will be seminal to paving a new understanding of how plants perceive iodine and how this knowledge can be explored toward iodine tolerance and biofortification in crops.

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PO3_23 SPATIOTEMPORAL ANALYSIS OF PHOTOSYNTHATES TRANSLOCATION TO STRAWBERRY FRUITS USING NON-INVASIVE ^{11}C IMAGING: LEAF POSITION-DEPENDENT TRANSLOCATION PATTERNS

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In protected horticulture, the photosynthates translocation from leaves to fruits governs carbon accumulation in harvestable organs and directly influences yield and quality. Controlling this translocation process is crucial for maximizing fruit productivity. Achieving high-yield and stable crop production requires a detailed understanding and precise regulation of this translocation process. However, conventional analytical techniques often rely on destructive sampling, making it difficult to capture real-time in vivo phenomenon within intact plants, posing a challenge to understanding the differential translocation mechanisms.

To address this challenge, we employed positron-emitting tracer imaging system (PETIS) with the radionuclide [^{11}C] to visualize and quantify translocation in living plants. In this study, we used strawberry plants (*Fragaria* × *ananassa* Duch. cv. Fukuoka S6) to examine the photosynthates translocation dynamics from leaves to fruits and investigated the influence of leaf position on translocation patterns. The cymose inflorescence consisted of one primary fruit, two secondary fruits, and four tertiary fruits, with eight leaves per plant. Given the short half-life of ^{11}C (20.39 min), repeated imaging was performed using different source leaves, and $^{11}\text{CO}_2$ was supplied to individual leaves to trace the translocation. PETIS was employed to capture serial images of ^{11}C -photosynthates translocation. A total of 1080 images were collected over 180 min, enabling a higher-resolution understanding of the leaf-to-fruit movement.

The PETIS imaging results confirmed that ^{11}C -photosynthates translocation from leaves to fruits occurred heterogeneously, with some leaves showing a strong allocation preference towards specific fruits, while other leaves showed a more dispersed translocation patterns depending on their position. Hierarchical cluster analysis was used to systematically classify these translocation patterns, revealing that fruits on the same peduncle tend to share similar source leaves for photosynthates supply. These findings suggest that the structural organization of the inflorescence plays a significant role in determining leaf-specific photosynthates translocation patterns. For instance, understanding these patterns provides insights into the effects of defoliation treatments, allowing for a more strategic approach to selective leaf removal. By optimizing defoliation, carbon allocation can be managed to support fruit development, potentially improving fruit quality and yield.

Our results provide novel insights into how photosynthates are distributed within a plant and emphasize the importance of considering inflorescence structure when optimizing photosynthates translocation for fruit production. The application of PETIS provides a high-resolution understanding of photosynthate translocation, clarifying the impact of cultivation practices on this process. This insight is expected to help identify strategies to optimize translocation.





PO3_24 UNTANGLING THE ROOT METABOLOME ASSOCIATED WITH IRON DEFICIENCY IN CROPS

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Nutrient uptake is carried out by roots, which immediately sense any shortage of essential elements. Root production and secretion of an array of metabolites with diverse functions are key features of plant adaptations to stress. Once in the rhizosphere, metabolites secreted by plants can directly mobilize scarcely bioavailable nutrient pools and attract, repel, inhibit or kill existing biota. Iron (Fe), an essential micronutrient for plants, is abundant in soils but largely unavailable due to its predominant presence as barely soluble ferric oxides, particularly in calcareous soils. Iron deficiency is a widespread challenge in crop production, often requiring Fe fertilizers—many expensive, synthetic, and environmentally persistent—or selecting Fe uptake-efficient species/genotypes to prevent yield and quality losses. Metabolomics provides a powerful approach to unravelling the chemodiversity plants use to tolerate stress, by enabling large-scale metabolite detection in complex matrices. However, a significant proportion of detected metabolites remains unannotated, limiting biological interpretations. Recent advances in bioinformatics have improved metabolite annotation, addressing this challenge. While Fe deficiency-associated root metabolomes have been studied in *Arabidopsis thaliana* and rice, they remain largely unexplored in crops.

Using metabolomics, this study investigated root responses to Fe deficiency in various crop species from the Solanaceae, Amaranthaceae, Fabaceae, and Cucurbitaceae families. Plants were hydroponically grown under Fe-sufficient and Fe-deficient conditions, and roots, growth media and root exudates were collected for analysis. Untargeted metabolomics was performed using liquid chromatography-high-resolution mass spectrometry (LC-HRMSMS), with advanced computational metabolomics tools such as molecular networking applied for data processing. In selected cases, RNA-seq analyses were conducted to complement metabolomics data, providing a more comprehensive view of Fe deficiency-induced root responses. We present findings on the chemodiversity of root metabolites and exo-metabolites associated with Fe deficiency, offering new insights into crop strategies for coping with Fe-limited conditions. By deepening our understanding of how crops adjust their metabolism under Fe scarcity, this study could help develop nature-based agricultural innovations to improve plant resilience and sustainability.

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PO3_25 INVESTIGATING ZN UPTAKE, DISTRIBUTION AND BIOTRANSFORMATION IN SOYBEAN LEAVES AFTER FOLIAR TREATMENT

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Many studies reported that the application of foliar sprays can help to preserve crop yields and quality by effectively correcting nutrient deficiencies, especially in relation to microelements with limited phloem mobility, such as Zn, Fe and Mo. However, the scientific background for this practice is still scarce. Hence, the main aim of this study was to investigate, using μ XRF techniques, the absorption, distribution and biotransformation of chelated zinc - ZnIDHA, applied in soybean leaves.

Three experiments were performed in a growth chamber. Plants were grown in hydroponics under Zn deficiency (-Zn), and as a control (+Zn). Foliar fertilizer treatments (400 mg Zn/L + 0.05% adjuvant) were done twice, at V3 stage, by spraying entire plants except the meristem, from which the measured leaves emerged.

All in vivo measurements were taken 18 days following the application. Metal distribution was analysed on intact, shock-frozen hydrated samples by μ XRF using a customized benchtop machine and by μ XRF tomography at the beamline P06 (PETRA III DESY, Hamburg, Germany). Zn speciation was studied by μ XANES tomography at the same beamline. The OJIP induction kinetics were measured in a direct imaging method on dark-adapted leaves before and after the benchtop μ XRF measurements.

Zinc distribution on tissue-level was examined by μ XRF. Higher accumulation was observed in the veins of positive control (optimal nutrition) and Zn-deficient leaves 18 days after treatment compared to negative control. Micro-XRF tomography revealed on cellular level that upon fertilization the incoming Zn in newly grown leaves arrived via the phloem and accumulated in the epidermis in addition to photosynthetic mesophyll. Zn distribution in the epidermis was mostly symplastic in the ZnIDHA treatment and similar to positive control. In Zn-deficient leaves, Zn was preferentially accumulated in the mesophyll. Micro-XANES demonstrated different ligands in the mentioned tissues and nutrition states.

Zn-foliar fertilization had also a positive effect on electron flow via PSI. Zinc deficiency inhibited the activity of photosynthesis compared to Zn treatment, visible by a significant decline of the efficiency/probability with which a PSII trapped electron is transferred until PSI acceptors, and the electron transport flux until PSI acceptors per PSII.

We demonstrated the delivery of Zn via phloem to Zn-deficient leaves that grew after ZnIDHA application (not treated with fertilizer), and it showed how Zn speciation and distribution differs between Zn-deficient, Zn-replete and Zn-fertilized plants. Our study confirmed that biodegradable ZnIDHA is a sustainable foliar fertilizer that improves zinc nutritional status of plants.

This work was carried out within the framework of the COST Action 19116 Plantmetals.



PO3_26 EFFECT OF UREA, NITRATE AND AMMONIUM AS DIFFERENT SOURCES ON XYLEM SAP COMPOSITION IN CUCUMIS SATIVUS

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Nitrogen fertilizers, particularly urea, are increasingly used because of their low cost and high nitrogen content. Plants absorb nitrogen in different chemical forms, which significantly influences their growth. The most common nitrogen sources urea, ammonium, and nitrate share the glutamate pathway for assimilation into amino acids. The key enzymes involved in this process are glutamine synthase (GS) and glutamate synthase (GOGAT) [1]. Understanding how plants differentially take up and utilize these forms of nitrogen is essential to optimize and improve nitrogen use efficiency in crops.

To investigate these processes, nitrogen uptake and transport were evaluated in hydroponically grown cucumber plants (*Cucumis sativus* L., var. 'Ashley medium-long cucumber'). Plants were grown in a Hoagland nutrient solution, which was replaced weekly with a progressively more concentrated solution.

After 21 days, plants were exposed to three nitrogen treatments: (1) Urea-based, (2) Ammonium-based, and (3) Nitrate-based. The nutrient compositions ($\text{mmol}\cdot\text{L}^{-1}$) for each treatment were as follows: Urea based (1.0), $\text{Ca}(\text{NO}_3)_2$ (0.45), K_2SO_4 (0.45), MgSO_4 (0.3), KH_2PO_4 (0.1), and CaCl_2 (0.55); Ammonium-based NH_4NO_3 (1.0), $\text{Ca}(\text{NO}_3)_2$ (0.45), K_2SO_4 (0.45), MgSO_4 (0.3), KH_2PO_4 (0.1), and CaCl_2 (0.55); and Nitrate-based $\text{Ca}(\text{NO}_3)_2$ (1.0), KNO_3 (0.9), MgSO_4 (0.3), and KH_2PO_4 (0.1). pH was adjusted to 6.5.

After one hour of exposure, the stem was cut, and the exuded sap was collected for two hours [2]. The collected sap was frozen for subsequent colorimetric quantification of ammonium [3], nitrate [4], and urea [5].

These findings contribute to a better understanding of nitrogen uptake dynamics in hydroponic cucumber cultivation and could inform more efficient fertilization strategies to optimize crop productivity and nitrogen use efficiency.

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PO3_27 EXPLORING FOLIAR PHOSPHORUS UPTAKE: RHIZOSPHERIC-LIKE P MOBILIZATION MECHANISMS IN THE PHYLLOSHERE OF WHEAT AND CHICKPEA

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Phosphorus (P) is a critical nutrient for plant growth, yet its low availability in soils limits crop productivity. Plants have evolved sophisticated mechanisms in the rhizosphere to overcome this limitation. These include exudation of organic acids, manipulation of pH, and interactions with P-solubilizing bacteria (PSBs) and mycorrhizal fungi to mobilize and acquire P from otherwise inaccessible sources. However, the ability of plants to access P through alternative pathways, such as the phyllosphere—the aerial leaf surface—has received little attention. This study investigates the mechanisms of foliar P uptake by wheat and chickpea plants, focusing on their ability to solubilize P from desert dust deposited on their leaves. Desert dust is enriched with P that is largely in unavailable forms, requiring plants to solubilize it before absorption.

To investigate foliar P uptake mechanisms, we applied natural desert dust to the leaves of wheat and chickpea genotypes under controlled conditions and analyzed leaf surface traits, metabolite exudation profiles, and microbial community composition. Additionally, we isolated and screened phyllosphere-associated bacteria for their ability to solubilize P. Some chickpea genotypes responded positively to dust application and significantly increased their biomass. Positive response to dust was linked to changes in leaf surface traits, including acidification, enhanced exudation of organic acids (e.g., oxalic and malic acids), higher trichome density and a high capacity to retain dust on the leaf surface.

Wheat genotypes that positively responded to dust application under P starvation showed higher exudation of sugars, alcohols, amino acids, and organic acids from their leaf surfaces. These exudations may directly contribute to P solubilization or may select for a microbial community that is enriched in PSBs. For several bacterial strains isolated from wheat leaves, we were able to demonstrate a strong capacity to release P from phosphate minerals *in vitro*. Our findings provide preliminary evidence of PSBs playing an active role in the phyllosphere.

Understanding the parallels and distinctions between rhizosphere and phyllosphere mechanisms opens new opportunities for improving nutrient acquisition. This knowledge holds significant potential for developing innovative strategies to enhance crop productivity, particularly in P-limited environments.





PO3_30 MECHANISM UNDERLYING BORON DEPENDENT UBIQUITINATION AND DEGRADATION OF ATBOR1

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In *Arabidopsis thaliana*, the borate transporter BOR1 is required for efficient transport of boron (B) under B limitation. BOR1 functions in the plasma membrane and its abundance is regulated by B availability. When the plant root is exposed to high boron, BOR1 is ubiquitinated at the C-terminal cytosolic region, and transported to vacuole via endocytic pathway for degradation. Previously, we identified key amino acid residues of BOR1 required for the ubiquitination. These amino acid residues were located around the borate binding pocket at the center of the transporter. Importantly, a BOR1 variant lacking transport activity was neither ubiquitinated nor down-regulated. Based on these results, we proposed that the conformational change during the transport is coupled to ubiquitination (Yoshinari et al. 2021). However, we also identified BOR1 variants that retain transport activity but exhibit little or no ubiquitination and down-regulation. Additionally, a recent structural study of BOR1 dimer revealed that the C-terminal cytosolic region of BOR1 is inserted into the vestibule of the opposing protomer (Jiang and Jiang, 2024). This conformation was suggested to be in inward-autoinhibited state.

In this study, we investigate the detailed mechanisms underlying the conformation-dependent regulation of transport activity and degradation of BOR1. We are analyzing the structure, transport activity, and degradation of BOR1 variants with amino acids substitutions potentially involved in the C-terminal insertion into the opposing protomer. We are also testing the contribution of phosphorylation/dephosphorylation in C-terminal cytosolic region of BOR1 in this regulatory process. Based on our findings, we would like to discuss a possible two-step regulation of BOR1 transport activity and degradation in response to boron availability.





PO3_31 PHOSPHORUS UPTAKE BY PEANUT: THE ROLE OF CULTIVAR, ROOT SYSTEM AND SOIL P DYNAMICS

Ph.D Carlos Felipe dos Santos Cordeiro (Brazil)1; Ph.D Student Anita Beltrame (United States)3; Ph.D Chad J. Penn (United States)4; 3; Ph.D Ciro A. Rosolem (Brazil)2; 1

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Peanut (*Arachis hypogaea* L.) root morphology plays a crucial role in the uptake of poorly labile phosphorus (P) forms. However, it remains unclear whether this depends on the cultivar or soil P solubility. This study aimed to evaluate P desorption, biomass yield, root morphology and P uptake by modern peanut cultivars under varying soil P levels and soil types. The study was conducted in a greenhouse with a 14-h photoperiod, max and min temperatures of 30 and 22 °C, respectively, for 67 days, using 4 L pots. Phosphorus uptake by two cultivars was tested in three soils (sandy loam, silty loam and clayey-silty loam) adjusted to three P levels (17, 35, and 70 mg kg⁻¹ Mehlich-3 P for low, medium, and high treatments, respectively). An early-maturing (IAC OL3) and a late-maturing peanut cultivar (IAC 503) were grown for each soil type-P level combination. Results showed that P desorption increased linearly across P levels for each soil. Maximum P desorption with water reached 4.8, 5.3, and 6.1 mg kg⁻¹ in the silty loam, sandy loam, and silty clay loam, respectively. The silty loam soil had a low capacity to release P into the soil solution after 24 h of continuous water flow. Interestingly, peanut biomass yield did not respond to high P levels. The late-maturing cultivar also showed no response to P in the silty loam soil. Under P deficiency, the late cultivar exhibited higher biomass yield and greater root length compared to the early-maturing cultivar. However, under high P availability, it developed thinner roots. Despite having a greater root length, this did not increase P uptake in the clayey soil. Higher labile P resulted in greater P uptake by the early cultivar. This was also observed in the late cultivar, but only for the more sorptive soils. On average, P uptake by the late cultivar was 22% higher than that of the early cultivar under low P availability. The late-maturing cultivar showed increased P uptake compared to the early-maturing cultivar in P-deficient soils, primarily due to higher carbon allocation in the roots and the soil's P desorption ability.





PO3_32 EXPLORING LIPOSOMES AS AN EFFICIENT FOLIAR FERTILIZER TARGETING THICK AND WAXY LEAF SURFACES

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Background A profound long-term challenge in agriculture is to improve the efficiency of crop fertilization in order to reduce nutrient requirements and thereby minimize the environmental impact. Foliar fertilization targeting the leaves drastically improves the efficiency for some nutrients and crops but is challenged by specific leaf conditions in certain important crops such as canola. Liposomes are lipid-based vesicles that have been utilized as versatile carriers in a drug-delivery setting. While no viable foliar fertilizers based on liposomes have been developed yet, they have the potential to enhance nutrient uptake through hydrophobic barriers and increase the mobility of immobile nutrients.

Methods In the current study we synthesized and assessed nanosized liposomes based on biodegradable soybean lecithin, a cheap by-product from soybean-based feed production. The shape, size and bilayer characteristics of the liposomes were verified by using dynamic light scattering (DLS), small-angle X-ray scattering (SAXS) and cryo-TEM. The interactions of liposomes with the various barriers encountered in canola leaves were studied through both adhesion and spreading behaviour on the leaf surface, and by tagging liposomes with a fluorophore and tracing the nanoparticles within the leaf tissue.

Results The obtained results indicated that liposomes adhered well to the waxy canola leaf surface. The main point of entry was shown to be through the stomates, and liposomes could be traced in the leaf tissue and at the vascular bundles. The nutrient delivery efficacy was assessed by applying liposomes containing manganese (Mn) to Mn-deficient canola plants to follow the restoration behaviour. Results indicate that liposomes efficiently deliver Mn to the deficient leaves and Mn-deficiency could be restored locally. Long-range translocation was investigated by encapsulating the tracer element cerium (Ce) into liposomes and applying the tracer liposomes to source leaves of canola plants. A preliminary mass spectrometry (MS) study of the different plant fractions suggested that liposomes did not to a significant degree translocate to the sink tissue.

Conclusion Liposomes were demonstrated to possess efficient leaf adherence and spreading properties, enabling penetration of the leaf tissue and effectively restoring nutrient levels in treated canola leaves. However, their ability to facilitate long-range translocation remains uncertain, requiring further investigations and optimization of the liposomal formulation.





PO3_33 RICE PLANTS EXPRESSING THE AQUAPORIN GENE PIP1;2 FROM BROMELIADS INCREASE THEIR NITROGEN ABSORPTION CAPACITY

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Some isoforms of aquaporins are capable of transporting NH_4^+ in addition to water. Therefore, besides their importance in the water relations of plants, they are also important for nitrogen metabolism. Rice cultivation demands a high use of nitrogen fertilizers, which leads to several environmental impacts and high production costs. Thus, the development of cultivars with greater efficiency in nitrogen use is of great importance. The epiphytic bromeliad *Vriesea gigantea* has a PIP1;2 type aquaporin that, in addition to transporting water, aids in NH_4^+ uptake. This is the most frequent form of nitrogen present in the water accumulated among the bromeliad's leaves (called a tank), coinciding with the common nitrogen form found in flooded rice fields. Previous work performed in our lab has provided some transgenic rice lines constitutively expressing VgPIP1;2 from *Vriesea gigantea*. So, a main question arose: could transformed rice plants have an increased capacity for nitrogen absorption? Thus, the objective of this study was to analyze the development of transgenic rice plants cultivated with different nitrogen sources and levels. Transgenic plants and the wild type (control) were grown in hydroponics with a modified Yoshida's (1976) nutrient solution. The roots of these plants were used for morphological measurements, transcriptome analysis by RNA-seq, and metabolome evaluation by gas chromatography and mass spectrometry. The roots of transformed plants showed a higher nitrogen content even when submitted to a significant reduction in nitrogen availability (1/10). Furthermore, the dry mass of the root system in transgenic plants was significantly higher under decreased nitrogen condition. Additionally, the transformed roots showed a change in the gene expression profile of various metabolic pathways, especially nitrogen metabolism, with upregulation of genes involved in nitrogen absorption and assimilation, as well as amino acid biosynthesis. Changes in the profile of metabolites were also observed, such as an increase in the levels of amino acids. The results suggest that expressing PIP1;2 from bromeliads in rice plants provides an effective pathway to increase plant nitrogen use efficiency. CNPq # 308054/2022-9





PO3_34 NODULES INFLUENCE SOIL-TO-SOYBEAN UPTAKE AND TRANSLOCATION OF CESIUM

Kazuki Murashima (Japan)¹; Nao Okuma (Japan)²; Hayato Maruyama (Japan)¹; Toshihiro Watanabe (Japan)¹; Takuro Shinano (Japan)¹

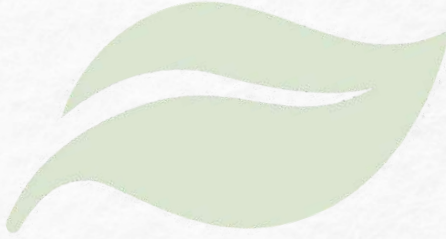
1 - Hokkaido University; 2 - RIKEN BRC

Soybean are known to have higher transfer for radioactive cesium (Cs) from soil to plant compared to other crops such as maize and wheat. In soybean, high-affinity potassium (K) transporters in roots are primarily recognized as being involved in Cs uptake from soil. Recently, high Cs accumulation in nodules has been reported. This observation suggests that the nodule formation may impact Cs accumulation and translocation within the plant. However, the molecular biological mechanisms underlying Cs accumulation in nodules remain unclear. This study aims to clarify the impact of nodule formation on Cs accumulation and translocation. Furthermore, we investigate the transporter involved in Cs accumulation and translocation in nodules.

Three soybean lines with different nodulation abilities (a normal nodulating line (Enrei), a hyper-nodulating line (En-b0-1), and a non-nodulating line (En1282)) were cultivated in a field at Hokkaido University under four fertilizer treatments: nitrogen-deficient (-N), phosphorus-deficient (-P), potassium-deficient (-K), and all nutrients supplied (+NPK). Soil and plant samples were collected at the flowering and maturity stages. Soil exchangeable cation concentrations were measured using ammonium acetate extraction. At the flowering stage, plants were separated into leaves, petioles, stems, roots, and nodules for inorganic element analysis, while seeds at maturity were also analyzed. Additionally, transcriptome analysis was conducted on roots and nodules at the flowering stage.

Under -K treatment, shoot dry weight at the flowering stage, as well as nodule weight and number, were significantly reduced compared to +NPK treatment. Cs concentrations in both seeds and leaves increased under -K across all lines. A significant negative correlation was observed between soil exchangeable K and Cs concentrations in seeds and leaves. However, this relationship in leaves differed among lines, indicating that the suppression effect of soil exchangeable K on Cs translocation was stronger in the hyper-nodulating line than in the normal nodulating line. Meanwhile, Cs concentrations in nodules were significantly higher than in other organs under both -K and +NPK, indicating specific Cs accumulation in nodules under these conditions. Furthermore, a significant negative correlation was found between nodule fresh weight and Cs concentration in seeds, which remained significant even after partial correlation analysis accounting for soil exchangeable K concentration. In conclusion, Cs accumulation in nodules may appear to play a role in suppressing Cs translocation to the shoots. Currently, candidate genes involved in Cs accumulation and translocation in nodules are investigated through transcriptome analysis.



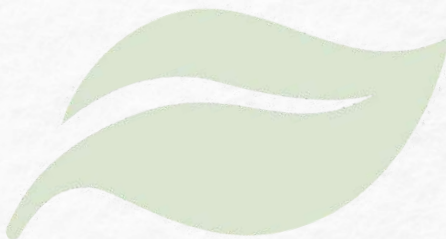


PO3_35 MORPHOLOGICAL DIFFERENCES AND GENETIC FACTORS CONTRIBUTE TO NITROGEN USE EFFICIENCY IN WHEAT

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The efficient uptake and utilization of nitrogen (N) is crucial for plant growth, and understanding the genetic basis of N acquisition is key to developing crops with improved N use efficiency (NUE). In order to explore physiological and morphological traits that contribute to NUE, 50 contrasting winter wheat genotypes were grown in soil-filled rhizotrons under adequate or limiting N conditions. In addition, 10 lines were further tested under different N fertilizer forms to evaluate their importance for N uptake. Roots and shoots were imaged daily for the assessment of the root and shoot growth dynamics as well as root architectural traits over 6 weeks. Genotypic differences in the shoot growth and N accumulation under limited N supply were highly related to the phenotypic variability in the root architectural traits in response to N deficiency. In parallel, contrasting lines from the rhizotron experiment were further grown in a hydroponic culture under sufficient N and mild N-deficient conditions. Influx analyses with ¹⁵N-labeled ammonium or nitrate and the subsequent gene expression analysis were conducted to establish a correlation between the root N uptake capacity and the induction of N transporter genes (AMTs and NRTs). We currently investigate to what extent transcript abundance of N transporter genes account for increased N uptake capacity both under adequate and limiting N nutrition to identify genetic markers associated with enhanced ammonium or nitrate uptake. Taken together, both approaches provide a comprehensive understanding of the morphological and genetic factors governing N uptake in winter wheat, with potential applications for improving NUE in crop breeding.



PO3_36 EVALUATION OF COMMON FOLIAR ZINC FERTILIZERS FOR UPTAKE EFFICACY AND TRANSLOCATION IN WHEAT

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Micronutrient deficiencies, particularly zinc (Zn), present a significant challenge for crop and human nutrition, necessitating effective agronomic strategies to enhance Zn uptake, transport and utilization. Foliar Zn fertilization has proven to be an effective agronomic method not only for correcting Zn deficiency but also for increasing grain Zn concentrations for biofortification. However, limited data exist on how different anion carriers influence Zn uptake and translocation from foliar-applied fertilizers. This study evaluates the efficacy of various foliar Zn fertilizers (ZnSO_4 , ZnCl_2 , $\text{Zn}(\text{NO}_3)_2$, ZnEDTA) applied with and without a surfactant (Tween 20) in enhancing Zn uptake and translocation, using wheat as an experimental plant species.

Short-term experiments were conducted using wheat seedlings grown in a modified Hoagland solution with marginal Zn supply ($50 \mu\text{M}$) under controlled growth chamber conditions. Each Zn form was applied at the same Zn rate equivalent to the Zn applied with 0.2 % (w/v) $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, a commonly used foliar Zn fertilizer. All foliar application solutions were labeled with Zn-65 (1480 KBq) to quantify Zn uptake from the treated leaf and its subsequent translocation to the remainder of the shoot and root. Relative Zn distribution among the application leaf, remainder of shoot and root was also calculated. Foliar application was performed by dipping the oldest leaf of a seedling into the corresponding labeled fertilizer solution for five seconds. Plants were harvested in three parts as the application leaf, remainder of shoot and root 24 after the foliar application. At harvest, the application leaf was sequentially rinsed in 0.1 N HCl and 10 mM EDTA to desorb unpenetrated Zn from the leaf surface.

Results showed that Zn uptake efficacy followed the order: $\text{ZnCl}_2 > \text{Zn}(\text{NO}_3)_2 > \text{ZnSO}_4 > \text{ZnEDTA}$, while Zn translocation ranked as: $\text{ZnSO}_4 > \text{Zn}(\text{NO}_3)_2 > \text{ZnEDTA} > \text{ZnCl}_2$. Surfactant addition significantly enhanced Zn uptake (by a factor of 10 to 20) but had no effect on Zn translocation to the shoot or root. The addition of chloride (1 mM) to foliar Zn solutions had no impact on Zn uptake or translocation, except in the case of ZnEDTA . Among the tested Zn formulations, ZnEDTA exhibited the lowest agronomic efficacy for foliar uptake and translocation. These findings highlight the importance of selecting the appropriate Zn formulation and surfactant to optimize foliar fertilization strategies in wheat, improving Zn nutrition and biofortification of food crops.





PO3_37 CROSSTALK BETWEEN SULFUR AND PHOSPHORUS DEFICIENCY RESPONSES IN RICE

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Background Sulfur (S) and phosphorus (P) are essential nutrients for plants and interact in their inter-organ transport and metabolism under their deficiencies. However, the molecular mechanisms underlying the crosstalk between S and P remain largely unknown. We hypothesized that the presence of S and P is crucial for modulating their respective deficiency responses in rice.

Methods [Experiment 1] Rice (*Oryza sativa* L. cv. Koshihikari) was grown for 10 days under four different combinations of P and S treatments (–P: 0.01, +P: 0.32, –S: 0, +S: 1.22 mM). Mineral and RNA-seq analyses were performed on roots and shoots. [Experiment 2] Rice was grown for 7 days under three treatments: –P–S, –P+S, and +P+S (with –P set to 0 mM). A subset of –P–S was then supplemented with either S alone or both S and P. Samples were collected before supplementation and at 1 and 3 days after supplementation. We conducted mineral analysis of roots and shoots, along with the expression analysis of P starvation response (PSR) gene *OsPII* and sulfate transporter genes (*OsSULTR1;1*, *OsSULTR1;3*, and *OsSULTR2;1*) in roots.

Results In Experiment 1, shoot dry weight decreased under –S, regardless of P conditions, whereas –P had no significant effect under +S. S and P concentrations in roots and shoots decreased in response to their respective deficiency treatments. Under +S, sulfate concentration in shoots decreased by –P but increased in roots. Additionally, phosphate concentration in shoots increased under –S, regardless of P conditions, suggesting the possible existence of crosstalk between S and P deficiency in their transport. Genes involved in S assimilation and sulfate transport showed expression changes in response to –S, regardless of P conditions. In contrast, regulators of PSR including *OsPII* and downstream phosphate transporters, acid phosphatases, and lipid metabolism-related genes did not show expression changes in response to –P under –S conditions (Figure 1). This suggests that S is crucial for regulating PSR gene expression. In Experiment 2, one day after S supplementation, shoot S concentration increased markedly from pre-supplementation levels (Figure 2A). *OsSULTR* gene expression was higher under –P–S than under +P+S, but it decreased to +P+S levels within one day of S supplementation. The –P-induced expression of *OsPII* was lower under –S than under +S conditions, but gradually increased following S supplementation (Figure 2B), suggesting that PSR was restored after alleviating S deficiency.

Conclusion This study revealed the crosstalk between S and P in rice under deficiencies and suggests that S is a critical factor modulating PSR.





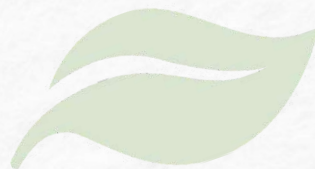
PO3_39 POINT OF DELIQUESCENT AND POINT OF EFFLORESCENCE OF DIFFERENT FOLIAR APPLIED SALTS AND THEIR ROLE IN NUTRIENT UPTAKE

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Foliar fertilization currently receives increased attention as it is an efficient way to improve plants' nutrient status. After being sprayed to plant leaves, salts and salt mixtures are exposed to strongly changing environmental conditions. Pronounced diurnal changes in humidity lead to alternating crystallization and re-dissolution of the applied fertilizer salts on leaves. The Point of Efflorescence (POE) and Point of Deliquescence (POD) characterize the humidity levels at which different salts dry out or get re-dissolved, hence they play a crucial role in the effectiveness of foliar fertilizers, as they determine moisture retention, nutrient solubility, and crystallization dynamics on leaf surfaces. Understanding these properties is essential for improving foliar fertilizer composition, preventing leaf surface damage, and ensuring efficient nutrient uptake [1]. This project aims to evaluate the POD and POE of different salts and salt mixtures using magnesium (Mg) and the micronutrients zinc (Zn), manganese (Mn), and copper (Cu). The study focuses on how different salt properties influence leaf cuticle permeability, the role of stomata, and nutrient uptake efficiency, providing information for improving the composition of foliar fertilizers. The study was conducted in a controlled-environment hydroponic system using wheat plants. Various magnesium salts commonly used in foliar fertilizers were analyzed for their POD and POE under different humidity conditions. Foliar applications were done to evaluate the effects of these physicochemical properties on transpiration as a source of humidity, leaf surface retention, and nutrient uptake efficiency. The results indicate that salts with a lower POD facilitated moisture retention on leaf surfaces, leading to enhanced nutrient uptake. Salts with a high POE showed premature crystallization, reducing bioavailability, also causing potential stress at the leaf surfaces. The study also found that salts with lower POD and POE values tend to bear a higher risk for phytotoxic effects. This research highlights the critical role of POD and POE in foliar fertilizer performance and nutrient uptake efficiency. Selecting salts with appropriate deliquescence and efflorescence properties can significantly enhance foliar nutrient supply to the plant. These findings provide the basis for optimizing POD and POE of salt mixtures that are most suitable for improved uptake of relevant nutrients used as foliar fertilizers. References: [1] Bahamonde, H. A., Pimentel, C., Lara, L. A., Bahamonde-Fernández, V., & Fernández, V. (2023). Foliar application of potassium salts to olive, with focus on accompanying anions. *Plants*, 12(3), 472.





PO3_40 THE APPLICATION OF PDMA (PROLINE-2'-DEOXYMUGINEIC ACID), FE SUPPLYING MATERIAL, INCREASES FE UPTAKE AND TRANSLOCATION IN PLANTS

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Background and Purpose

Approximately, one-third of the world's arable land consists of alkaline soil, which often causes iron (Fe) deficiency in plants. Plants employ two strategies for Fe uptake: gramineous plants acquire Fe in the form of Fe(III) with secreting mugineic acid family phytosiderophores (MAs) from their roots, while non-gramineous plants acquire Fe by reducing Fe(III) in soil.

PDMA (A synthetic MAs analogue, proline-2'-deoxymugineic acid) is a promising Fe-supplying material that functions similarly to MAs. Previous study reported that application of PDMA to soil alleviated Fe deficiency in both gramineous and non-gramineous plants (Suzuki et al., 2021; Ueno et al., 2021). This study aims to clarify the Fe uptake and transport pathway in plants when PDMA is applied.

Methods

Rice, pumpkin and soybean were cultivated hydroponically under Fe-sufficient and Fe-deficient conditions. Fe(III)-PDMA was added to the solution and xylem sap was collected for 5 hours. In the case of soybean, xylem sap was also collected until the third day after treatment. The Fe content and the concentrations of PDMA, 2'-deoxymugineic acid (DMA) and nicotianamine (NA) in the xylem sap were determined by LC-TOF/MS.

Results and Discussion

In the xylem sap of rice, the concentration of PDMA increased as the Fe concentration increased. In the xylem sap of soybean, PDMA was detected and the Fe concentration was significantly higher in Fe(III)-PDMA treated plants compared to Fe(III)-EDTA treated plants under Fe-deficient condition. In pumpkin, however, the increase in Fe concentration was small even as PDMA concentration increased.

The application of PDMA can contribute to an increase in the Fe content of rice, suggesting that rice recognizes and utilizes PDMA as same as MAs. The detection of PDMA in the xylem sap of soybean and pumpkin suggests that these non-gramineous plants may be able to absorb Fe(III)-PDMA. However, since the concentration of PDMA was lower than that of Fe, it is inferred that the primary role of PDMA is to facilitate Fe solubilization in the rhizosphere and serve as a substrate for ferric reductase, with Fe uptake in non-gramineous plants mainly occurring through this reduction process.

- Suzuki M, et al. 2021 Development of a mugineic acid family phytosiderophore analog as an iron fertilizer. Nature Comm 12: 1558.

Ueno D, et al. 2021 A synthetic phytosiderophore analog, proline-2'-deoxymugineic acid, is efficiently utilized by dicots. Plant Soil 469: 123–134.





PO3_41 THE DEVELOPMENT OF RICE WITH LOWER CADMIUM ACCUMULATION BUT SUFFICIENT MANGANESE UPTAKE VIA OSNRAMP5 MUTATION

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Heavy metal pollution in soil is a critical environmental issue that threatens agricultural productivity, ecosystem health, and human well-being. Among these metals, cadmium (Cd) is particularly hazardous due to its toxicity and tendency to accumulate in food crops. In Asia, where rice is a staple food, rice plants are highly susceptible to Cd uptake, making it essential to study Cd absorption, translocation, and accumulation.

OsNRAMP5 has been identified as a key transporter responsible for Cd and manganese (Mn) uptake in rice roots (Ishikawa et al., 2012). Knockout of OsNRAMP5 significantly reduces Cd accumulation in rice grains by preventing its uptake from soil. However, this also leads to reduced Mn absorption, potentially causing Mn deficiency and impairing plant growth.

In our previous research, we introduced random mutations into the OsNRAMP5 gene using error-prone PCR. Among the resulting mutants, the A512T mutation was commonly found in yeast strains exhibiting tolerance to a -Mn/+Cd environment (Qu & Nakanishi, 2023). Further analysis of OsNRAMP5 mutants with different amino acid substitutions at position 512 suggested that alanine at this site plays a crucial role in Mn and Cd absorption.

To investigate the functional significance of alanine at position 512 in plants, we introduced OsNRAMP5 variants carrying different amino acids at this position into an OsNRAMP5-knockout (N5KO) rice line (cv. Nipponbare). Physiological data revealed that A512 mutants exhibited greater tolerance under -Mn, +Cd, and -Mn/+Cd conditions. Under Cd treatment, both N5KO and A512 mutants showed significantly lower Cd accumulation in roots and shoots compared to wild-type (WT) rice and an OsNRAMP5-reintroduced line.

Metal concentration analysis further highlighted the role of alanine at position 512 in regulating Cd and Mn uptake in rice. Our findings suggest that mutations at A512 can modulate Mn uptake under Mn-deficient conditions while simultaneously reducing Cd absorption. This discovery holds potential for developing rice varieties with improved metal tolerance and optimized nutrient uptake.

Ishikawa et al. (2012) Proc Natl Acad Sci USA 109, 19166–19171.

Qu & Nakanishi (2023) Plants 12, 4182.





PO3_42 **ROLE AND REGULATION OF MYB59 IN LOW-POTASSIUM TOLERANCE IN ARABIDOPSIS THALIANA**

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1 - Faculty of Agriculture, Saga University; 2 - The United Graduate School of Agricultural Sciences, Kagoshima University; 3 - Institute of Crop Science, NARO; 4 - Graduate School of Agricultural and Life Sciences, The University of Tokyo

K⁺ is a major cation essential for establishing osmotic potential in plant cells and plays a crucial role in various osmosis-based physiological processes, such as stomatal opening and cell expansion. In *Arabidopsis thaliana*, the K⁺ transporter NPF7.3 mediates K⁺ loading into the xylem in roots, and the transcription factor MYB59 regulates NPF7.3 expression. Recently, we demonstrated that MYB59 is regulated by alternative splicing in response to low K⁺ conditions. The splicing isoform encoding the functional protein increases under low K⁺ conditions, thereby inducing NPF7.3 expression, whereas other splicing isoforms retaining the full or partial sequence of the first intron decrease. These non-functional isoforms lack a complete DNA-binding motif. RNA-Seq analysis revealed that their expression hardly affects gene regulation. Additionally, ribosome profiling data retrieved from a public database suggest that these isoforms are not translated by ribosomes.

ChIP-Seq analysis showed that MYB59 binds to the region 5.5–7.5 kb upstream of NPF7.3. By integrating ChIP-Seq and RNA-Seq data, we identified putative downstream targets of MYB59, suggesting that MYB59 has additional, yet unknown, roles under low K⁺ conditions. Interestingly, although the abundance of the functional MYB59 isoform changes in response to K⁺ availability, NPF7.3 expression remains constant regardless of K⁺ conditions. Moreover, no significant difference in NPF7.3 expression was observed between the MYB59 knockout mutant and the wild type under normal K⁺ conditions. These findings indicate that MYB59 is not essential for NPF7.3 expression under K⁺-sufficient conditions, implying the involvement of an unknown transcription factor in NPF7.3 regulation.

To examine the spatial regulation of MYB59 expression under heterogeneous K⁺ conditions, we conducted a split-root experiment. The results showed that the functional MYB59 isoform increased not only on the low K⁺ side but also on the normal K⁺ side, indicating that MYB59 is regulated by systemic signaling from shoots to roots. In contrast, HAK5, a high-affinity K⁺ uptake transporter gene, did not appear to be regulated by systemic signaling. Intriguingly, despite the fact that NPF7.3 expression remains unchanged under homogeneous K⁺ conditions, its expression increased on the normal K⁺ side compared to the low K⁺ side under heterogeneous conditions. This suggests that plants possess a mechanism to preferentially express K⁺ transporters in root regions localized at K⁺-rich hotspots in heterogeneous soil conditions, an economically rational strategy. We hypothesize that this biased NPF7.3 expression is partially influenced by the systemic signaling of MYB59.





PO3_44 EVALUATION OF THE EFFECTS OF NITROGEN, PHOSPHORUS, AND POTASSIUM APPLICATIONS ON THE GROWTH, YIELD, AND QUALITY OF LETTUCE (LACTUCA SATIVA L.)

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Lettuce (*Lactuca sativa* L.), a popular edible vegetable, is highly responsive to mineral fertilizers. A two-year field trial was carried out to determine how nitrogen (N), phosphorous (P), and potassium (K) application ratios affected lettuce growth, yield, and quality. Within a certain range of nutrient application rate, the plant height, stem diameter, yield, and the concentrations of vitamin C and soluble sugar were higher than those without fertilization. Compared with no fertilization condition, the yield increased approximately 13.56–22.03%, 15.15–42.42% and 7.14–10.32% under increased N, P, and K application conditions, respectively. Furthermore, substantial quadratic parabola relationships were observed between lettuce yield and fertilizer application amounts as well as most quality traits. The nitrate concentration was proportional to the N fertilization rate, while the concentrations of soluble sugar and vitamin C positively correlated with N and P application ratios, respectively. The lettuce leaves had the largest N (60.59%) and K (52.25%) accumulations, whereas the lettuce stem had the highest P (46.33%) accumulation. Above all, the optimal N, P, and K application amounts for lettuce were 315 kg N ha⁻¹, 210 kg P₂O₅ ha⁻¹, and 285 kg K₂O ha⁻¹, respectively.





PO3_45 **GENOME-WIDE ANALYSIS OF TRANSLATIONAL RESPONSE OF ARABIDOPSIS THALIANA TO SULFUR DEFICIENCY**

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The importance of translational regulation in plant nutrient responses has been reported for an increasing number of genes. However, the comprehensive picture of the impact of plant nutrient status on gene translation is still unclear. In this study, we focused on the essential element sulfur and analyzed the genome-wide impact of its deficiency on gene translation in *Arabidopsis* using ribosome profiling (Ribo-seq), which obtains ribosome distribution on mRNA using next-generation sequencing. In parallel, we analyzed mRNA abundance using RNA-seq and evaluated the translation efficiency of each gene. Using these datasets, we compared the translation profiles of *Arabidopsis* shoots under sulfur-sufficient and sulfur-deficient conditions. The ribosome abundance on each mRNA measured by Ribo-seq and the mRNA abundance indicated by RNA-seq showed a weak correlation, suggesting that many genes are regulated at the translation stage. Using gene ontology enrichment analysis for the differentially expressed/translated genes, we found that many of the genes whose translation efficiency changes under sulfur-deficient conditions are related to stress responses, sulfur compound metabolism, and photosynthesis. These results suggest that translation regulation plays an important role in the regulation of many genes in sulfur deficiency adaptation.





PO3_46 DAUCIFORM ROOT FORMATION AND ION PROFILES OF MONOCOTYLEDONOUS PLANTS GROWN IN HARSH ENVIRONMENTS IN JAPAN

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Introduction

Monocotyledonous plants including family Cyperaceae, Juncaceae and Poaceae grow in a wide range of environments, including poor nutrient soils, and other harsh environments such as strong acid soils, serpentine soils, saline soils, and low temperature landscapes. It is believed that these plants have developed some nutrient uptake and utilization strategies to cope with harsh environments. As one of the strategies, many Cyperaceae and Juncaceae species can form dauciform roots (DRs) on the lateral roots under phosphorus (P)-limited conditions to enhance P acquisition. Carboxylate exudation is important strategy to alleviate the stress of solubilized aluminum ion (Al^{3+}) or to mobilize P from insoluble forms. However, the strategies of these plant species for nutrient uptake and stress tolerance remained unclear.

Aim

The aim of this study is to investigate the ion profiles and DR-forming capacities of monocotyledonous plants grown in harsh environments and to discuss the P nutrient status and DR formation.

Methods

We conducted the study on the monocotyledonous species grown in poor nutrient soils, volcanic acid soils, serpentine soils, and saline soils in coastal area of western Japan. Ion profiling in leaves was conducted by colorimetric measurements and ICP-MS analysis.

Results and Discussion

We confirmed the formation of DRs in species belonging to the families Cyperaceae and Juncaceae, but not in the family Poaceae. Dauciform roots were found at all environments tested, volcanic acid soils, high pH soils, saline soils, and poor nutrient soils. DR-forming species included many species in genus *Carex*, and others in the genera such as *Bulbostylis*, *Fimbristylis*, and *Rhynchospora* as newly discovered groups.

Ionic profiling of mature leaves was conducted on the samples collected in Hiroshima sites. Dauciform root-forming species generally had lower P concentrations than the non-DR-forming species. Manganese (Mn) concentration in leaves of the family Cyperaceae showed an inversely proportional relationship with P concentration. Since it has been reported that Mn concentration in leaves reflects the carboxylate exudation capacity, it may imply that the carboxylate exudation is an important strategy in Cyperaceae to mobilize P under P-limited conditions. Interestingly, aluminum and iron concentrations also showed inversely proportional relationships with P concentration, suggesting that these elements may be mobilized by the carboxylate exudation.

Conclusion

DR-forming species may be generally present in Cyperaceae and Juncaceae in the Japanese natural habitat. Cyperaceae have developed various strategies to cope with harsh environments including tolerance to low internal P concentration and carboxylate exudation.



PO3_48 MAGNESIUM UPTAKE BY TOMATO CULTIVARS AND ROOTSTOCKS

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Magnesium (Mg) is the third most abundant cation in plants which importance is often overlooked in modern crop production. Tomato is one of the most important horticultural crops, often grown in greenhouses where abiotic and biotic stressors seriously limit production. One of the ways to avoid or reduce production losses caused by adverse conditions is to graft tomato onto proper rootstocks. Grafting is considered as an effective tool to improve nutrient uptake and use efficiency, but present scarce findings showed negative effect on tomato Mg leaf concentration.

The aim of this study was screening of tomato cultivars and rootstocks for Mg uptake and use efficiency. A diversity panel consisting of 14 tomato cultivars and 10 rootstocks from different gene banks were grown in greenhouse using floating system on aerated nutrient solution with 2 Mg levels (1 and 0.1 mM Mg). One month after sowing seedlings in stage of 5-6 leaves were harvested and vegetative traits were measured. Same plant organs after drying were prepared for Mg determination and Mg use efficiency parameters were calculated.

The cultivars and rootstocks grown under Mg deficient conditions as not expected on average had higher biomass production and lower root length, although some genotypes had opposite results. Mg concentrations in both cultivars and rootstocks leaves and stems were significantly higher in cultivation under optimal Mg, while it was not found same for roots where for 5 cultivars and 3 rootstocks difference in Mg concentration under both Mg supply levels were not found. Regarding Mg content or total plant Mg uptake maximum 3-fold differences were found for cultivars between both Mg supply, while for rootstocks 2-fold difference were measured. Rootstocks on average accumulated more Mg under optimal supply than cultivars while in deficient conditions both plant types of genotypes had similar Mg content per plant. After calculating Mg use efficiency it was showed that Mg uptake efficiency varied 5-fold in used tomato cultivars and 4-fold in rootstocks. Regarding Mg utilization efficiency and agronomic use efficiency the differences were less pronounced.

Our study showed that there are high variability in Mg uptake traits in commercially used tomato cultivars and rootstocks available on EU market. Taking into account results obtained in our experiment, most tolerant and sensitive tomato cultivars and rootstocks on Mg deficiency will be chosen for future experiment where they will be grafted to each other to find effect of grafting on Mg uptake.





PO3_49 SODIUM-POTASSIUM INTERACTION IN CONTRASTING CROPS

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Antagonistic interactions among cationic nutrients during root uptake are a common topic in plant nutrition research. While most studies on Na interactions have been conducted under salt stress conditions, the interaction of Na with other nutrients under non-saline conditions, as well as the substitution of Na for K, has received limited attention. This study investigated the effects of varying cationic nutrient supplies (including 0, 0.2, and 0.75 mM Na; 0.75 and 2.25 mM K; 0.75 and 2.25 mM Ca; and 0.25 and 0.75 mM Mg) on nutrient concentrations and role of Na in charge balance in maize, soybean, and rapeseed. The experiment was conducted in a hydroponic solution.

The different cationic nutrient treatments did not significantly impact plant growth. However, significant findings were found in the accumulation of cationic nutrients in roots and shoots, as well as Na's contribution to charge balance. In 27-day-old maize plants, shoot Na of all treatments remained consistently very low and ranged between 30 to 70 mg kg⁻¹ dry matter, while root Na levels were much higher (1500–10,000 mg kg⁻¹). On a molar basis, Na accounted for 40–63% of the sum of K and Na ($\Sigma[K, Na]$), and 15–37% of the sum of K, Na, Ca, and Mg ($\Sigma[K, Na, Ca, Mg]$) in maize roots. Despite this substantial Na substitution at the tissue level, no negative growth effects were observed. In soybean, the highest shoot K concentration was observed when K, Ca, and Mg were all adequately supplied, indicating that the root-to-shoot translocation of K was optimized by proper basipetal tissue saturation with other cations. As with maize, soybean shoot Na levels remained very low, while root Na concentrations were much higher. The maximal Na substitution in soybean roots was 25% of $\Sigma[K, Na]$ and 15.5% of $\Sigma[K, Na, Ca, Mg]$ under high Na and Ca, and low K and Mg treatments. In contrast to maize and soybean, rapeseed exhibited much higher Na concentrations in both roots (3300–18 500 mg kg⁻¹) and shoots (850–9350 mg kg⁻¹). Nonetheless, rapeseed retained significantly more Na in roots compared to shoots, especially under low K supply.

These results demonstrate that the crop plants, particularly maize, retain most of their sodium in the roots, contributing significantly to the charge balance of the root system. This mechanism facilitates enhanced translocation of K, Ca, and Mg to the shoots, supporting shoot growth and minimizing Na-related potential impairments in the shoots.





PO3_51 INFLUENCE OF THE QUALITATIVE COMPOSITION OF ABSORBED CATIONS ON THE LEVEL OF EXCHANGEABLE ACIDITY IN SOILS WITH CLAY-ENRICHED SUBSOIL

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Exchangeable acidity reflects the potential of soil acidity and shows the most likely pH level during the future vegetation of plants. Exchangeable acidity is determined by measuring the pH of a soil extract prepared on the basis of a neutral salt (in particular, 1N KCl). The pHKCl value is a universal indicator that characterizes the variety of soil properties and chemical soil processes, and its level depends, first of all, on the ability of hydrogen and aluminum ions absorbed by the soils colloids to exchange for other cations and pass into the soil solution.

We conducted a study of the qualitative composition of exchangeable cations and the level of exchangeable acidity in Zhytomyr region of Ukraine (151 samples, soil cover represented by Umbric Retisols, pHKCl – 4,25-6,92), and in the Vinnytsia region (297 samples, Albic Luvisols, pHKCl – 4,73-7,28).

According to research results, in Umbric Retisols the reaction of the soil environment is most influenced by hydrogen, iron and aluminum cations: the correlation coefficient (r) is -0,79, -0,76 and -0,91, in accordance. In turn, the degree of acidity of Albic Luvisols is mainly influenced not only by hydrogen ($r=-0,68$), iron ($r=-0,71$) and aluminum ($r=-0,85$), but also by calcium cations ($r=0,82$). This is explained by a noticeable increase in the content of exchangeable calcium in Luvisols (the average value is 13,1 mg-eq/100 g of soil), compared to Retisols (6,0 mg-eq/100 g of soil). It is significant that in the studied soils, not only hydrogen ions, but also iron and aluminum cations play a decisive role in the acidification of the soil solution. This is due to their displacement from the soil absorption complex by cations of a neutral salt of a strong base and a strong acid with the appearance of hydrolytically acidic salts and their subsequent decomposition under the influence of water with the formation of hydrochloric acid (the Kappen-Daikuhara hypothesis). We also note the unexpectedly high influence of iron ions on the pH level in the studied soils, the mechanism of action of which is apparently similar to the mechanism of influence of aluminum ions. Therefore, it can be argued that the use of mineral fertilizers in the form of neutral salts can act as a factor in the transformation of latent (exchange) acidity into active (actual), harmful to crops. This is especially clearly manifested when potassium-containing fertilizers are applied to the soil in the form of potassium salts.





PO3_52 CML13 NEGATIVELY REGULATES THE VACUOLAR MAGNESIUM TRANSPORTER MRS2-1 IN ARABIDOPSIS

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In plants, vacuolar Mg^{2+} transporters contribute to Mg homeostasis by sequestering or releasing Mg^{2+} in response to environmental conditions. The Arabidopsis MRS2-1 transporter, localized to the vacuolar membrane, has been identified as a key regulator of Mg^{2+} efflux from the vacuole to the cytoplasm. However, the regulatory mechanisms controlling MRS2-1 activity remain largely unknown.

In this study, we employed a yeast two-hybrid screen using a membrane protein-specific system and identified a calmodulin-like protein, CML13, as an interactor of MRS2-1. The bimolecular fluorescence complementation assay and microscale thermophoresis analysis confirmed a direct interaction between MRS2-1 and CML13. Despite containing EF-hand motifs characteristic of calmodulin family proteins, CML13 did not bind Ca^{2+} or Mg^{2+} , suggesting a unique regulatory function independent of classical Ca^{2+} signaling.

Interestingly, under high-Mg conditions, wild-type plants showed upregulated expression of CML13, while CML13-deficient plants displayed shorter root lengths, indicating a potential role in excess Mg adaptation. Notably, the *mrs2-1* mutant exhibited better growth than the wild type under high-Mg conditions, suggesting that MRS2-1-mediated Mg^{2+} efflux may negatively impact growth under excessive Mg environments. Furthermore, complementation assays in Mg-deficient *E. coli* revealed that co-expression of MRS2-1 and CML13 led to reduced Mg^{2+} transport activity compared to MRS2-1 alone, suggesting that CML13 negatively regulates MRS2-1 function.

Structural analysis using AlphaFold3 predicted that CML13 binds to the cytosolic domain of MRS2-1, specifically interacting with the ¹²⁶DNYVL¹³⁰ motif. Mutational analysis confirmed that this motif is essential for MRS2-1–CML13 binding. Based on these findings, we propose that under high-Mg conditions, CML13 functions as an inhibitory regulator of MRS2-1, preventing excessive Mg^{2+} efflux from the vacuole and contributing to Mg homeostasis. This study provides new insights into the regulation of vacuolar Mg^{2+} transport and highlights the role of CML13 in modulating Mg homeostasis under high-Mg stress.





PO3_54 OPTIMIZING LEAFY GREENS FERTILIZATION VIA IONOME DYNAMICS IN TROPICAL CONDITIONS: A DATA-DRIVEN PHYSIOLOGICAL APPROACH

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A plant's ionome is defined by the internal composition and crosstalk among 17 essential minerals and trace elements that support growth and development. Traditionally, fertilizer studies have emphasized agronomic traits such as biomass and yield, often overlooking how whole-plant water relations interact with ionic shifts. Yet, these intertwined factors can provide deep insights into the physiological mechanisms underlying plant homeostasis, particularly under the high-temperature and high-humidity conditions characteristic of many tropical regions. This study seeks to determine how single-mineral alterations in fertilizer composition - ranging from deficient to excessive concentrations - affect the correlation between the whole-plant ionome and key physiological properties of leafy greens grown in tropical environments. By examining both nutritional composition and plant performance, we aim to elucidate strategies that optimize resources and support sustainable agriculture in regions where extreme conditions can challenge conventional farming practices.

We cultivated two leafy greens from Southeast Asia, *Brassica oleracea* (Chinese broccoli) and *Amaranthus dubius* (Chinese spinach), using a functional phenotyping array (PlantArray, Plant-Ditech) that continuously measures key water- and mineral-relation traits. Eight nutrition solutions with varying mineral concentrations were delivered in a tropical greenhouse. We assessed transpiration, water use efficiency (WUE), mineral use efficiency (NUEcrop), and yield, and further analyzed the harvested leaves for their mineral composition. Traditional and correlation analyses explored how modifying one mineral affects the uptake of others and how these shifts relate to plant water-balance regulation physiological behavior.

Our findings reveal optimum curves for nitrogen (N as 75% NO_3^- and 25% NH_4^+), potassium (K^+), phosphorus (P as PO_4^{3-}), calcium (Ca^{2+}), and magnesium (Mg^{2+}) across deficiency-to-toxicity ranges, with clear implications for mineral use efficiency. For instance, 120, 160, and 200 ppm of N maximized transpiration, yield, and WUE; yet NUEcrop at 200 ppm was notably lower. Interestingly, 120 ppm yielded minimal nitrogen waste, indicating that higher (160-200 ppm) N rates commonly used by growers may be superfluous. Furthermore, we found a negative correlation between increased N and reduced leaf concentrations of K^+ , P, Ca^{2+} , Mg^{2+} , Fe^{2+} , and Zn^{2+} , alongside strong positive correlations between N and Fe^{2+} ($R^2=0.94$, $p<0.0001$) and between Ca^{2+} and Mg^{2+} ($R^2=0.94$, $p<0.0001$).

Our functional approach supports advanced decision-making for optimal nutrition by jointly considering physiological and environmental traits. Moreover, these detailed plant-response data can feed machine learning algorithms, enabling targeted interventions and refining fertilization strategies for tropical leafy greens.





PO3_55 TRACER EXPERIMENTS FOR ESTIMATION OF CONTRIBUTIONS OF PHLOEM AND XYLEM TO INFLUX OF CA INTO FRUITS IN TOMATO

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In plants, calcium (Ca) is mainly transported via xylem through transpiration and less via phloem. Ca is preferentially transported to high-transpiration tissue like leaves but poorly to low-transpiration tissue like fruits. Even with sufficient soil Ca, local deficiency can occur, leading to Ca-deficiency symptoms such as blossom-end rot. In fruit, nutrient transport mainly depends on the phloem. The ratio of contributions of xylem (higher Ca concentration) and phloem (lower Ca concentration) to fruit Ca accumulation remains unclear. This study aimed to clarify the contributions of xylem and phloem transport to Ca delivery into tomato fruits. Using strontium (Sr), a chemical analog of Ca, we examined transport pathways involved in Ca accumulation, providing basic data for our planned experiments using Ca⁴⁵ in the near future. We used a large-fruited commercial tomatocultivar "House Momotaro", pinched at two leaves above the first truss. Sr solution (10 mM) with methylene blue (as apoplastic marker) was administered by two methods: (1) Stem injection: The outer layer of the main stem was shaved to expose the xylem. Sr solution was applied to quartz wool attached to the wound using a drip system under both light (7.5 h) and dark (9.5 h) conditions, aiming to reflect xylem transport. (2) Leaf dipping: The tips of the leaflet below the truss were cut and immersed in Sr solution for 6 h under light conditions, aiming to reflect phloem transport. After administration, tissues including petiole, stem, and fruit were sampled for methylene blue observation, and part of tissues above including fruit and whole sepals were used for Sr quantification. In the stem injection, methylene blue was detected near the truss under light condition but was not in dark. Under light, plants absorbed 950 μmol Sr, with 1.5 μmol Sr (0.16 %) detected in the sepal. Sr was also detected in the fruit in both conditions, with higher concentrations under light. In the leaf dipping, methylene blue did not reach main stem, but Sr was detected in the fruit. Sr concentration in fruit was lower than in the stem injection under light. In this method, <10 μmol Sr was absorbed, with 0.06 μmol Sr (>0.6 %) was detected in the sepal. These results suggest that Ca delivery to tomato fruits primarily occurs via xylem under transpiration-driven conditions in light. However, whether Ca is directly transported to fruits or is first retained in nearby leaves before phloem transfer remains unclear. Future studies using radioactive isotopes will investigate this further.





PO3_57 IONOME SCREENING OF BRRI DHAN84 MUTAGENIZED POPULATION

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Rice is the primary source of calories for nearly half of the global population, including Bangladesh. However, excessive rice consumption poses significant health risks, as rice accumulates high quantities of toxic metals like arsenic (As) and cadmium (Cd) while being low in essential micronutrients such as iron (Fe) and zinc (Zn), contributing to “hidden hunger.” Marker-assisted breeding offers a promising approach to improve grain nutritional quality and reduce toxic elements. However, little breeding material for DNA marker-assisted breeding in Bangladeshi rice cultivars has been established for grain element concentrations.

To isolate materials with altered element accumulation in grain, first, we prepared a mutagenized population of BRRI dhan84, a Bangladeshi rice cultivar, by exposure to different levels of ethyl methanesulfonate (EMS) (0.5 and 1%) or gamma rays (250, 300, 350, and 400 Gy). The M2 plants were grown in fields in Bangladesh, and 19 element concentrations of brown rice were determined by inductively coupled plasma-mass spectrometry (ICP-MS). The candidate mutants were selected based on the robust Z score of the elements for individual plants: Z-scores below -2 or above 2 for further screening. In total, 8503 lines were analyzed by ICP-MS, and 38 mutants with altered concentrations of Fe, Zn, As, or Cd in grain were isolated. Among the mutants, to validate our screening process, we focused on two mutants with obvious phenotypes: a high grain As mutant (hgas-1) and a low Zn and Cd mutant (lzcd-1). We determined the whole genome sequence of mutants and searched for the candidate genes/mutations based on phenotype. hgas-1 has a point mutation in the exon-intron junction of the OsABCC1 gene, which is reported to detoxify and reduce grain As (Song et al., 2014). lzcd-1 has a 3.3 kb insertion in the OsHMA2 gene, responsible for root-to-shoot translocation of Zn and Cd in rice (Takahashi et al., 2012). The correlation between genotype and phenotype in the F2 population confirmed that these genes are responsible for the mutant phenotypes. For lzcd-1, we evaluated the growth and yield in two fields of Bangladesh and Japan and found similar growth and yield between BRRI dhan84 and lzcd-1 mutant, suggesting that this mutant can be used as breeding material for low Cd in rice. The identified mutants provide valuable genetic resources for further gene characterization and breeding of safe and nutritious rice.





PO3_58 EFFECTS OF ^{15}N FERTILIZER ON THE INITIAL GROWTH AND DEVELOPMENT OF ENERGY CANE

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Introduction

Energy cane (*Saccharum* spp.) is a promising bioenergy crop due to its high biomass yield and adaptability to marginal lands. Optimizing nitrogen (N) fertilization is essential to improving nitrogen use efficiency (NUE), reducing fertilizer waste, and minimizing environmental impacts such as nitrous oxide (N_2O) emissions. The use of ^{15}N -labeled fertilizers enables precise tracking of nitrogen absorption, translocation, and losses, refining fertilization strategies. This study aligns with the United Nations' Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action).

Objective

This study evaluated the effects of different nitrogen doses on nitrogen uptake, biomass production, and initial growth of energy cane (Vertex 3 variety), using ^{15}N isotopic techniques to quantify nitrogen accumulation and efficiency.

Methods

The experiment was conducted in a greenhouse at CENA/USP, Piracicaba, Brazil. Energy cane seedlings were grown in 3.5 L pots filled with Ferralsol soil. A completely randomized design (CRD) was used with four nitrogen treatments (0, 60, 180, and 300 kg ha⁻¹), each with three replications (12 experimental units). Phosphorus (P) and potassium (K) were applied at 180 kg ha⁻¹ as single applications. Nitrogen was applied in three split doses using ^{15}N -enriched urea. Water supply was maintained at 100% field capacity via gravimetric irrigation. Growth parameters, nitrogen accumulation in the plant from the fertilizer (%NPPF), nitrogen derived from the fertilizer (NPPA mg pot⁻¹), aerial nitrogen concentration, biomass production, and nitrogen and water use efficiency were evaluated.

Results

The highest dry biomass production (40.54 g plant⁻¹) occurred at 180 kg ha⁻¹ of N. Nitrogen concentration in the aerial part increased with fertilization, reaching 13.40% (%NPPF) at 180 kg ha⁻¹. Nitrogen uptake from fertilizer (NPPA) was 17.15 mg pot⁻¹ at 180 kg ha⁻¹, but at 300 kg ha⁻¹, NPPA increased to 41.13 mg pot⁻¹, indicating excess nitrogen application and potential losses. NUE was highest at 180 kg ha⁻¹ (0.07 g biomass kg⁻¹ N), decreasing at 300 kg ha⁻¹ (0.025 g biomass kg⁻¹ N). Water use efficiency (WUE) peaked at 180 kg ha⁻¹ (2.57 g biomass L⁻¹ water), declining at higher nitrogen levels due to stress-related growth limitations.

Conclusion

The 180 kg ha⁻¹ N dose was the most efficient for biomass accumulation and NUE. Higher N rates increased nitrogen accumulation but reduced NUE and posed higher environmental risks. ^{15}N isotopic techniques proved effective in assessing nitrogen dynamics and optimizing fertilization strategies for sustainable bioenergy production.



PO3_60 ANALYSIS OF THYLAKOID MEMBRANE PROTEINS RESPONSIBLE FOR PROTECTION OF PHOTOSYSTEM I IN BARLEY CULTIVAR “SARAB 1” WITH HIGH FE DEFICIENCY TOLERANCE

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[Introduction]

Iron (Fe) is an essential element for plants and is particularly indispensable for the functioning of the photosystem in chloroplasts. Fe deficiency perturbs the photosystem I (PSI) function since it requires a large amount of Fe and thus generates photo-oxidative stress. The barley cultivar “Sarab 1” exhibits extremely high tolerance to Fe deficiency, which is associated with PSI maintenance with high photosynthetic Fe-use efficiency during Fe deficiency. However, how “Sarab 1” maintains PSI function has not been clarified.

[Aim of this study]

This study explores the mechanisms associated with maintaining PSI in “Sarab 1” during Fe deficiency.

[Methods]

Barley cultivars (*Hordeum vulgare* L.) with different Fe deficiency tolerances were grown hydroponically with 30 μ M Fe for control plants and 0.5-3 μ M for Fe-deficient plants, respectively. A live autography system consisting of a high-sensitivity CCD camera and a fluorescent plate with a phosphor layer was used for analyzing ⁵⁹Fe influx rates. The function of the photosystem was determined by Dual-PAM-100 and LI-6800F.

[Results]

The live autography to monitor the ⁵⁹Fe influx revealed that “Sarab1” had the lowest rate of Fe absorption during Fe deficiency compared to the other cultivars with lower Fe deficiency tolerance. Consistent with the low Fe absorption, the amount of PSI was significantly decreased in Fe-deficient “Sarab 1.” Nevertheless, the electron transfer rate of the remaining PSI of Fe-deficient “Sarab 1” was as high as that of the control leaves.

Electron microscopy analysis revealed that “Sarab 1” had more non-stacked stroma lamellae in thylakoid membranes than other cultivars we investigated. Predicting that this membrane organization of “Sarab 1” is associated with maintaining PSI function, we isolated the stroma lamellae-enriched lower-density thylakoid (L-Thy) membrane. We found that “Sarab 1” had a higher allocation of the light-harvesting antenna Lhcb1 into L-Thy than other cultivars. Furthermore, higher amounts of Fe-binding proteins were detected in the thylakoid membrane of “Sarab 1.”

[Discussion]

“Sarab 1” acclimates to Fe deficiency by maintaining a small amount of but high-performance PSI. We assumed that the abundant Lhcb1 on the L-Thy of “Sarab 1” plays a role in avoiding photodamage in PSI since Lhcb1 in barley has a significant role in the photoprotective thermal dissipation during Fe deficiency, as we have reported. In addition to such a photoprotective mechanism, some Fe-binding proteins could allow “Sarab 1” to maintain PSI integrity and promote the efficient turnover of damaged PSI.



PO3_61 INOSITOL PYROPHOSPHATES ARE MASTER REGULATORS OF PLANT ROOT ENDOSYMBIOSIS

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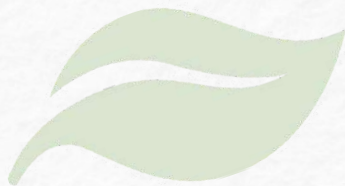
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Tight regulation of nutrient homeostasis is vital for every cell. Plants have evolved elaborate systems to sense and signal extracellular and intracellular e.g. phosphate levels and to regulate cellular nutrient concentrations. However, many soils are deficient in plant-available phosphate or nitrogen, necessitating the extensive use of mineral fertilisers with severe implications for the environment. Beneficial plant root endosymbioses offer a promising strategy to reduce the demand for mineral fertilisers. Most land plants establish Arbuscular Mycorrhiza with phosphate-acquiring fungi, and selected members of the Fabales, Fagales, Cucurbitales and Rosales engage in root nodule symbiosis with nitrogen-fixing bacteria.

While many genes involved in symbiont perception and downstream genetic reprogramming have been well characterized, the signalling events that take place between the plasma membrane and the nucleus and the signalling hubs connecting symbiosis with nutrient homeostasis remain largely obscure. Plant phosphate homeostasis is regulated by inositol pyrophosphates (PP-InsPs), which act as low abundant high energy signalling molecules. These messengers bind to SPX domains - selective high-affinity PP-InsP receptors - to mediate the interaction with PHR transcription factors, thereby controlling the expression of phosphate starvation-induced genes. Increasing evidence suggests that phosphate homeostasis and Arbuscular Mycorrhiza are interconnected via SPX and PHR. Furthermore, phosphate and nitrogen homeostasis are directly linked through SPX, which, upon degradation, allows PHR and NIN-like proteins migrate to the nucleus and activate phosphate starvation- and nitrate-induced genes, coordinating phosphate and nitrate utilization.

It is our goal to scrutinize the role of PP-InsP ligands and putative precursors in symbiosis and nutrient homeostasis and thus to illuminate the interplay of these different plant strategies to overcome nutrient limitations. Our findings reveal that PP-InsPs serve as master regulators of Arbuscular Mycorrhiza, orchestrating the crosstalk between phosphate starvation responses and plant root endosymbiosis. In the long run, these findings hold promise for breeding crops with enhanced nutrient-efficiency, ultimately contributing to more sustainable and environmentally friendly agricultural practices.





PO3_63 INTRACELLULAR MANGANESE HOMEOSTASIS DETERMINES THE LONG-DISTANCE MANGANESE TRANSPORT IN MAIZE

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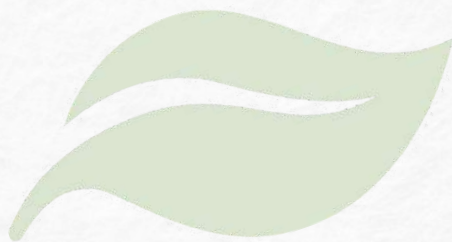
Manganese (Mn) is an essential micronutrient for plants, especially for oxygen-evolving complex (OEC) of photosystem II and superoxide dismutase. In plants, the Intracellular Mn homeostasis have been well described, but the long-distance Mn transport remain to be elucidated. In this study, we performed the forward and reverse genetic analyses to identify the Mn transporters involved in the root-to-shoot translocation and node-based distribution of Mn within maize plants. The functions of these genes were further investigated through the comprehensive approaches including analyses of their subcellular and cellular localizations, transport activities in yeast, and Mn-nutrition related phenotypes in their loss-of-function mutants.

First, our findings revealed that one member of the Natural Resistance-Associated Macrophage Protein (NRAMP) family, ZmNRAMP2, localized to tonoplast in xylem parenchyma cells of root stele in maize, and mediated the vacuolar Mn release into the cytosol. Under Mn deficiency, compared to wildtype (WT), *zmnramp2* mutants exhibited the reduced Mn concentration in xylem sap, Mn translocation from roots to shoots, and consequently impaired photosystem II efficiency (Fv/Fm reduction by 20%) and plant growth inhibition. Overexpression of ZmNRAMP2 in transgenic maize enhanced root-to-shoot Mn translocation and improved tolerances to Mn deficiency. Our results reveal the vacuolar Mn release by ZmNRAMP2 in maize root xylem parenchyma cells is essential for xylem loading and subsequent long-distance translocation from root to shoot.

Second, by the genome-wide association studies (GWAS), another NRAMP family member, ZmNRAMP7, was identified to regulate Mn accumulation in maize grain. This transporter localized to the trans-Golgi network (TGN) in the vascular cells of node, and mediated intracellular Mn influx in yeast. Compared to WT, *zmnramp7* mutants showed 20-50% decreased Mn concentration in the node and grain, without affecting leaf Mn concentration. A Valine-to-Alanine substitution in ZmNRAMP7 protein was verified as functional natural variation that altered Mn transport activities in yeast. These results reveal intracellular TGN Mn hemostasis mediated by ZmNRAMP7 determines the long-distance Mn distribution to grain in the node.

Taken together, this work provides a new insight and comprehensive understanding of how the intracellular Mn transport determines the long-distance transport of Mn, offering reliable targets for low-Mn tolerance improvement and Mn biofortification in grain for maize breeding.





PO3_64 ELUCIDATING THE BIOSYNTHETIC PATHWAY OF RIBOFLAVIN DERIVATIVES

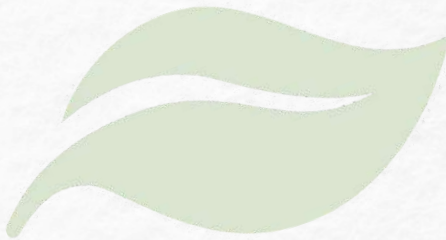
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In the recent years it has been demonstrated that iron uptake in dicotyledonous plants relies heavily on the exudation of redox-active molecules. While coumarins have been identified as the primary exuded compounds in *Arabidopsis thaliana* and other species, certain plants are known to release flavins under iron-deficient conditions. These redox-active compounds, coumarins and flavins, are crucial for survival, particularly in alkaline soils where iron bioavailability is limited. Significant progress has been made in the last decade elucidating the coumarin biosynthetic pathway in *Arabidopsis*. This four-enzyme pathway, converting feruloyl-CoA to scopoletin, fraxetin, and sideretin, appears to be conserved across coumarin-producing species. However, the biosynthesis of flavins other than the common co-factors riboflavin, FMN and FAD, remains less understood. Flavins exhibit greater chemical diversity than coumarins, varying across species, and the biosynthetic pathways of specific derivatives, are completely unknown. This work aims to identify the genes responsible for producing two distinct riboflavin derivatives: riboflavin sulfates (found in the *Amaranthaceae* family) and 7-demethyl-7-hydroxy-riboflavin (found in the *Medicago* genus). We are evaluating the efficacy of these compounds in rescuing plants grown in calcareous soils, comparing their performance against the common iron fertilizer Fe-EDDHA. To identify candidate genes, we analyzed RNA-seq data from iron-deficient *Beta vulgaris* (*Amaranthaceae*) and *Medicago truncatula* plants. Our selection criteria included protein homology to known enzymes capable of producing the expected derivatizations, induction of gene expression under iron deficiency, and co-expression with other riboflavin biosynthesis genes. Selected candidate genes were cloned into pHTP4 and pHREAC vectors for ectopic expression in *E. coli* and *Nicotiana benthamiana* leaves, respectively. Ectopic expression has been confirmed, and we are currently optimizing activity assays for riboflavin derivatization, including substrate and co-substrate selection. Ultimately, this research is expected to inform the development of novel, bio-based fertilizers for agriculture, offering a more sustainable approach to correct iron chlorosis.

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PO3_67 HOW DO BELOWGROUND INTERACTIONS MEDIATE OVERYIELDING THROUGH INTERSPECIFIC FACILITATION?

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Resource complementarity enhances ecosystem functioning, yet the role of facilitation in this process remains poorly understood. We first investigated how phosphorus (P) facilitation contributes to complementarity, using leaf manganese concentration ([Mn]) as a proxy for rhizosheath carboxylate concentration. Our results show that mixtures with *Carex korshinskyi*, a P-mobilizing species, exhibited greater biomass and complementarity effects than those lacking it in P-deficient soils. Species that inefficient in P mobilization showed a 27% increase in leaf [Mn] and a 21% increase in leaf [P] when grown with *C. korshinskyi*, compared to growth with another inefficient species. This highlights how P facilitation enhances complementarity in low-P environments, with facilitated species demonstrating greater root morphological plasticity.

We also conducted a long-term field experiment (since 2009) to examine the effects of intercropping on P efficiency. Twelve years of intercropping increased productivity by 30% and the apparent recovery efficiency of applied P by 33%, compared to monocultures. Companion crops such as faba bean and oilseed rape exhibited higher P-mobilizing capacity than maize. The improved P-use efficiency was primarily attributed to the plasticity of maize's root morphological traits and the recruitment of keystones in the rhizosphere of intercropped maize. These bacteria enhanced maize yield and P uptake by inducing carboxylate secretion and fostering more acquisitive root traits.

Overall, our study underscores the importance of P facilitation in driving resource complementarity and improving P-use efficiency, particularly through belowground interactions. We also highlight that successful facilitation requires the matching of specific belowground responses between facilitated species and facilitators. These findings suggest that facilitation could enhance productivity and reduce P fertilizer inputs in managed ecosystems.





PO3_68 **GETTING NEW INSIGHTS INTO THE CONTROL OF PLANT IRON HOMEOSTASIS**

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Iron (Fe) is an essential micronutrient for plant productivity and plays a major role during plant growth and development. It is a cofactor for numerous reactions involving electron transfer/oxidation-reduction such as photosynthesis, respiration, nitrogen assimilation etc. Iron homeostasis is tightly regulated in order to avoid deficiency or excess that could be detrimental to the plant. The regulation of the plant response to fluctuations in Fe availability has been extensively studied in many species, highlighting the importance of the transcriptional regulation in this process. In this context, we aim to further characterize the molecular mechanisms that control iron homeostasis in plants, focusing on three main transcription factors URI/ bHLH121, ILR3/bHLH105 and PYE/bHLH47 in the model plant *Arabidopsis thaliana* (non-grass species). For this purpose, large scale expression analysis aiming at studying variation in gene expression analysis and genome plasticity were set up. Recent results and findings will be presented and discussed.





PO3_69 THE ARABIDOPSIS CIT1 IS A COUMARIN IMPORT TRANSPORTER INVOLVED IN ROOT IRON ACQUISITION

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Iron (Fe) is essential for a wide range of physiological processes in several organisms including plants since it serves as cofactor of various types of metalloproteins. However, plants frequently suffer from Fe deficiency because the majority of Fe in natural soil is in the form of insoluble ferric (hydr)oxides, which is not bioavailable. To overcome this limitation, plants exude plant-specialized metabolites capable of ferric Fe solubilization from roots in response to poor Fe environments. Fe-mobilizing coumarins (FMC), such as fraxetin, form a metabolite group contributing to this process in non-grass species. In Arabidopsis, FMC emission from cortex and epidermis into the rhizosphere relies on the ABC transporter PDR9 (ABCG37). Interestingly, these cell layers were also shown to absorb coumarins exogenously supplied in Fe-limiting conditions. Whether or not this mechanism plays a role in FMC secretion-based Fe acquisition was an open question. To answer this question, we aimed to identify membrane transporters involved in FMC uptake and characterized their physiological functions in Arabidopsis. We isolated Coumarin Import Transporter1 (CIT1), whose expression responds to Fe deficiency in Arabidopsis roots. Loss-of-function of CIT1 resulted in the disruption of coumarin secretion and seedling growth in Fe-limiting conditions. CIT1 protein accumulation was strongly induced in root epidermis encountering Fe deficiency, consistent with the major site of PDR9 localization. Transport assay using yeast cells demonstrated an uptake activity of CIT1 against fraxetin and its precursor scopoletin, but not against other compounds related to FMC biosynthesis. Given that coumarins are abundant in both cortex and epidermal cell layers, these results suggest that CIT1 reinforces PDR9-mediated FMC secretion from the epidermis by loading cortex-derived coumarins into the epidermis, and therefore Fe acquisition.





PO3_70 **COMPETITIVE UPTAKE DYNAMICS OF IRON AND NICKEL IN RICE (ORYZA SATIVA L.) PLANTS**

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Nickel (Ni) is an emerging contaminant in paddy soils, but its uptake by rice and competitive interactions with other elements like iron (Fe) have been largely overlooked. Rice plants (Selenium variety) were grown hydroponically under controlled conditions. After 44 days, plants were exposed for 7 days to modified Yoshida solutions with varying Ni:Fe ratios, fixing Ni concentration at 5 or 20 μM , and Fe concentration ranging from 0 to 100 μM . The plant biomass was measured, and the metal accumulation analyzed via ICP-MS. Additionally, plants grown for two weeks at Ni:Fe ratios of 10:1 and 1:2 in agar were examined for Ni and Fe distribution using μXRF .

The Ni concentration did not affect the dry biomass of rice plants. At low Ni levels, biomass remained unaffected by Ni:Fe variations, though a rising trend with Fe concentration was noted. However, at 50 μM Ni, a significant biomass upward trend emerged with increasing Fe. Ni and Fe accumulation was higher in roots than in shoots, especially at high Ni concentrations. The decline in root Ni levels at 5 μM Ni with increasing Fe suggests Fe inhibits Ni uptake, likely due to competition at Fe transporters (IRT), which have a higher Fe affinity. The stable Fe concentration in roots indicates a steady state, where plants maintain adequate Fe levels without further IRT induction. At high Ni concentrations, root Ni decreased, while Fe significantly increased, reinforcing Fe-Ni competition and suggesting plants enhance Fe uptake to counter Ni toxicity. The decrease in root Ni concentration at 5 μM Ni with increasing Fe also led to a progressive Ni reduction in shoot. However, at 50 μM Ni, shoot Ni levels were significantly higher than at 5 μM and remained largely unaffected by increasing Fe, except for a slight decrease at 100 μM Fe. This suggests that at high Ni concentrations, plants maintain a stable Ni accumulation in shoots, while increased Fe may be required for antioxidant enzyme synthesis to counteract Ni toxicity. The rise in Fe under high Ni could also indicate distinct translocation mechanisms for these metals. The Ni:Fe ratio decreased significantly in plants at both Ni concentrations. At low Ni, the decline is due to reduced Ni accumulation, while at high Ni, it results from increased Fe uptake. μXRF analysis confirms that Ni accumulation in roots is reduced by Fe, whereas Fe accumulation in roots is not apparently affected by high Ni.





PO3_73 THE IMPACT OF HETEROGENEOUS ZINC AVAILABILITY IN THE SUBSTRATE ON ZINC HOMEOSTASIS IN TOBACCO

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A relatively large number of studies focus on the processes of uptake and transport of elements and metals by plants. However, most research is conducted under standardized laboratory conditions that do not accurately reflect the complexity of natural environments. In this study, we used a heterogeneous transparent soil system to better simulate the variable zinc (Zn) availability characteristic of natural settings. This approach allowed us to investigate the mechanisms of Zn homeostasis and gain deeper insights into plant adaptive strategies in dynamic soil environments.

The aim of this study was to explore how heterogeneous Zn availability influences Zn distribution and redistribution mechanisms in tobacco (*Nicotiana tabacum* L.). To achieve this, we used plants expressing the GUS reporter gene under the NtZIP4b promoter, which is upregulated under Zn deficiency. As expected, NtZIP4b promoter activity was higher in the roots of plants grown in Zn-deficient homogeneous substrates compared to those grown in Zn-sufficient conditions, confirming its role in the Zn deficiency response. Interestingly, under heterogeneous Zn conditions, NtZIP4b expression in lateral roots located in Zn-deficient zones was comparable to that in roots from Zn-sufficient homogeneous substrates. These findings suggest that Zn is transported from Zn-rich regions to deficient zones, maintaining Zn homeostasis under heterogeneous conditions. However, the precise mechanisms governing Zn distribution and redistribution within the root system remain unclear.

To further elucidate Zn localization, we performed micro X-ray fluorescence (μ XRF) analysis, which confirmed the GUS assay results, showing a relatively even Zn distribution between the upper and lower root zones in plants grown in heterogeneous Zn⁺/Zn⁻ and Zn⁻/Zn⁺ substrates. Notably, plants in Zn⁺/Zn⁻ substrates exhibited higher total Zn content in the root system compared to those in Zn⁻/Zn⁺, suggesting differences in Zn uptake capacity between root regions. In leaves, the highest Zn concentrations were observed in plants grown under homogeneous Zn availability, while in plants from heterogeneous substrates, Zn levels were lower and primarily localized in the veins.

Our findings indicate that Zn is actively redistributed within the root system to maintain homeostasis and prevent the activation of deficiency-related responses. Additionally, our results suggest that different root regions may exhibit varying Zn uptake capacities, highlighting the complexity of Zn acquisition and allocation under heterogeneous soil conditions.





PO3_74 ARBUSCULAR MYCORRHIZAL FUNGI INFLUENCE THE CONCENTRATION AND BIOAVAILABILITY OF ZINC IN RICE AND WHEAT

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1 - Wageningen University; 2 - University of Adelaide; 3 - Hue University; 4 - University of South Australia; 5 - Flinders University; 6 - University of Melbourne

Bread wheat and rice are two of the world's major food crops and are crucial for global human nutrition. Enhancing the zinc (Zn) bioavailability in cereals can combat human nutritional deficiencies. Arbuscular mycorrhizal (AM) fungi have previously demonstrated potential to increase the uptake of Zn into wheat and rice. However, AM fungi can also increase plant P uptake, leading to greater accumulation of the anti-nutrient phytic acid, which can hinder Zn absorption in the digestive system.

Five commercial rice varieties and eight bread wheat varieties were grown with or without AM fungal inoculation (*Rhizophagus irregularis*), under two soil P availabilities. At plant maturity, the grain nutrition was examined on total concentration basis, and specifically in the aleurone layer by Synchrotron x-ray fluorescence microscopy.

In rice, the effect of AM fungi on grain Zn concentration was positive when the aleurone layer was considered, but negative for whole grain concentrations. The AM-colonised plants also accumulated more phytate in their grain compared to the non-AM plants, leading to lower overall Zn bioavailability in rice. In contrast, in wheat the AM-colonised plants accumulated greater amounts of P and Zn in whole grain and Zn in aleurone layer, but the increased P did not raise phytate levels, leading to overall higher Zn and Fe bioavailability in AM-inoculated plants.

AM fungi could be a promising strategy for increasing Zn bioavailability in wheat, but not in rice. Furthermore, the effect of AM fungi on Zn bioavailability in cereals was highly influenced by soil P availability.





PO3_75 JASMONIC ACID PARTICIPATING IN THE SYSTEMIC REGULATION OF PHOSPHATE STARVATION RESPONSE IN BRASSICA NAPUS

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Due to the non-uniform distribution of inorganic phosphate (Pi) in the soil, plants modify their root architecture to improve acquisition of this nutrient. In this study, a split-root system with two separated compartments was employed to mimic heterogeneous Pi distribution in the soil and to examine the effect of heterogeneous Pi supply, and JA or DIECA (JA biosynthesis inhibitor) on growth, root morphology, Pi concentration, Acid phosphatase (APase) activity, nutrition uptake, JA concentration and expression of Pi starvation systemically-induced (PSSI) genes of *B. napus*. Heterogeneous Pi supply systemically modified root morphology that increased the total root surface area (TRSA), total root volume (TRV), total root length (TRL) and total lateral root number (TLRN) of root with local Pi supply (R+) and decreased them of root with local no Pi supply (R-) when compared to root with homogeneous Pi supply (R++) and root devoid of Pi (R-), respectively. Anthocyanin, APase activity and JA concentration in shoot and root of *B. napus* were systemically regulated by heterogeneous Pi supply. In addition, heterogeneous Pi supply significantly promoted nutrient uptake when compared with homogeneous no Pi supply. Root morphology of *B. napus* was significantly changed by exogenous addition of JA or DIECA in a split-root system. JA enhanced Pi starvation response by inducing expression of PSSI genes in shoots and roots. Our results suggest that JA enhances systemic Pi starvation response of *B. napus* by regulating root morphology, Pi homeostasis and inducing expression of PSSI genes under heterogeneous Pi supply.





PO3_76 A NODE-LOCALIZED EFFLUX TRANSPORTER FOR LOADING IRON TO DEVELOPING TISSUES IN RICE

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Iron (Fe) is an essential micronutrient for plant growth, and its proper distribution is critical for plant development and productivity. However, the molecular mechanisms regulating Fe distribution within plants remain poorly understood. Recent studies have highlighted the role of rice nodes in the distribution of mineral nutrients, including Fe. In this study, we identified OsIET1 (*Oryza sativa* iron efflux transporter 1), a transporter localized in rice nodes, and investigated its role in Fe distribution to developing tissues.

OsIET1 was localized to the plasma membrane and exhibited efflux activity for ferrous iron using proteoliposome assay system. Expression pattern analysis showed that OsIET1 was highly expressed in the xylem regions of the diffuse vascular bundles in rice nodes and its expression was up-regulated by high Fe supply.

To examine the physiological role of OsIET1, we generated knockout mutants (*iet1*) and analyzed Fe distribution in different plant tissues at different growth stages using hydroponic culture. At the vegetative stage, knockout of OsIET1 resulted in increased Fe allocation to the basal nodes and older leaves but reduced Fe distribution to developing leaves at both low and high Fe concentrations. A short-term ⁵⁷Fe labeling experiment confirmed these results. These findings suggest that OsIET1 plays a key role in prioritizing Fe allocation to young tissues. We further investigated the role of OsIET1 at the reproductive growth stage. Under Fe-limiting conditions, *iet1* mutants exhibited reduced growth, with decreased Fe allocation to panicles and an accumulation of Fe in the nodes. Under Fe-sufficient conditions, more Fe was distributed to leaf II blade and less to brown rice in the mutants compared to WT. These results indicate that OsIET1 is crucial for the efficient loading of Fe into the xylem of rice nodes, enabling the preferential allocation of Fe to developing tissues.

In conclusion, OsIET1 plays a critical role in regulating Fe distribution in rice by mediating Fe efflux in the nodes. This process is essential for maintaining proper Fe allocation to developing tissues, thereby supporting optimal plant growth and productivity.





PO3_77 TAIRT1 IS INVOLVED IN METAL HOMEOSTASIS IN WHEAT

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Metal homeostasis is critical for plant growth, development, and tolerance to abiotic stress. In wheat (*Triticum aestivum*), a staple crop with global importance, maintaining appropriate levels of essential metals such as iron (Fe), zinc (Zn), and manganese (Mn) is vital for both plant health and nutritional quality of the grain. The present study investigates the role of the TaIRT1 (*Triticum aestivum* Iron-Regulated Transporter 1) gene in the regulation of metal homeostasis in wheat.

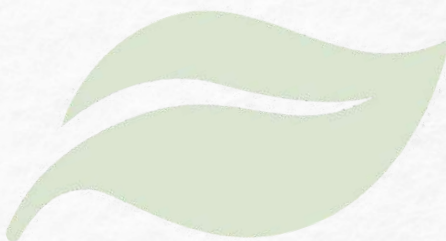
TaIRT1 is a member of the ZIP (Zrt/Irt-like Proteins) family, known for its involvement in metal transport. We characterized TaIRT1 through bioinformatics analysis, expression profiling, and functional assays. Phylogenetic analysis revealed that TaIRT1A/B/D shares 89.4-91.9% and 78.2-79.7% identity with HvIRT1 and OsIRT1, respectively, suggesting a conserved function in metal uptake. Quantitative real-time PCR (qRT-PCR) analysis showed that TaIRT1A/B/D is predominantly expressed in root tissues, with higher expression in the basal root region compared with root tips, indicating its involvement in metal acquisition from the soil.

To investigate the functional role of TaIRT1, we utilized a heterologous expression system in yeast mutants deficient in metal uptake. Expression of TaIRT1A/B/D in these mutants successfully restored growth under Fe-, Zn-, and Mn-limited conditions, suggesting their functionality as metal transporters. However, the extent of growth restoration varied among the TaIRT1A, TaIRT1B, and TaIRT1D isoforms, indicating functional differences between them. Further investigation of TaIRT1's subcellular localization was conducted by fusing the open reading frame (ORF) of TaIRT1A/B/D with GFP at the N-terminus and expressed in wheat leaf protoplasts under the control of a 35S promoter. Co-expression of TaIRT1A/B/D-GFP with the plasma membrane marker mCherry-OsRac3 revealed co-localized of the GFP and mCherry signals, indicating that TaIRT1 is localized at the plasma membrane.

Additionally, CRISPR/Cas9-mediated knockout of TaIRT1 in wheat is being employed to further investigate its physiological role in metal homeostasis. The impact of TaIRT1 knockout on metal ion levels and plant growth will be assessed.

In conclusion, TaIRT1 plays a crucial role in metal homeostasis in wheat, particularly in the uptake and transport of essential metals. Understanding the mechanisms underlying TaIRT1 regulation and function could provide valuable insights for developing wheat varieties with improved nutrient profiles and enhanced stress tolerance, contributing to agricultural productivity and nutritional security.





PO3_78 GENOME-WIDE ASSOCIATION STUDY REVEALS CANDIDATE GENES CONTROLLING ROOT SYSTEM ARCHITECTURE UNDER LOW PHOSPHORUS SUPPLY AT SEEDLING STAGE IN BRASSICA NAPUS

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Optimal root system architecture (RSA) is essential for vigorous growth and yield in crops. Plants have evolved adaptive mechanisms in response to low phosphorus (LP) stress, and one of those is changes in RSA. Here, more than five million single-nucleotide polymorphisms (SNPs) obtained from whole genome re-sequencing data (WGR) of an association panel of 370 oilseed rape (*Brassica napus* L.) were used to conduct genome-wide association study (GWAS) of RSA traits of the panel at LP in 'pouch and wick' system. Fifty-two SNPs were forcefully associated with lateral root length (LRL), total root length (TRL), lateral root density (LRD), root number (RN), mean lateral root length (MLRL) and root dry weight (RDW) at LP. There were significant correlations between phenotypic variation and the number of favorable alleles of the associated loci on chromosomes A06 (chrA06_20030601), C03 (chrC03_3535483) and C07 (chrC07_42348561), respectively. Three candidate genes (BnaA06g29270D, BnaC03g07130D and BnaC07g43230D) were detected by combining transcriptome, candidate gene association analysis and haplotype analysis. Cultivar carrying "CCGC" at BnaA06g29270DHap1, "CAAT" at BnaC03g07130DHap1 and "ATC" at BnaC07g43230DHap1 had greater LRL, LRN and RDW than lines carrying other haplotypes at LP supply. The RSA of cultivar harboring the three favorable haplotypes was further confirmed by solution culture experiments. These findings define exquisite insights into genetic architectures underlying *B. napus* RSA at LP, and provide valuable gene resources for root breeding.





PO3_79 **FUNCTIONAL DIVERGENCE BETWEEN BNPHT5;1B AND BNPHT5;1A IN PHOSPHATE HOMEOSTASIS IN RAPESEED**

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The vacuole is the largest P reservoir in plant and play important roles in the P homostasis in cell. Both BnA09PHT5;1b and BnCnPHT5;1b, which shared similar sequence, structure, Pi transport activity and tonoplast location to Arabidopsis VPT1, were induced by high P. Compared with the wild type, the BnPHT5;1b DM had smaller shoot growth and higher Pi concentration in the shoot, which was very different from the Atpht5;1 mutant, indicating that PHT5;1 functioned a unique mechanism of cellular Pi homeostasis in *B. napus*. Mutation of the BnPHT5;1b also affected the reproductive growth of rapeseed, increased P in flower organs, decreased seed yield, and changed seed trait. These results suggested that BnPHT5;1bs were vacuolar Pi influx transporter and played an important role in maintaining cellular Pi homeostasis at reproductive stage in *B. napus*. Both BnA09PHT5;1a and BnC09PHT5;1a are induced by Pi-deplete and also located to the tonoplast. The P concentration and distribution ratio in old leaves in BnPHT5;1a DM were higher than that in wild type (W10), indicating that BnPHT5;1a affected the remobilization of P from old leaves to new leaves. The lower seed germination rate of BnPHT5;1a DM than that of BnPHT5;1b DM was due to the lower phytic acid concentration in the seed, indicating that BnPHT5;1a affected the accumulation of phytic acid in rapeseed seeds. Both BnPHT5;1a DM and BnPHT5;1b DM exhibited Pi toxicity symptoms under Pi fluctuation in the growth medium, indicating that BnPHT5;1a also plays an important role in Pi homeostasis. At high P, the Pi concentration of BnPHT5;1a DM was lower than that of W10 but higher than BnPHT5;1b DM in leaves, indicating that BnPHT5;1a was not the key gene which affect Pi accumulation. The Pi concentration in BnPHT5;1a DM roots did not change during 0 to 12 h at low P, indicating that BnPHT5;1a might affect Pi consumption.





PO3_80 THE IMPACT OF DIFFERENT MORPHOLOGICAL AND BIOCHEMICAL ROOT TRAITS ON PHOSPHORUS ACQUISITION AND SEED YIELD OF BRASSICA NAPUS

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Oilseed rape (*Brassica napus* L.) is an important crop in China. Although its yields are restricted by phosphorus (P) supply, the response of its root system to P supply has not been explored systematically. This study aimed to investigate the contribution of root morphological and biochemical traits to P acquisition from soils with deficient P (30 kg P₂O₅ ha⁻¹) and sufficient P (90 kg P₂O₅ ha⁻¹) supplies in the field at the leaf development, stem elongation, flowering, pod development and ripening stages. The total root length and root surface area in the surface soil (0-10 cm soil layer) were both reduced significantly by decreasing P supply. However, a larger root/shoot ratio and root length ratio were observed in plants with the deficient P supply at the flowering stage. Roots of plants with a deficient P supply also secreted more acid phosphatase and organic acid into the rhizosphere from stem elongation to pod development than plants with a sufficient P supply. Seed yield (SY), shoot dry weight (SDW) and total P content (TPC) were strongly correlated with root morphological traits at the leaf development and flowering stages, especially with the coarse root length (CRL) and root surface area in the surface soil. However, there were no correlations between SDW or TPC and root biochemical traits (rhizosphere pH, acid phosphatase activity and organic acid content). It is hypothesized that greater CRL in the surface soil (0-10 cm soil layer) at the leaf development and flowering stages, served as a scaffold for fine roots, enhancing soil exploration and P acquisition, and, thereby, increasing seed yield.





PO3_81 **BIOLOGICAL FUNCTIONS AND DIFFERENCES OF BNAA4.BOR2 AND BNAC4.BOR2 IN RESPONSE TO BORON DEFICIENCY IN BRASSICA NAPUS**

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Boron (B) is an essential micronutrient for plants, and Brassica napus (rapeseed) requires a high amount of B and is sensitive to B deficiency. AtBOR1 from Arabidopsis is the first B efflux transporter cloned and reported in plants. There are 20 BOR genes in rapeseed, except for BnaC4.BOR1;1c2, the biological functions of other homologous genes in rapeseed have not been reported. There are two BnaBOR2 genes in rapeseed, namely BnaA4.BOR2 and BnaC4.BOR2. Here, we report the biological functions of these two genes. In our research, we found that BnaA4.BOR2 is mainly strongly expressed in roots and is not regulated by B levels. BnaC4.BOR2 gene is also strongly expressed in both roots and shoots, but it is upregulated in roots induced by low B stress. In root, both are expressed in the stele cells, but BnaC4.BOR2 is specifically expressed in root cap cells, while BnaA4.BOR2 is expressed in all cells of the root tip. The B transport capacity test in yeasts showed that BnaA4.BOR2 has stronger B efflux ability than BnaC4.BOR2, and the order is AtBOR1 > BnaA4.BOR2 > BnaC4.BOR2 > pYES2. The critical concentration of the above differences is 0.3 μ M in response to B deficiency between the two genes. By using CRISPR-Cas9 gene editing technology, rapeseed mutants of BnaA4.BOR2 and BnaC4.BOR2 were created, and it was found that all the mutants of BnaA4.BOR2 and BnaC4.BOR2 showed supersensitive to B deficiency. Through nutrition solution cultivation and soil pot experiments with the mutants under B deficiency and normal conditions, it was found that BnaA4.BOR2 involves the loading of B to xylem and the transport of B from roots to shoots; BnaC4.BOR2 not only participates the transport of B, but also involves the uptake of B in roots. The B concentration of flowers and seed yield significantly decreased in all the mutants, suggesting that both BnaA4.BOR2 and BnaC4.BOR2 are essential for the formation of rapeseed seed yield under B deficiency.

1)Liu W, Wang SL, Ye XS, Xu FS. BnaA4.BOR2 contributes the tolerance of rapeseed to boron deficiency by improving the transport of boron from root to shoot. Plant Physiology and Biochemistry, 2024, 208: 108508

2)Liu W, Xu FS, Ye XS, Cai HM, Shi L, Wang SL. BnaC4.BOR2 mediates boron uptake and translocation in Brassica napus under boron deficiency. Plant, Cell and Environment, 2024, 47(10): 3732–3748





PO3_83 MULTI-TISSUE EXPRESSION OF BNAC3.BOR1 IS ESSENTIAL FOR BORON HOMEOSTASIS IN BRASSICA NAPUS UNDER LOW BORON CONDITIONS

Sheliang Wang (China)¹; Ling Liu (China)²; Dan Zou (China)²; Fangsen Xu (China)³; 4; Lei Shi (China)³; 4

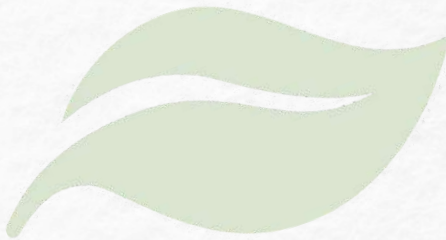
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Brassica napus L (*B. napus*), an allotetraploid crop species, exhibits a high boron (B) demand. Six BOR1 homologous genes have been identified in *B. napus*, displaying multi-tissue expression patterns that are not entirely coincident. While research has implicated BnaC4.BOR1 in root B loading and shoot B distribution, the specific contribution of BOR1 genes with distinct expression pattern to B homeostasis in *B. napus* remains to be fully elucidated. This study presents a comprehensive investigation of the expression pattern of BnaC3.BOR1 expression pattern and demonstrates its functional involvement in B homeostasis in *B. napus*.

qRT-PCR analysis revealed robust BnaC3.BOR1 expression in the roots, stems, nodes and flowers of *B. napus*, which was corroborated by ProBnaC3.BOR1:GUS induction in *Arabidopsis*. Notably, GUS activity was particularly intense in the vascular tissue of both roots and stems. Subcellular localization studies using GFP-tagged BnaC3.BOR1 demonstrated exclusive co-localization with FM 4-64, a plasma membrane (PM) marker, confirming its PM localization. Heterologous expression of BnaC3.BOR1 in *Scbor1* yeast enhanced cell survival under elevated B conditions, likely through B efflux activity. Furthermore, BnaC3.BOR1 expression fully complemented the growth defects of the *Arabidopsis bor1* mutant under low B conditions. These findings collectively indicate that BnaC3.BOR1 encodes a PM-localized B efflux transporter.

To assess the role of BnaC3.BOR1 in B homeostasis, BnaC3.bor1 mutants were established using the CRISPR/Cas9 gene-editing system. Hydroponic experiments demonstrated that disruption of BnaC3.BOR1 function significantly impaired B loading in roots and reduced B concentration in shoots under low B conditions, consequently hindering mutant development. In a subsequent pot experiment conducted under low-B conditions, stem splitting was observed specifically below the petiole in BnaC3.bor1 mutants, but not in wild-type (WT) plants. Further analysis revealed differences in cell wall components within these affected tissues compared to WT *B. napus*. Crucially, B concentrations within these affected tissues were markedly lower in mutants than in the WT. Moreover, the mutants exhibited severe phloem developmental abnormalities, ranging from deformation to complete absence, consistent with the observed strong and specific BnaC3.BOR1 expression in phloem cells below the petiole. At the reproductive stage, BnaC3.BOR1 mutation led to decreased B concentration in floral organs under low B conditions, resulting in impaired flower development and ultimately reduced seed yield compared to WT *B. napus*. Collectively, this study elucidates the crucial role of BnaC3.BOR1 in xylem B loading and B homeostasis within stems and floral organs of *B. napus* under low B conditions.





PO3_84 UNCOUPLING TRANSPORT OF CADMIUM AND BENEFICIAL MICRONUTRIENTS

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Cadmium (Cd) is present in many soils and, when enter a food chain, represents a major health threat to humans. Reducing Cd accumulation in plants is complicated by the fact that most known Cd transporters also operate in transport of essential nutrients such as Zn, Fe, Mn, or Cu. Thus, sustainable food production is critically dependent on ability of breeders and growers to uncouple transport of Cd and essential micronutrients.

Using wheat as an example we show that selecting low-Cd-accumulating varieties come with a possible caveat of affecting uptake other essential nutrients and, specifically, Zn, with major consequences to food quality and human health. To deal with the above conundrum, we looked at the molecular and physiological mechanisms mediating Cd uptake, radial transport, and translocation within the plant. We suggest that the problem can be resolved by understanding the structure-function relations of various transporters isoforms involved in Zn and Cd transport. Of specific importance are two tissues. The first one is a xylem parenchyma in plant roots; a major “controller” of Cd loading into the xylem and its transport to the shoot. The second one is a phloem tissue that operates in the last step of a metal transport. Another promising and currently underexplored avenue is to understand the role of non-selective cation channels in Cd uptake and reveal mechanisms of their regulation.

To understand a mechanistic basis of regulation of Cd uptake in plants, we used two different approaches. In the first one we used maize genotypes with contrasting capacity for Cd accumulation in grains, and then undertook a multi-omics approach to identify key genes associated with reduced Cd content. Transcriptomic sequencing identified 84 low-grain-Cd associated genes which are mainly involved in the S-adenosylmethionine (SAM) cycle, metal transport, and vacuolar sequestration. Also critical was control of redox balance under Cd exposure. NADPH oxidase, an enzyme associated with the plasma membrane, constitutes one of the main sources of reactive oxygen species (ROS). By using Arabidopsis rboh mutants lacking functional NADPH oxidase, we showed that the loss of function of RBOH isoforms resulted in higher Cd²⁺ influx, and that AtrbohD and AtrbohF were central to this process. We also shown that NADPH oxidase can be regulated by H₂, opening the prospects of amelioration of Cd stress by application of Hydrogen Reach Water under field conditions.





PO3_86 ANALYSIS OF THE SECRETION PATTERN OF ACID PHOSPHATASE AND ITS MECHANISM OF PARTICIPATING IN PHOSPHORUS ACQUISITION IN SUGARCANE (*SACCHARUM OFFICINARUM* L.)

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Sugarcane (*Saccharum officinarum* L.) is the most important sugar crop, mainly grows in acid soil areas. The lack of available phosphorus (P) in acid soil has become an important limiting factor for sugarcane growth, affecting the development of sugarcane industry and sugar safety. The organic P in soil accounts for 30%-65% of total P and is an important P pool for plants. Acid phosphatase (APase) plays a key role in the activation of organic P, but it is rarely reported in sugarcane. In this study, two sugarcane genotypes (P-efficient Z9 and P-inefficient GT) were used as materials to analyze the secretion pattern of the root-secreted APase induced by low P in sugarcane, and to explore the mechanism of APase participating in the activation of organic P and P acquisition in sugarcane. The results showed that the root-secreted APase increased significantly under low P condition, and gradually increased with the decrease of P supply concentration and the extension of treatment time, but the root-secreted APase did not change significantly under nitrogen, potassium or iron deficiency treatment. At the same time, the APase activity on the root surface of sugarcane was obviously activated under low P condition, and the APase activity secreted by root tip was significantly higher than that of mature root segments with an increase of 45%. Under low P treatment, the root-secreted APase increased significantly, and Z9 was significantly higher than GT, which was 2.5 times that of GT. The total amount of inorganic P released from organic P was significantly higher than that of normal P treatment, and the total amount and speed of inorganic P released by Z9 were significantly higher than those of GT, which were 3.1 times and 3.4 times respectively. Under the treatment of organic P, the plant P content, P accumulation and biomass of Z9 sugarcane were significantly higher than those of GT, which were 2.9 times, 3.6 times and 1.2 times respectively. The secretion pattern of the root-secreted APase and its role in obtaining P and adapting to low P were analyzed, and the theory of high P efficiency mechanism of sugarcane was expanded in this study, which provided scientific basis and technical support for the subsequent cultivation of sugarcane varieties with high P efficiency and genetic improvement of sugarcane P efficiency.





PO3_87 ALKALINE CONDITIONS INHIBIT RICE GROWTH BY AFFECTING IRON ACQUISITION

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About one-third of the world's soils are alkaline, which restricts iron (Fe) availability in plants due to the low solubility of Fe. Rice plants have a unique mechanism called Strategy II to uptake Fe from the soil utilizing mugineic acid, which is thought to enhance tolerance to low-Fe environments. Additionally, mugineic acids are suggested to facilitate not only Fe uptake but also its internal metal transport within the plant. This study aims to distinguish between Fe deficiency under alkaline conditions and absolute Fe deprivation and their effects on rice growth and Fe transport.

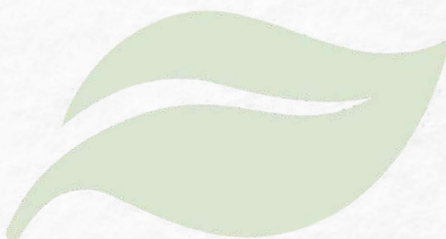
Rice plants (*Oryza sativa* 'Nipponbare') pre-cultivated under control conditions were grown for 10 days under four treatments: control, iron-deficient (-Fe), alkaline (pH 9), and alkaline-iron-deficient (-Fe pH 9). To analyze the effects on plant growth, SPAD values and plant heights were measured every two days for 10 days after treatment application. Metal concentrations in different plant tissues (newest leaf, largest leaf, basal part, and root) were analyzed using inductively coupled plasma mass spectrometry (ICP-MS). Additionally, the concentrations of deoxymugineic acid (DMA), a type of mugineic acid, and its precursor, nicotianamine (NA), in plant tissues and hydroponic solution were analyzed using liquid chromatography time-of-flight mass spectrometry (LC-TOF-MS).

Plant height and SPAD value on day 10 significantly decreased under -Fe, alkaline, and -Fe pH 9 treatments compared to the control. Fe concentrations in plant tissues were significantly reduced under the -Fe and -Fe pH 9 conditions. In contrast, under alkaline treatment, Fe concentrations declined in the newest and largest leaves but significantly increased in the basal part and root.

DMA concentrations in the newest and largest leaves significantly increased under -Fe, alkaline, and -Fe pH 9 treatments compared to the control. However, in the basal part and roots, DMA concentrations were significantly elevated under -Fe and -Fe pH 9 treatments, while no significant change was observed under the alkaline conditions. Furthermore, DMA concentrations in the hydroponic solution increased under -Fe and -Fe pH 9 conditions but significantly decreased under alkaline conditions.

These findings suggest that Strategy II may be regulated differently in alkaline conditions than in typical iron-deficient conditions, influenced by variations in iron status across different tissues in rice plants. Additionally, the problem under alkaline conditions for plants may be that the limitation of iron transport from the roots to the shoots is more critical than the ability to absorb iron itself.





PO3_88 MAIZE ZINC UPTAKE IS INFLUENCED BY ARBUSCULAR MYCORRHIZAL SYMBIOSIS UNDER VARIOUS SOIL PHOSPHORUS AVAILABILITIES

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1 - China Agricultural University; 2 - Technical University of Munich

The antagonistic interplay between phosphorus (P) and zinc (Zn) in plants is well established. However, the molecular mechanisms mediating those interactions as influenced by arbuscular mycorrhizal (AM) symbiosis remain unclear. In this study, we investigated Zn concentrations, root AM symbiosis, and transcriptome profiles of maize roots grown under field conditions upon different P levels. We also validated genotype-dependent P–Zn uptake in selected genotypes from a MAGIC population and conducted mycorrhizal inoculation experiments using mycorrhizal-defective mutant *pht1;6* to elucidate the significance of AM symbiosis in P–Zn antagonism. Finally, we assessed how P supply affects Zn transporters and Zn uptake in extraradical hyphae within a three-compartment system. Elevated P levels led to a significant reduction in maize Zn concentration across the population, correlating with a marked decline in AM symbiosis, thus elucidating the P–Zn antagonism. We also identified *ZmPht1;6* is crucial for AM symbiosis and confirmed that P–Zn antagonistic uptake is dependent on AM symbiosis. Moreover, we found that high P suppressed the expression of the fungal *RiZRT1* and *RiZnT1* genes, potentially impacting hyphal Zn uptake. We conclude that high P exerts systemic regulation over root and AM hyphae-mediated Zn uptake in maize. These findings hold implications for breeding Zn deficiency-tolerant maize varieties.





PO3_89 RELATIONSHIP BETWEEN THE SPATIAL DISTRIBUTION OF BORON AND CALCIUM AND THE INCIDENCE OF BLOSSOM-END ROT IN PAPRIKA

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The incidence of blossom-end rot (BER), causing necrosis of the distal end of paprika (*Capsicum annuum* L.) fruits, is generally attributed to calcium (Ca) deficiency, although the detailed mechanism remains unclear. Previous studies have indicated that the distribution of boron (B), which, like Ca, is a pectin cross-linker, to the fruit placenta plays an important role in the incidence of BER. Furthermore, it has been observed that BER tends to occur around the pericarp attached to the septum at the distal end of fruits. In this study, we hypothesized that the xylem vessel in the pericarp of paprika passes through the middle of the septal junctions in parallel and that B and Ca are less likely to be distributed to the septal junctions at a greater physical distance from the xylem vessel, resulting in the incidence of BER. Paprika cultivar 'Arteaga' was grown in a greenhouse on rockwool. Ripe fruits were harvested from the second node and divided into five tissues: pedicel, calyx, seed, septum (placenta), and pericarp. The septum and pericarp were equally divided into a proximal and distal part at the equatorial plane, and then, the pericarp on the junction side of the septa and on the xylem vessel side were equally cut perpendicular to the equatorial plane. All tissues were analyzed for elements by ICP-MS and the concentration of each element in each fruit tissue was calculated. The B concentrations in each fruit tissue were significantly higher on the septal junction side of the distal pericarp compared to the xylem vessel side, indicating that B is distributed at similar levels both at the proximal and distal pericarp and is supplied more from the septum rather than from the xylem vessel of the pericarp. In contrast, Ca concentrations at the distal side were significantly lower in both the septum and the pericarp compared to the proximal side, with no significant difference between the septal junction side and the xylem vessel side at the distal pericarp, demonstrating a gradual decrease from the proximal to the distal end of fruit. The previous study showed a significant negative correlation between B concentrations in the placenta (including the septum) and Ca concentrations in the whole fruit and the incidence of BER, suggesting that BER may occur when B distribution from the septum to the pericarp and total Ca supply to the fruit are decreased.





PO4_1 EFFECTS OF FOLIAR MINERAL TREATMENTS ON CHERRY TREE LEAVES

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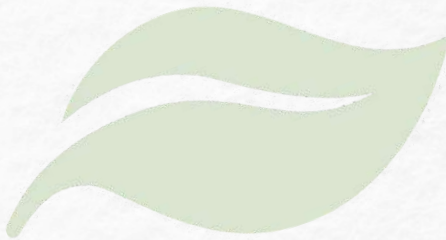
Introduction Foliar application of agrochemical sprays can improve crop yield and quality in agriculture under stress conditions which are becoming increasingly common. Although this practice is used as a routine treatment in some fruit-growing, the impacts on plant physiology remain unclear.

Purpose and aims The aim of this study was to evaluate the effect of supplying calcite (CaCO_3) and kaolinite ($\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$) to cherry leaves (*Prunus avium* var. Sweetheart), to obtain a protective white coating, and to measure plant responses and surface related parameters.

Methods The experiment was carried out at the end of the summer in a commercial plantation in Jumilla (Murcia, Spain). Leaves were immersed in 5, 10 or 15% (w/v) suspensions of kaolinite and calcite with a particle size of 1.5 μm . Physiological parameters such as, stomatal conductance (G_s), leaf temperature (T_{leaf}) and chlorophyll fluorescence were measured several times after foliar treatment. Leaf mineral element concentrations were also analysed at the end of the experimental period. These measurements were combined with microscopic techniques to characterise the leaf surface topography and anatomy, as well as to estimate the wettability and surface free energy of the adaxial and abaxial surfaces of cherry leaves.

Results Chlorophyll fluorescence was not affected by foliar application, but short-term effects on G_s and T_{leaf} lasting only for few days after treatment, were recorded. Leaves treated with suspensions with surfactant had higher G_s values, while T_{leaf} generally decreased with all treatments, but only for few days after foliar particle supply. The tissue balance of several elements was altered in association with foliar treatments. Increases in aluminium and silicon were determined after kaolinite supply, and low calcium levels were recorded after calcite application. Furthermore, potassium, magnesium, manganese and zinc concentrations increased with both particle treatments, but sulphur and copper concentrations decreased after foliar application.

Conclusion Mineral particle suspensions supplied to cherry leaves induced changes in stomatal conductance, leaf temperature and mineral element concentrations. Such foliar treatments may trigger plant responses leading to better tolerance to transient stress situations, such as heat waves, but further research is required for improving their efficacy.



PO4_2 IDENTIFICATION OF ALUMINUM RECEPTOR ALR1 AND ITS REGULATORY NETWORK IN PLANTS

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Plant survival requires an ability to adapt to differing concentrations of nutrient and toxic soil ions, yet ion sensors and associated signaling pathways are mostly unknown. Aluminum (Al) ions are highly phytotoxic, and cause severe crop yield loss and forest decline on acidic soils which represent 30% of land areas worldwide. Here, we revealed the mechanism of the receptor-like kinase Aluminum Receptor 1 (ALR1) in mediating Al perception/signaling and its dynamic regulatory network. Binding of Al ions to the cytoplasmic domain of ALR1 recruits the co-receptor BAK1 and promotes ALR1-dependent phosphorylation of the NADPH oxidase RbohD, thereby enhancing reactive oxygen species (ROS) generation. ROS in turn oxidatively modify the RAE1 F-box protein to stabilize the central transcription factor STOP1, ultimately activating organic acid anion secretion for Al detoxification. The activation of this Al resistance pathway is tightly controlled by phosphorylation switching at ALR1 Ser696/698 residues. Al ions rapidly induce PP2C-type phosphatases (PP2CH1/2) to dephosphorylate ALR1 S696/698, enhancing ALR1-BAK1 interaction and downstream signaling. Conversely, the receptor-like cytoplasmic kinase PBL27 phosphorylates these residues to suppress Al resistance, establishing a kinase-phosphatase regulatory switch. Moreover, we further found that ALR1 itself can also function to turn off the STOP1 activated downstream Al resistant genes by phosphorylating a RLCK, which in turn phosphorylates STOP1 and suppress its transcriptional activity. This phosphorylation-dependent "on-off" switch ensures precise modulation of ALR1 function and STOP1-dependent Al tolerance. This hierarchical framework provides novel insights into the ion-sensing mechanisms in living organisms, and will inform future molecular breeding of Al resistant crops and trees.





PO4_3 THE MECHANISMS OF STOP1 IN SYNERGISTICALLY ENHANCING NITRATE UPTAKE AND PLANT ADAPTATION TO ACIDITY

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Acidic soils, covering 40–50% of global arable lands, severely constrain crop productivity by impairing root growth and nutrient acquisition. Nitrogen fertilizers exacerbate soil acidification, generating toxic protons (H⁺) that threaten agricultural sustainability. However, the mechanisms by which plants optimize their biological processes to coordinate H⁺ stress adaption and nitrate uptake remain largely unclear. Here, we showed that in the roots of *Arabidopsis thaliana*, the C2H2-type transcription factor STOP1 in the nucleus was enriched by low pH in a nitrate-independent manner, with the spatial expression pattern of NITRATE TRANSPORTER 1.1 (NRT1.1) established by low pH required the action of STOP1. Then, we identified an upstream regulator, named ACID-SENSITIVE REPRESSOR of STOP1 (ASRS1), physically interacts with STOP1 and suppresses NRT1.1 activation under chronic acidity. The *asrs1 stop1* and *asrs1 nrt1.1* double mutants, as well as the *nrt1.1* and *stop1* mutants, had a similar hypersensitive phenotype to low pH, indicating that ASRS1 acts as upstream regulator of STOP1-NRT1.1 module for H⁺ tolerance. Notably, ASRS1 does not affect STOP1 protein accumulation but directly inhibits its transcriptional activation of NRT1.1. Molecular assays revealed that ASRS1 is degraded by low pH, releasing STOP1 to directly bind to the genomic region of NRT1.1 to activate its transcription, thus upregulating its nitrate uptake. This action improved the NUE of plants and created a favorable rhizospheric pH for root growth by enhancing H⁺ depletion in the rhizosphere. These results demonstrate that ASRS1-STOP1-NRT1.1 is a key pathway that dynamically balances nitrate acquisition and rhizospheric pH homeostasis under acidic stress. This pathway offers a dual-benefit strategy to enhance crop resilience in acidified soils while mitigating fertilizer-driven acidification through improved nitrate use efficiency, providing a genetic target for sustainable agriculture.





PO4_4 EXPLORING THE NUTRITIONAL DIVERSITY OF EUROPEAN BEAN CULTIVARS FOR SUSTAINABLE FOOD SYSTEMS

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The European food market is currently booming with demands for alternatives to meat and dairy products. This increase causes a high demand for new healthier, eco-friendly food products, highlighting the importance of learning about the diversity of European crop nutritional resources, in order to properly make use of them.

This study aims to identify outstanding accessions of common bean (*Phaseolus vulgaris*) with superior nutritional profile for future breeding programs. The properties being evaluated are micro and macronutrients, protein content and total phenolic compounds, which contribute to both the nutritional value and potential antioxidant benefits of the crop. Through these analyses, high performing accessions can be identified, contributing for the development of nutrient-dense, resilient, and climate-smart bean varieties, ensuring a more sustainable and nutritious food supply.

Mineral analysis was performed by conducting microwave-assisted acid digestion on bean samples, followed by Inductively coupled plasma mass spectrometry (ICP-MS), while total polyphenolic content was determined by the Folin-Ciocalteu assay and protein content was obtained by the Dumas method.

The data obtained so far pertains to bean samples cultivated in Poland, and it revealed that the average protein content percentage of 186 landraces is 23.10 ± 2.56 , while the total polyphenolic content of 188 different cultivars was of 64.24 ± 27.15 mg/100g. In relation to the macronutrient composition analysis of 207 varieties, it was determined that they averaged 654.4 ± 108.3 mg/100g of phosphorous, 1498.0 ± 213.00 mg/100g of potassium, 112.2 ± 52.24 mg/100g of calcium and 189.6 ± 19.55 mg/100g of magnesium. Finally, concerning the micronutrient content of these same varieties, the samples had an average of 8.12 ± 1.50 mg/100g of iron, 1.45 ± 0.25 mg/100g of manganese and 3.06 ± 0.77 mg/100g of zinc. A Principal Component Analysis (PCA) was performed to identify the variety with the best nutritional and antioxidant properties, best suited to thrive in Poland's climate.

The findings of the research the large variability in nutritional as well as antioxidant characteristics of the common bean accessions cultivated in Poland. The differences noted in the protein, polyphenolic and mineral content indicate the potential for selecting better varieties for breeding programs to enhance nutritional quality as well as environment tolerance. The application of Principal Component Analysis (PCA) allowed the selection of accessions with outstanding nutritional and antioxidant traits, offering valuable information for generating climate-tolerant, high-nutrient bean varieties. The results conform to the support of sustainable agriculture and the counteraction of increasing demand for healthy, plant-based protein foods on the European food market.





PO4_5 POTASSIUM THIOSULFATE EFFECT ON ALMOND (PRUNUS DULCIS) YIELD, NUTS QUALITY AND MINERAL STATUTE CV MAZZETTO

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Potassium (K) is a vital macronutrient essential for the growth, fruit development, and overall health of almond (*Prunus dulcis*) trees. It plays a significant role in key physiological processes, including photosynthesis, water regulation, and carbohydrate metabolism. Adequate potassium supply is crucial for optimizing yield and quality in almond production. However, potassium deficiency is prevalent in almond orchards and can lead to reduced fruit set, impaired nut quality, and increased disease susceptibility. This experiment investigates the effects of potassium fertilization using KTS® fertilizer on yield, nut quality, and nutrient content of the Mazzetto cultivar grafted on Garnem rootstock. Conducted in 2023 in a commercial orchard planted in 6 × 4 m spacing of North Tunisia. A randomized block design with 4 blocks for each treatment was adopted, involving 5 repetitions (trees) per block. Four treatments were implemented: a control (T0) with no potassium supply, and three treatments with increasing doses of KTS: T1 (20 L/ha), T2 (30 L/ha), and T3 (40 L/ha). A single application occurred in June during the second fruit stage growth. At harvest, yield, nuts and kernels diameter, length, width, weight, and shelling rate were measured for each treatment and analyzed using one-way ANOVA. Mineral leaf analysis was also done for the four treatments. Results revealed no significant effects of treatments on yield although a trend toward increased yield with KTS application was noted, particularly in treatment T3 (40 L/ha). Treatments T2 and T3 exhibited the highest nut and kernel dimensions and weights. T3 and T2 enhanced nut width and T3, along with T1 and T2, improved kernel width compared to the control. Potassium levels were below the standard for the control and T1, while T2 and T3 met optimal levels. Nitrogen, phosphorus, calcium, sodium and copper content showed no significant differences among treatments, while treatment T3 had the highest iron level. All treatments were below the zinc standard. In conclusion, while treatments of KTS did not significantly affect yield or shelling rate, they positively influenced the physical characteristics of almonds, notably increasing the diameter, length, width, and weight of both nuts and kernels. Treatments T2 and T3 demonstrated optimal potassium levels, enhancing quality nut and kernel traits. These results highlight the potential of KTS applications to improve almond quality, warranting further investigation into their long-term impacts.





PO₄-7 NITRATE ALLEVIATES AMMONIUM TOXICITY IN BRASSICA NAPUS BY COORDINATING RHIZOSPHERE AND CELL PH AND AMMONIUM ASSIMILATION

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In natural and agricultural situations, ammonium (NH₄⁺) is a preferred nitrogen (N) source for plants, but excessive amounts can be hazardous to them, known as NH₄⁺ toxicity. Nitrate (NO₃⁻) has long been recognized to reduce NH₄⁺ toxicity. However, little is known about *Brassica napus*, a major oil crop that is sensitive to high NH₄⁺. Here, we found that NO₃⁻ can mitigate NH₄⁺ toxicity by balancing rhizosphere and intracellular pH and accelerating ammonium assimilation in *B. napus*. NO₃⁻ increased the uptake of NO₃⁻ and NH₄⁺ under high NH₄⁺ circumstances by triggering the expression of NO₃⁻ and NH₄⁺ transporters, while NO₃⁻ and H⁺ efflux from the cytoplasm to the apoplast was enhanced by promoting the expression of NO₃⁻ efflux transporters and genes encoding plasma membrane H⁺-ATPase. In addition, NO₃⁻ increased pH in the cytosol, vacuole, and rhizosphere, and down-regulated genes induced by acid stress. Root glutamine synthetase (GS) activity was elevated by NO₃⁻ under high NH₄⁺ conditions to enhance the assimilation of NH₄⁺ into amino acids, thereby reducing NH₄⁺ accumulation and translocation to shoot in rapeseed. In addition, root GS activity was highly dependent on the environmental pH. NO₃⁻ might induce metabolites involved in amino acid biosynthesis and malate metabolism in tricarboxylic acid cycle, and inhibit phenylpropanoid metabolism to mitigate NH₄⁺ toxicity. Collectively, our results indicate that NO₃⁻ balances both rhizosphere and intracellular pH via effective NO₃⁻ transmembrane cycling, accelerates NH₄⁺ assimilation, and up-regulates malate metabolism to mitigate NH₄⁺ toxicity in oilseed rape.





PO4_8 APPLICATION OF PHOSPHORUS ALLEVIATES ALUMINUM TOXICITY AND IMPROVES THE ADAPTABILITY OF RHIZOSPHERE MICROBIOME ON BRASSICA NAPUS TO ACIDIC SOIL

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Aluminum (Al) toxicity is a key factor limiting crop growth in acidic soils, primarily due to the toxic effects of Al ions in the soil solution. Although phosphorus (P) fertilizers are known to reduce Al³⁺ concentrations in acidic soils, the underlying mechanisms remain poorly understood in *Brassica napus*. This study investigated the effects of two concentrations of P on *B. napus* grown in acidic soil by a pot trial, focusing on their potential to alleviate stress and improve plant performance. The results demonstrated that soil pH increased with depth across all treatments, with surface soils exhibiting more acidification compared to subsurface layers. Application of P fertilizers effectively reduced reactive Al³⁺ concentrations in all soil layers, creating a less toxic environment for plant roots. Furthermore, P fertilization significantly influenced soil bacterial community composition, potentially enhancing plant growth through improvements in the soil microbial environment. Results also showed that P fertilizers substantially increased the dry weight, plant height, and seed yield of *B. napus* compared to untreated controls, while reducing Al³⁺ accumulation in roots and straw. Overall, this research underscores the critical role of P fertilizers in mitigating Al toxicity, improving soil quality, and enhancing crop productivity in acidic soils. These findings offer valuable insights into sustainable agricultural practices for improving the adaptability of *B. napus* in acidic soil regions.





PO4_9 DROUGHT TOLERANCE IN DURUM WHEAT: UNDERSTANDING GENOTYPIC VARIABILITY AND NUTRIENT PLASTICITY

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Drought poses a significant challenge to durum wheat cultivation, a crop vital for global food security, particularly in the Mediterranean basin. Recent studies highlight the complex adaptations of durum wheat to endure drought conditions, involving various adaptations. Specifically, plants adjust their mineral nutrient profiles to cope with water scarcity, highlighting the importance of nutrient plasticity for acclimation. Identifying different behaviors among durum wheat genotypes under drought stress is crucial for selecting drought-tolerant varieties. This involves exploring the plasticity of mineral nutrient profiles in relation to morphological, physiological, and biochemical parameters under drought stress. Defining drought tolerance in plants, particularly in durum wheat, is complex due to its dependence on various factors, including the plant's phenological stage. Therefore, the research study has investigated the responses of different durum wheat genotypes to drought stress at the seedling and vegetative stages. At the seedling stage, drought stress was simulated using hydroponic systems with polyethylene glycol (PEG 6000), while during the vegetative stage, plants were grown in rhizobox systems filled with soil substrate at 40% of field capacity (FC). Overall, the study allowed the categorization of wheat genotypes based on their resistance to drought stress, highlighting the importance of understanding the different adaptations that contribute to drought tolerance. Notably, genotypes such as SVEMS16, SVEVO, and BULEL exhibit superior drought tolerance, whereas genotypes like ETRUSCO and S.CAP demonstrated susceptibility to drought stress. At the seedling stage, the drought tolerance of SVEMS16, SVEVO, and BULEL was related to their capacity to maintain or increase nutrient accumulation and mitigate drought-induced damage, as evidenced by reduced malondialdehyde (MDA) accumulation and chlorophyll degradation. Conversely, the limited nutrient acquisition capability of S.CAP and enhanced damage likely contributed to its susceptibility to drought. During the vegetative stage, genotypes such as SVEVO, SVEMS16, and BULEL displayed enhanced tolerance to water stress due to their ability to maintain an effective osmotic balance, increased membrane fluidity, and high production of antioxidants. These mechanisms helped limit water and oxidative stress damage. In contrast, ETRUSCO and S.CAP were more susceptible to drought, characterized by increased arsenic accumulation, reduced capacity for osmotic regulation, and lower efficiency in protecting against oxidative stress. By understanding the adaptive strategies of durum wheat genotypes in response to drought stress, breeding programs can select and develop new drought-tolerant varieties with enhanced drought resilience. This can significantly enhance food security in arid regions by improving crop resilience to drought conditions.





PO4_10 TWO NATIVE PLANT SPECIES FROM MEDITERRANEAN SOUTHWESTERN AUSTRALIA HAVE DIVERGENT PHOSPHORUS-ACQUISITION TRAITS IN PASTEURISED SOIL AND DURING INTERSPECIFIC INTERACTIONS WITH A CLUSTER-ROOT FORMING COMPETITOR

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On the phosphorus (P)-impoverished soils of Mediterranean southwestern Australia, plant diversity is sustained by species-specific strategies to overcome extreme P limitation. While cluster-root-forming species like *Banksia attenuata* (Proteaceae) efficiently mobilise P via carboxylate exudation, the mechanisms that allow mycorrhizal species to persist alongside these competitors remain unclear. Furthermore, in ecosystems where *B. attenuata* dominates, its influence on coexisting mycorrhizal species is not well understood.

Soil pasteurisation, by eliminating both beneficial and antagonistic microbes, provides a means to assess the net impact of soil microbial communities on plant P-acquisition traits and growth. We tested whether soil microbial communities specifically associated with *Agonis flexuosa* (Myrtaceae) and *Bossiaea linophylla* (Fabaceae) constrain or facilitate plant growth, and how interactions with *B. attenuata* modulate their P-acquisition traits under extreme P limitation. To address these questions, we conducted a glasshouse experiment comparing plant growth and P-acquisition traits in pasteurised versus non-pasteurised soils, with species grown either in monoculture or in mixture with *B. attenuata*.

Our results revealed species-specific responses to soil pasteurisation. *Agonis flexuosa*'s growth was stimulated in pasteurised soil, with total biomass increasing by 69% in monoculture and 105% in mixture compared to growth in non-pasteurised soil. This enhancement was driven by coordinated shoot-root growth and elevated carboxylate exudation (indicated by increased leaf manganese concentrations). When grown with *B. attenuata*, these benefits were further amplified, boosting *A. flexuosa* biomass by 50% over the monocultures. In contrast, *B. linophylla* exhibited strong microbial dependency (82% greater biomass in non-pasteurised soil) but severe growth suppression under interspecific competition with *B. attenuata*, with total biomass declining by 79% and root biomass by 88%. Root morphology diverged: *A. flexuosa* maintained root-to-shoot ratio despite pasteurisation, with only a reduction in specific root length and root tissue density, indicating altered root traits without compromising biomass allocation. Conversely, *B. linophylla* developed an exploratory root system under competition in non-pasteurised soil indicated by increased specific root length.

These findings demonstrate that *B. attenuata* significantly promoted *A. flexuosa* growth in pasteurised soil, with carboxylate-based P acquisition playing a crucial role in this process. However, this advantage was diminished by the presence of native microbial communities despite arbuscular mycorrhizal colonisation. Meanwhile, microbial communities facilitated *B. linophylla* growth, but competition with *B. attenuata* imposed strong suppression. Our study underscores the complex interplay between microbial communities and interspecific competition in shaping plant P-acquisition strategies in severely P-impoverished ecosystems.



PO4_11 MULTI-OMICS PROFILING OF DROUGHT STRESS ADAPTATION IN TWO DURUM WHEAT GENOTYPES

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Crop productivity is threatened by climate change, which has led to increasing water scarcity in various regions of the world, in particular the Mediterranean area. Drought is one of the most common environmental stresses, and it negatively impacts on the normal plant physiology and growth in many ways, including nutrient uptake and utilization. Although durum wheat is adapted to semi-arid climates, extreme weather conditions and prolonged drought have a negative effect on yield potential and survival. Accordingly, the identification of more resilient genotypes able to cope with suboptimal water and maintain efficient nutrient acquisition could allow to counteract yield losses. This study describes the physiological, ionomic, transcriptomic and metabolomic characterization of drought stress in two wheat genotypes, Svevo and Svems16, a TILLING mutant derived from Svevo. Plants were grown hydroponically and exposed to drought for six days adding 10% PEG 6000 to the nutrient solution. The physiological analysis revealed that Svems16 was more tolerant to drought than Svevo, and this response was related to the morphological traits of root system and potential impacts on nutrient mobilization. RNA-seq analysis showed that the transcriptome reprogramming induced by PEG treatment was more intense in the sensitive genotype (Svevo) compared to the tolerant one (Svems16) and in root than in shoot tissue. The root specific-response included genes involved in nicotianamine biosynthesis, membrane modification, and glycosylation which are all critical for nutrient transport and signaling, whereas the leaf specific-response was mainly associated to the metabolic processes related to carbohydrates and amino acids. Interestingly, a positive modulation by drought was observed in both genotypes for genes involved in glutathione and sulfur compound metabolic processes, confirming the functional role of sulfur in plant response to oxidative stress. To investigate genotypic differences in drought-responsive metabolic changes, we analyzed roots and shoots of Svevo and Svems16. Under drought stress, root metabolomes revealed 214 unique differentially expressed metabolites (DEMs) in Svems16, 203 in Svevo, and 72 shared DEMs. In shoots, Svevo exhibited 194 unique DEMs, Svems16 172, and 73 were shared. Notably, both genotypes displayed significant upregulation of phenylpropanoid and terpenoid pathways in both tissues, highlighting their crucial role in wheat's drought response. This multi-omic approach provided comprehensive insights into drought tolerance mechanisms, offering potential avenues to enhance grain yield, quality, and nutrient use efficiency in water-limited environments.

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PO4_12 IONOME PROFILING DISCRIMINATE GENOTYPE-DEPENDENT RESPONSES TO DROUGHT IN DURUM WHEAT

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Low-resource environments, such as dry or infertile soils, result in limited plant growth and development, which in turn constrain crop productivity. Water shortage is a significant threat to agricultural productivity all over the world. Drought may also affect plant nutrient uptake and assimilation capability causing nutrient deficiencies even in fertilized fields. Durum wheat is an important staple food crop for ensuring food security in the Mediterranean area, which is increasingly subjected to periods of severe drought due to global changes. Thus, identifying wheat cultivars/genotypes able to cope with suboptimal water, and with unbalanced nutrient availability deriving from drought is crucial to mitigate climate change's adverse effects on agriculture. In this study, a detailed analysis of the phenome, including biomass production, proline production, and characterization of root system architecture, and the ionome, was performed on a panel of 15 *Triticum turgidum* genotypes, differing for drought tolerance, in order to understand the genotype-specific physiological responses to drought and to identify those genotypes characterised by a positive correlation between ion homeostasis and drought response. The characterization of root system architecture helped our understanding of the morphological responses of wheat plants to drought. The ionome profile of most genotypes was significantly affected after drought exposure for 7 days in both shoot and root tissues, but at different extent. The Lcye A - B - genotype showed the highest accumulation efficiency for most nutrients in shoots, while Bulel tritordeum and Karim in roots. It is also important to understand how micronutrients interact with each other and with macronutrients. Thus, we performed a nutrient correlation network analysis, which showed that the interactions that occur among nutrients were modified by drought in most tested genotypes. Understanding the interplay between ionic profiles and environmental conditions can provide valuable insights into developing more resilient crops that can thrive in challenging environments, ultimately contributing to global food security in the face of climate change.

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PO4_13 INFLUENCE OF HEAT STRESS ON WHEAT GROWTH PARAMETERS AND PROJECTED CHANGES IN FE AND ZN BIOAVAILABILITY

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Introduction: Wheat is a vital staple food for millions worldwide, significantly contributing to the global food system by providing essential calories and nutrients, such as iron (Fe) and zinc (Zn). Through climate change, rising temperatures present serious challenges to wheat production, adversely affecting both yield and quality. Understanding the variation in wheat response to heat stress and its impact on beneficial nutrients, and the anti-nutrient phytate is essential for improving wheat resilience and nutritional quality.

Methods: This research investigated the influence of heat stress on macro- and micro-nutrients (specifically Fe and Zn), and phytate levels. 1540 spring, bread wheat genotypes were grown at Narrabri, in north-western New South Wales (Australia). Mineral concentrations were analyzed using an ICP-MS, while phytate (IP6) levels were measured by HPLC.

Results: Across the wheat population, heat stress reduced grain yield by up to 9.3%, thousand kernel weight by up to 15.8%, and plant height by up to 12.7%, while also shortening the days to heading and maturity by 28.4% and 27.9% respectively. Heat stress increased IP6 and most minerals, with notable rises in IP6 (42.6%) and Mo (43.1%), as well as increases in Mn (34.5%), Zn (20.9%), P (17.4%), Fe (13.4%), and Ca (14.3%). Protein concentration rose by 5.6%, and the IP6/Fe and IP6/Zn ratios increased by 24.9% and 16.9% respectively. In comparing the top and lowest yielding 10% of genotypes within the population, the low phytate genotypes demonstrated lower yield, higher concentrations of Fe and Zn, and lower IP6/Fe and IP6/Zn ratios, indicating improved theoretical mineral bioavailability.

Conclusion: Heat has a major negative impact on yield and the nutritional quality of seed. This in turn will greatly impact consumers who rely on wheat as a staple food crop. Going forward, breeding biofortified wheat, targeting a hotter environment, will need to consider Fe and Zn bioavailability, and even consider the inclusion of low phytate or high phytase mutants, to further drive down the phytate levels of seeds to an acceptable level for maintaining human nutrition. It is imperative to integrate phytate interactions into both nutritional strategies and food processing practices to improve mineral bioavailability as heat stress elevated the level of phytate and reduced the theoretical bioavailability of Fe and Zn.

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PO₄-15 TaYSL15 IS INVOLVED IN IRON UPTAKE IN WHEAT

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Iron (Fe) is a vital micronutrient for plant growth, influencing key physiological processes such as chlorophyll synthesis, respiration, and enzyme activity. In wheat (*Triticum aestivum*), efficient iron acquisition from the soil is essential for optimal growth and grain development, especially in soils with limited bioavailable iron. The present study investigates the role of TaYSL15 (*Triticum aestivum* Yellow Stripe-Like 15), a member of the YSL (Yellow Stripe-Like) family of metal-transport proteins, in iron uptake in wheat.

TaYSL15 is homologous to well-characterized YSL transporters in other plant, which mediate metal uptake and translocation through chelation with phytosiderophores. Phylogenetic analysis revealed that TaYSL15A/B/D shares 74.02-74.47% and 95.28-96.17% identity with ZmYS1 (from maize) and HvYS1 (from barley), indicating a conserved role in iron uptake across species. To further investigate its function, we examined the expression patterns of TaYSL15 were analyzed using quantitative real-time PCR (qRT-PCR). The results showed that TaYSL15 is highly expressed in the root basal region than root tips, and its expression is strongly upregulated under iron-deficient conditions in roots, suggesting its involvement in iron acquisition from the soil.

To determine the subcellular localization of TaYSL15, the coding sequence was fused with GFP and expressed in wheat leaf protoplasts. Co-expression of TaYSL15A/B/D-GFP with the plasma membrane marker mCherry-OsRac3 revealed co-localized of the GFP and mCherry signals, indicating that TaYSL15 is localized at the plasma membrane, supporting its function as a metal transporter. Additionally, CRISPR/Cas9-mediated knockout of TaYSL15 in wheat was performed to assess its physiological role in iron uptake. Knockout lines of TaYSL15A/B/D exhibited growth retardation, chlorosis, and significantly reduced SPAD values-only 49.44% of those observed in wild-type plants, indicating impaired iron uptake and homeostasis.

In conclusion, TaYSL15 plays a critical role in iron uptake in wheat, facilitating the transport of iron into the roots under iron-deficient conditions. These findings highlight the importance of TaYSL15 in iron homeostasis and suggest that enhancing its function could improve wheat's ability to acquire iron, ultimately benefiting both crop yield and the nutritional quality of wheat.





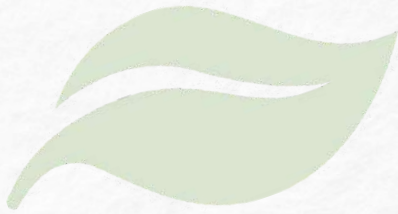
PO5_1 DOES SILICON ENHANCE ANATOMICAL AND PHYSIOLOGICAL ASPECTS OF SOYBEAN UNDER WATER DEFICIT?

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There is still scarce information about the role of Si applied in soil against water deficit conditions in non-accumulating plants such as soybean. The objective was to evaluate whether Si influences anatomical, physiological aspects, and biomass of soybean under moderate or severe water deficit. An experiment was conducted in pots (100 L) filled with a sand soil Quartzipsament under greenhouse conditions. A completely randomized factorial scheme with eight repetitions, with and without Si (equivalent to zero Si, and 600 kg ha⁻¹Si), applied in the soil as Ca-Mg silicate, and three levels of water: 100% (well-watered, WW), 60 % (WD60) and 40% (WD40) soil field capacity (FC). All treatments were maintained under WW conditions until the R5 phase, when moderate (WD60) and severe water deficit (WD40) were imposed for 11 days. After this period, the values of chlorophyll a and b (chl_a, chl_b), carotenoid, relative water content (RWC), net CO₂ assimilation rate (A), stomatal conductance (g_s) electron transport rate (ETR), transpiration (E), water potential (Ψ), and electrolyte leakage (EL) in the second trifoliolate soybean leaves, and dry biomass (pod, leaf, stem) of soybean were evaluated. The Si deposition and anatomical modifications in leaves were also evaluated using scanning electron microscopy with energy dispersive spectroscopy (SEM/EDX), and light microscopy. There was only an influence (p<0.05) of water deficit on chl_a, chl_b, carotene, A, g_s, and E, which reduced these values. Fertilization increased only the values of A, Si concentration, and Si was distributed in the epidermal cells. When Si was not applied, thickness of leaf, mesophyll and abaxial epidermis were reduced with WD60 and WD40 compared to WWW. On the contrary, no difference was observed between WW and WD60, WD40 in leaf and mesophyll thickness with Si fertilization. It was concluded that Si fertilization maintains the leaf thickness of leaves of soybean plants under moderate and severe water deficit, but it does not influence physiological and gas exchange responses of leaves, and the dry biomass. Acknowledgments: FAPESP22/00733-7





PO5_5 INTERACTIVE EFFECT OF SILICON AND ARBUSCULAR MYCORRHIZAL FUNGI ON PLANT WATER STATUS AND ITS RELATION WITH THE GENE EXPRESSION OF AQUAPORINS IN WHEAT PLANTS GROWN UNDER WATER DEFICIT

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The benefits of silicon (Si) and arbuscular mycorrhizal fungi (AMF) on plants exposed to water deficit have been widely recognized, but their interactive effects on the gene expression of aquaporins in plants facing water limitation remain poorly understood. Accordingly, we evaluated the effect of Si uptake and AMF symbiosis on plant water status, and its relation with the gene expression of aquaporins in wheat plants subjected to different Si, AMF and water irrigation treatments. A pot experiment by using wheat cv. Kiron was conducted, and plants were subjected to two irrigation regimes [90% of water holding capacity (WHC) and 40% WHC], two Si doses (0 or 1000 mg Si kg⁻¹ soil), and two AMF levels (-AMF, +AMF). Plants were harvested at tillering stage, and the relative water content (RWC) and water potential (Ψ_w) were determined. The relative expression pattern of aquaporin genes belonging to PIP, TIP and NIP subfamilies were also analyzed in roots by quantitative real-time polymerase chain reaction (qPCR). Despite water deficit reduced RWC and Ψ_w under water limitation, a significant increase in these parameters was found when Si, AMF or Si+AMF were applied to water-deficient plants. Compared to 90% WHC, the transcript levels of TaPIP1 increased under water deficit conditions, with a further increase being observed after Si was applied to low-watered plants. In contrast, a reduction in the expression of TaPIP1 occurred when AMF was applied alone or in combination with Si under water scarcity. Different to 40% WHC, the application of AMF or Si+AMF increased the expression of TaPIP1 in well-watered plants. On the other hand, TaTIP2 was down-regulated in plants subjected to water deficit. Although Si or AMF did not induce significant changes in the transcript levels of TaTIP2 at 40% WHC, the expression of this gene was up-regulated by the simultaneous application of Si+AMF. Whereas an induction of TaTIP2 was found in response to the addition of Si or AMF at 90% WHC, the combination of Si+AMF reduced the expression of TaTIP2 to levels comparable to those of well-watered plants. Interestingly, an up-regulation of the Si transporter TaLsi1 was detected in response to AMF inoculation to low-watered plants, with no further increase being observed under Si+AMF. Overall, the join action of Si and AMF improved plant water status and differentially modulated the expression of aquaporin genes in wheat plants subjected to water deficit stress. Acknowledgments: FONDECYT Projects N°11240738, N°1241718 and N°11240769, ANID, Chile.





PO5_6 INFLUENCE OF SILICON ON GROWTH, WATER STRESS TOLERANCE AND DEFENCE AGAINST THE NEOPESTALOTIOPSIS LUSITANICA FUNGUS, IN EUCALYPTUS GLOBULUS

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Silicon (Si), the second most abundant element on Earth, primarily exists in soil as insoluble orthosilicic acid. Recognized as a plant-beneficial element, Si has been widely used in fertilization to enhance crop growth. However, its uptake, transport, accumulation, and effects on hardwood trees, particularly eucalyptus, remain largely unexplored. Beyond promoting plant growth, Si plays a crucial role in strengthening tolerance to both biotic and abiotic stresses by forming chemical and physical barriers. This is especially relevant for eucalyptus during its transition from nursery to field conditions, where drought stress and fungal pathogens, such as *Neopestalotiopsis* sp., pose major threats. While *Neopestalotiopsis* sp. is an endophytic fungus, it can become pathogenic, causing significant economic losses in eucalyptus nurseries in Portugal.

This study investigated the effects of Si supplementation on *Eucalyptus globulus* growth and its resilience to both drought and *Neopestalotiopsis lusitanica* infection. We used two genotypes susceptible to the fungus and treated them with 1 and 2 mM calcium silicate via substrate irrigation for one month. Our goal was to assess whether Si could enhance plant growth and provide protection against water limitation and fungal infection, thereby justifying its inclusion in nursery fertilization programs. In addition to evaluating Si absorption, transport, and accumulation in eucalyptus plants, we conducted biometric and biochemical analyses, including enzyme activity and stress marker assessments, to determine its impact on plant metabolism.

Our findings revealed that, although *E. globulus* is a non-accumulator of Si, supplementation significantly promoted growth and enhanced resilience to both drought and fungal infection without causing phytotoxicity. Si increased plant height, photosynthetic pigment levels, and starch concentration in leaves. Notably, the 2 mM calcium silicate treatment was particularly effective in improving drought resistance by mitigating oxidative stress and strengthening antioxidant defences. Additionally, this treatment reduced the severity of *N. lusitanica* infection, delaying lesion formation and lowering plant mortality.

These results suggest that Si supplementation could be a valuable strategy for improving eucalyptus resilience in nursery conditions. By enhancing growth and stress tolerance, Si may help eucalyptus plants better withstand environmental challenges and fungal threats. However, further research is needed to optimize its application across different genotypes and environmental conditions to maximize its benefits.





PO5_8 SHOOT-SILICON-SIGNAL PROTEIN REGULATING SILICON UPTAKE IN RICE

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Uptake of silicon (Si) in rice, a typical Si-accumulating species, is mediated by three transporters, Lsi1 and Lsi2, which are polarly localized in the root exodermis and endodermis, while Lsi3 is localized in pericycle for Si xylem loading. The expression of these transporter genes is down-regulated by sufficient Si accumulation in the shoot, however, the underlying molecular mechanisms remain unknown. Through several aspect transcriptome analyses, we identified a gene (designated Shoot-Silicon-Signal, SSS) expressed in the leaves and nodes that was significantly down-regulated by Si supply within a few hours and disappeared within one day. SSS is a unique homolog (OsFTL12) of the flowering hormone “florigen” that has diversified in Poaceae. Interestingly, while this gene was not expressed in the roots, its encoded protein was detected there, suggesting that SSS is translocated from the shoot to the root. To determine whether this protein is present in the phloem for the movement from the shoot to the root, we developed a “DIY-insect-laser” technique to collect the pure phloem sap. This method involves snipping the stylet of phloem-sucking brown planthopper using a blue diode laser, allowing collection of rice phloem sap from the cut end. Using this technique, we detected SSS protein in the phloem sap. To investigate the role of SSS in plants, we generated knockout lines. Knockout of SSS resulted in decreased Si uptake. Furthermore, the expression levels of Lsi1, 2 and 3 no longer responded to Si supply and were reduced to a level similar to those in wild-type plants under Si-sufficient conditions. The grain yield of the mutants decreased to 1/3 of that of the wild type, likely due to insufficient Si accumulation. Our findings demonstrate that SSS is a shoot-derived mobile signal protein that regulates Lsi1, Lsi2 and Lsi3 for Si uptake and xylem loading. Further analysis showed that SSS orthologs are also present in other Si-accumulating graminaceous species. We confirmed that these orthologs in wheat, maize and Moso bamboo exhibited similar responses to Si as observed in rice SSS. Although Si is not considered an essential element, its high accumulation is crucial for protecting plants from abiotic and biotic stresses. The identification of SSS highlights that graminaceous plants have evolved a finely tuned system integrating root Si uptake and shoot Si accumulation by neo-functionalization of the flowering hormone.





PO6_1 **CALCIUM NITRATE FERTIGATION REDUCES THE INCIDENCE OF POSTBLOOM FRUIT DROP AND IMPROVES NITROGEN USE EFFICIENCY IN SWEET ORANGE TREES**

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Postbloom fruit drop (PFD) is a fungal disease caused by *Colletotrichum* spp., which severely compromises the productivity of sweet orange orchards, challenging the sustainability of citrus industry. In a greenhouse, we demonstrated that balanced nitrogen (N) and calcium (Ca) management promotes the formation of well-organized floral tissues with thick cell walls, reduced epidermal roughness, and reduced hyphal colonization as revealed by light and electron microscopy. We validated our results in a field experiment conducted in a commercial orchard for three years, with 'Natal' orange [*Citrus sinensis* (L.) Osb.] grafted onto Swingle citrumelo [*C. paradisi* Macfad × *Poncirus trifoliata* (L.) Raf.], in a completely randomized design with split plots. The plots corresponded to the application or not of fungicide (Trifloxystrobin + Tebuconazole). The subplots consisted of three N sources supplied via fertigation: CN (100% NO_3^-), CN+AN (75% NO_3^- + 25% NH_4^+) and AN (ammonium nitrate; 50% NO_3^- + 50% NH_4^+), applied via fertigation (200 kg ha^{-1} year $^{-1}$ of N). Flower buds in field trees were inoculated with *Colletotrichum acutatum* (10^5 conidia mL^{-1}) and maintained in humid chambers for 24 h. The incidence of PFD was evaluated one week after inoculation. We analyzed the Ca content in flowers, soil pH and Ca availability, fruit yield, and N use efficiency of trees (NUE). The results demonstrate that CN increased soil pH, favoring plants availability and uptake of Ca, as evidenced by significant correlations between soil pH and available Ca ($R^2 = 0.99^*$) as well between soil pH and Ca content in flowers ($R^2 = 0.99^*$). CN contributed to higher Ca content in flowers (4.4 g kg^{-1}) and increased fruit yield (50 t ha^{-1}) and NUE (196 kg kg^{-1}). Furthermore, plants fertigated with CN exhibited a 25% reduction in the incidence of PFD compared to those fertigated with CN+AN or AN. We concluded that the use of CN in fertigation strengthens the tolerance of orange trees to PFD, promoting greater availability and uptake of Ca, formation of more structured floral tissues, and reduced susceptibility to infection by *Colletotrichum* spp., a condition tested under a controlled environment and validated in the field. This sustainable strategy integrates mineral nutrition with phytosanitary management, resulting in greater productivity and NUE. By reducing the dependence on fungicides and optimizing the use of fertilizers, CN redefines the nutritional and healthy management of citrus, contributing to food security and the resilience of agricultural systems in the face of global challenges.





PO6_2 IMPACT OF SOIL AMENDMENTS AND RESIDUAL NITROGEN ON SOYBEAN NITROGEN FIXATION AND NUTRIENT UPTAKE

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Soil acidity is a crucial factor influencing biological nitrogen fixation (BNF) in legumes, impacting crop productivity. Previous studies indicate that calcium (Ca) plays a fundamental role in root infection by *Bradyrhizobium*, which is essential for nodule formation in soybean. This study hypothesizes that the application of lime and gypsum enhances soil conditions, increasing nitrogen fixation efficiency in soybean, with potential effects on maize yield. This research aimed to evaluate the effects of soil acidity correction (lime and gypsum) and different nitrogen (N) fertilization rates on soybean BNF and subsequent maize growth in a tropical cropping system. A field experiment was conducted in Botucatu, SP, from 2016 to 2018, with soybean as the summer crop followed by a maize-Guinea grass intercropping system in the second season. A randomized complete block design with four replications (48 experimental units) was used, applying three soil treatments (control, lime, and lime + gypsum) and four N doses (0, 80, 160, 240 kg ha⁻¹) in maize. Soybean leaf ureide content was analyzed as an indicator of BNF efficiency. Macronutrient levels in leaves were also measured to assess soil amendment effects on nutrient availability. Lime application increased nitrogen and magnesium concentrations in soybean leaves, enhancing BNF efficiency, as indicated by higher N-ureide content (up to 59.9 g kg⁻¹ N). Gypsum application reduced phosphorus levels but improved N-ureide accumulation in the second year, reaching 27.9 μmol g⁻¹ in the lime + gypsum treatment. The number and dry mass of nodules were lower in lime-treated plots, but their efficiency was higher. In the 2017/18 season, lime application resulted in higher grain nitrogen content (56.57 g kg⁻¹ N) compared to the control (53.52 g kg⁻¹ N) and lime + gypsum (53.84 g kg⁻¹ N). Increasing N fertilization reduced N-ureide concentration in lime treatments but increased it in gypsum-treated plots. Soil acidity correction improved nitrogen availability and BNF efficiency in soybean, with lime and gypsum treatments enhancing nutrient uptake. Although lime + gypsum reduced phosphorus levels in soybean leaves, it contributed to higher BNF efficiency. The results suggest that optimized soil management strategies, balancing acidity correction and nitrogen fertilization in the following crop, can enhance legume nitrogen fixation and overall crop productivity in tropical systems. These findings highlight the importance of soil amendments in maximizing nitrogen efficiency, ultimately contributing to sustainable agricultural practices.

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PO6_4 SILICON AS A NUTRITIONAL STRATEGY TO MITIGATE ABIOTIC STRESSES FOR SUGARCANE RATOON PRODUCTION IN CENTRAL BRAZIL

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Silicon is a beneficial element capable of inducing plant resistance to abiotic stresses, especially due to high temperatures and water deficit, common in tropical regions. The objective of the research was to evaluate the physiological behavior, as well as the production of stalks (TCH) and sugar (TAH) in sugarcane ratoons as a function of foliar fertilization with silicon applied in the pre-drought phase, as well as to evaluate the differential profit obtained by the applied treatments. Four experiments were carried out under field conditions, in the 2022/23 harvest, two with the second sugarcane ratoon (varieties: CTC-9002, RB 98-5476) and two with the third sugarcane ratoon (varieties: CTC 03-9365 and RB 97-5242). The experimental design for each crop was in randomized blocks, consisting of five silicon doses (0-control, 250, 500, 750 and 1,000 g ha⁻¹ of Si) applied in the form of potassium silicate, both in a solution stabilized with 10% sorbitol and with six replicates each. The treatments were applied at the end of the rainy season, in May 2022. The results obtained were subjected to analysis of variance by the F test and, if there was significance in the treatments, a regression study was carried out. In both experiments, there were increases in plant gas exchange, with gains of 21% and 56% in internal CO₂ concentration and stomatal conductance of the plants, respectively, with the highest dose applied. The dose of 500 g ha⁻¹ of Si promoted the greatest increases in the rates of net photosynthesis, in the chlorophyll index, in the production of stalks (TCH) and sugar (TAH) of the plants, being 36%, 9%, 19% and 22.6%, respectively, in relation to the control treatment. Also at this dose, there was an 8% reduction in the flavonol index of the plants and promoted the greatest possible differential profits for the production of stalks (US\$ 254 ha⁻¹) and sugar (US\$ 456 ha⁻¹). It is concluded that the use of 500 g ha⁻¹ of Si applied in pre-drought and in a single dose emerges as a viable alternative to mitigate the deleterious effects of abiotic stress for the production of sugarcane ratoons in a tropical climate.





PO6_5 CONTROLLED-RELEASE FERTILIZERS TECHNOLOGIES FOR BETTER USE OF NITROGEN IN COFFEE CROP ENVIRONMENTS

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The adoption of nitrogen (N) fertilizer innovations and technologies can mitigate N-losses and ensure greater productive efficiency in coffee crops environments. To promote better N-use efficiency the aim of this research was to evaluate the performance of N-fertilizer technologies in *Coffea arabica* L., using controlled-release blends, conventional urea, and organomineral fertilizers applied at different rates, and to observe their effects on the N dynamics in the soil-plant-atmosphere system. The field trial was conducted in Santo Antônio do Amparo city, Minas Gerais state, Brazil, during the 2022/2023 (1st) and 2023/2024 (2nd) harvests. The experimental design was a randomized block design with three replications and four treatments: 1) conventional urea; 2) organomineral fertilizer; 3) blend "1"; 4) blend "2". These N-fertilizers were applied at rates of: 200; 280; and; 400 kg ha⁻¹ year⁻¹. Conventional urea was applied in three splits and the others in a single application. Quantification of ammonia volatilization losses (N-NH₃), nitrous oxide (N-N₂O) emissions, N-release evaluations under field and laboratory conditions, productivity, yield, and N export by the beans and husks were carried out. N-release evaluations under field and laboratory conditions, it was observed that the curves for the organomineral fertilizer were always above the curves for blends 1 and 2. Blend 1 promotes greater longevity, followed by blend 2, confirming the controlled-release characteristic of both, which makes single-dose N-fertilization feasible without compromising productivity. In both harvests, N-NH₃ accumulated losses were influenced by the N-fertilizers in the following descending order: urea > organomineral > blend 1 = blend 2, with average N-losses over the two coffee growing seasons ranging from 42.8 to 99.1 kg ha⁻¹ year⁻¹. N-NH₃ losses were reduced compared to urea, with reductions of 40.5% for the organomineral fertilizer, 71.2% for blend 1, and 71.3% for blend 2 in the 1st harvest. In the 2nd harvest, the loss reductions were 19.6%, 36.9%, and 39.8% for the organomineral fertilizer, blend 1, and blend 2, respectively. N₂O fluxes showed statistical differences ($p \leq 0.05$) between N-fertilizers. Blend 1 (133,4 g N₂O ha⁻¹) reduced the N₂O emission flux by 82% compared to conventional urea (747,9 g N₂O ha⁻¹), while blend 2 (250,7 g N₂O ha⁻¹) and the organomineral fertilizer (284,1 g N₂O ha⁻¹) decreased the N₂O emissions by 67% and 62%, respectively. Productivity, yield, and N export by the beans and husks were not influenced by the N-technologies and rates applied in coffee orchard.





PO6_8 OPTIMISING COMMON BEAN YIELD: THE IMPACT OF LATE UREA APPLICATION ON PHOTOSYNTHESIS AND NITROGEN NUTRITION

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The common bean (*Phaseolus vulgaris* L.) is characterised by a short phenological cycle and high nitrogen (N) use efficiency. Current practices involve nitrogen application rates of up to 300 kg ha⁻¹ to achieve high yields, with the majority applied during sowing and early developmental stages. However, peak nitrogen demand occurs during the reproductive phase, particularly in the grain-filling period. This study evaluated the efficiency of nitrogen fertilisation in common bean cultivation as a function of application timing. A field experiment was conducted using a strip-plot design, with strips measuring 32 x 450 m. The experimental design comprised four treatments, corresponding to nitrogen doses applied at the V7 and R8 growth stages (90 and 40; 70 and 60; 50 and 80; 30 and 100 kg ha⁻¹ of N, respectively). Four random evaluations were conducted within each strip. Seven days after V7 stage application, assessments included leaf nitrogen content, chlorophyll a, b, and total indices, chlorophyll fluorescence indices, photosynthesis rates, and the number of pods greater than and less than 40 mm. Seven days after R8 stage application, evaluations focused on leaf nitrogen content, chlorophyll a, b, and total indices, and chlorophyll fluorescence indices. At harvest, measurements included plant height, pod count (greater than and less than 40 mm), grain yield, thousand-grain weight, grain nitrogen content, and nitrogen export. Data were analysed using analysis of variance and Tukey's mean test ($p \leq 0.05$). During the vegetative stage, lower nitrogen doses increased pod count in the common bean cultivar Veloz at the onset of the reproductive stage, alongside higher net photosynthesis rates but lower photochemical efficiency indices. Conversely, the highest nitrogen dose reduced pod count, net photosynthesis, and increased tissue ammoniacal nitrogen concentrations. At the R8 stage, plants fertilised with 80 kg ha⁻¹ of N exhibited the highest photosystem electron transport efficiency, quantum efficiency, and nitrogen nutritional status, as indicated by elevated leaf nitrogen content. The results demonstrate that applying 50 kg ha⁻¹ of N at the V7 stage and 80 kg ha⁻¹ of N at the R8 stage maximised grain yield in the common bean cultivar Veloz, attributed to enhanced photochemical efficiency and reduced pod loss.





PO6_9 EFFECT OF TEMPERATURE ON MAIZE SEEDLINGS DEVELOPMENT AND NUTRIENT UPTAKE

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Temperature plays a fundamental role in seedlings development and nutrient uptake by influencing physiological and biochemical processes. In a climate change scenario, global temperatures are expected to increase and heat stress can alter the dynamics of nutrient uptake modifying root and soil activity, accelerating chemical reactions, and enhancing nutrient solubility in the soil. Maize is an important global commodity. Although it is a crop with higher photosynthetic efficiency, which provides advantages in specific environmental conditions, its development is affected by high temperatures and seed sieve could mitigate environmental stress. The objective of this study was to evaluate the effect of two temperatures on nutrient uptake in maize (*Zea mays* L.) seedlings. Experiment was conducted in a greenhouse at Soil Science Department of University of São Paulo, Luiz de Queiroz campus, in Piracicaba, São Paulo. Two types of soil temperatures, 25°C (control) and 38°C (high), and two types of sieves, RM2 and C3M, with four replicates in randomized block design in factorial scheme 2x2. Temperatures were monitored using soil temperature sensors during seed emergence. Seedlings were collected, dried in a forced-air circulation oven at 60°C for 72 hours, weighed and grounded. Nitrogen (N) analysis was performed through acid digestion with H₂SO₄ and ammonia distillation using a Kjeldahl distiller. For the other nutrients, digestion was performed using nitro perchloric acid in a microwave oven, and determinations were taken using Inductively Coupled Plasma (ICP). Data were subjected to analysis of variance and Tukey's test at a 5% significance level. Seedlings grown at 24°C showed higher levels of macronutrients (g kg⁻¹) N, P, K, Ca, Mg, and S, and micronutrients (mg kg⁻¹) B and Zn, with values of 31.1, 5.6, 12.9, 5.0, 3.9, 4.4, 73.4 and 98.8, respectively. At 38°C, highest level was observed for the elements Co, Fe and Ni with values of 3.9, 4,740.3, and 48.5, respectively. Higher nitrogen levels were measured for the RM2 sieve and higher calcium levels for the C3M sieve at both temperatures. The micronutrients Cu, Mn, and Mo were not significant for any of the factors. Lower values of shoot dry mass, 1,39g (RM2) and 1,21g (C3M), were found in seedlings grown at the higher temperature. Thus, this study highlighted the changes in nutrient uptake under higher temperature abiotic stress and contributes to the development of new knowledge and alternatives to ensure productivity and global food security.





PO6_10 FATE OF ¹⁵N-LABELED FERTILIZER AND GRAIN YIELD OF MAIZE INTERCROPPED WITH TROPICAL GRASS

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In tropical regions, intercropping forage grasses like *Urochloa* (syn. *Brachiaria*) and *Megathyrsus* (syn. *Panicum*) with maize (*Zea mays* L.) has significantly increased over the last decade. This agricultural system enhances chemical, biological, and physical soil properties, as tropical forages promote nutrient cycling through deep rooting. However, limited knowledge exists regarding the fate of nitrogen (N) fertilizer in the system when different tropical forage grasses are intercropped with maize. We aimed to investigate the effects of Guinea grass (*M. maximus*), palisade grass (*U. brizantha*), and ruzigrass (*U. ruziziensis*) intercropped with maize on the fate of ¹⁵N-labeled fertilizer, N accumulation, and crop yield in a two-year field experiment (2016-2018) conducted in southeastern Brazil. The experiment followed a randomized complete block design with four replications. The forage species Guinea grass, palisade grass, and ruzigrass were intercropped (planted in the same row but deeper) with maize in the summer season (December-April) during two growing seasons. At planting, 30, 48, and 38 kg ha⁻¹ of N, P, and K were applied, respectively, while 150 and 61 kg ha⁻¹ of N and K, respectively, were applied during topdressing at the V5 maize stage. A microplot was established within each plot, and (15NH₄)₂SO₄ with 4.5 and 2.8 atom % ¹⁵N excess was applied in the first and second seasons. At harvest (R6 stage of maize), samples of maize, forage, litter, and soil were taken from the microplots. Higher maize yield was observed in the second season than the first, regardless of the forage grass, with increases ranging from 44% to 94%. In the 2018-2019 season, Guinea increased maize yield by 17%, on average, relative to the other intercropping systems. ¹⁵N-fertilizer recovery in maize shoots was not influenced by the forages, while ¹⁵N in litter was higher in the second season than the first, irrespective of the intercropping system. Guinea grass recovered 93% more ¹⁵N in its biomass than the other forages in the second season. Residual ¹⁵N in the soil was similar across crop seasons, with 62%, 14%, 13%, 6%, and 5% of the total found in the 0-10, 10-20, 20-40, 40-60, and 60-80 cm layer, respectively. The intercropping systems did not affect the total ¹⁵N recovered in the system. In conclusion, all three intercropping systems can be adopted during the summer season in tropical Brazil, with Guinea grass exhibiting more potential to increase maize yield and retain fertilizer-derived N in the biomass than palisade grass and ruzigrass.





PO6_11 SOIL P AVAILABILITY, DROUGHT AND CULTIVAR MODULATING PEANUT ROOTING IN THE SOIL PROFILE

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Peanut (*Arachis hypogaea* L.) is known for its robust root growth, which is an adaptation strategy to tropical sandy soils prone to drought. However, the combined effects of phosphorus (P) availability and cultivar on root system growth under varying water availability and cropping systems remain unclear. This study aimed to evaluate how the distribution of the peanut root system of peanut cultivars in the soil profile correlates with pod yield in different soil water and P availabilities. From 2021 to 2023, four field experiments were conducted in southeastern Brazil on sandy soils. Each year, two experiments were conducted simultaneously, one following a degraded pasture with low initial P and the other in a crop rotation system with medium initial P. The treatments included peanut cultivars (early maturing – IAC OL3 and late maturing – IAC 503) and P levels (0, 17, 35, 52 and 70 kg ha⁻¹). The fertilizer was applied in the seeding furrow, using triple superphosphate. Roots were collected at the R4-R5 stages of peanuts. A probe was used to collect root samples at depths of up to 80 cm. During the first and second years, rainfall was 680 and 1225 mm, respectively. Due to drought conditions and low soil fertility (2021/2022 – low P initial area), there was a higher root concentration in the 0-10 cm layer, accounting for 45% of the total. In the moister year, the concentration of roots below 40 cm increased, with 21% and 18% with low and medium P, respectively. Under P deficiency, or when the optimum P rate between 17 and 52 kg ha⁻¹ was applied, the late-maturing cultivar showed greater dry matter and root length than the early-maturing cultivar. The effect of P fertilization on root growth was evident up to the 20-40 cm layer in soils with low initial P and up to 40-60 cm in soils with medium initial P. A positive correlation was found between pod yield and root dry matter in the 0-10 and 10-20 cm soil layers, while for root length, the positive correlation was mainly observed in the 0-10 cm layer. Optimal P fertilization (17 to 52 kg ha⁻¹) associated with the use of late-maturing cultivar and adequate water availability enhanced peanut root growth, particularly in the uppermost soil layer, leading to increased pod yield. In contrast, drought and low initial soil P availability restrict peanut root growth in deeper soil layers.





PO6_12 NITROGEN AND SILICON AS NUTRITIONAL STRATEGIES TO INCREASE THE PRODUCTIVE YIELD OF SUGARCANE PRODUCED IN BRAZIL

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The production of sugarcane in Brazil has significantly increased in recent years, emphasizing sustainable practices. Nutritional strategies, particularly adequate nitrogen supply, influence the longevity of sugarcane fields. Additionally, silicon is recognized as a key factor in enhancing plant resistance to abiotic stresses, thereby maintaining or boosting crop yields. This research aimed to assess the impact of nitrogen sources and foliar silicon fertilization on the yield and profitability of sugarcane ratoons in Brazilian tropical conditions. Two field experiments were conducted during the 2022/2023 harvest in Bom Jesus de Goiás, focusing on the third ratoon of the CTC-4 variety and the fifth ratoon of the IAC 91-1099 variety. Each experiment utilized a randomized block design in a 3x5 factorial scheme, incorporating three nitrogen sources (urea, ammonium nitrate, and calcium ammonium nitrate (CAN) with a nitrification inhibitor, DMPSA) and five silicon doses (0-control, 450, 900, 1,350, and 1,800 g ha⁻¹), applied in three equal sprayings throughout the cycle, with six repetitions. The potassium silicate used was liquid and stabilized with sorbitol at a 10% concentration, ensuring balanced potassium levels in the foliar solutions. Evaluations included leaf silicon content, water use efficiency (WUE), tons of stalks per hectare (TCH), tons of sugar per hectare (TAH), and differential profit based on treatments. Results were analyzed using variance analysis with the F test, followed by polynomial regression for quantitative data and the Scott-Knott test for qualitative variables. The findings revealed that the highest silicon dose led to increased leaf silicon content (13 and 12 g kg⁻¹), WUE (59 and 107 kg mm⁻¹), TAH (11.9 and 18.3 t ha⁻¹), and TCH (71 and 103 t ha⁻¹) for the CTC-4 and IAC 91-1099 varieties, respectively. Ammonium nitrate and calcium were more effective for CTC-4, while CAN+DMPSA was better for IAC 91-1099. The study concluded that using ammonium nitrate and calcium, along with foliar silicon at 1,350 g ha⁻¹ in three applications, is effective for sugarcane ratoon production in central Brazil, yielding the highest differential profits of US\$ 1,547 ha⁻¹ for CTC-4 and US\$ 2,212 ha⁻¹ for IAC 91-1099.





PO6_13 OPTIMIZING PHOSPHORUS MANAGEMENT IN SOYBEAN-MAIZE CROPPING SYSTEMS: BALANCING YIELD AND AGRONOMIC EFFICIENCY

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1 - Yara International S/A; 2 - Fundação MT, Researcher

To enhance phosphorus (P) fertilizer efficiency in crop production, plants must absorb more P from the soil and use it effectively for growth and yield. In the soybean-maize cropping system in the Midwest region of Brazil (primarily the Cerrado biome), soybean is cultivated during the summer rainy season (October/November to January/February), followed by maize, which is sown between January and February immediately after soybean harvest. This production system requires strategic P application timing to optimize uptake in crops that respond well to P fertilization. This study investigates the influence of applying P either to soybean or maize in an Oxisol with low P-Mehlich-1 levels (5 mg dm^{-3}) and approximately 43% clay content in the 0–20 cm layer. Conducted in Itiquira, Mato Grosso, Brazil, the experiment was established in the 2019/2020 season using a randomized block design with four replications and 12 treatments: 0/0 – no P application in both crops; 40/0 – 40 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ in soybean; 80/0 – 80 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ in soybean; 120/0 – 120 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ in soybean; 160/0 – 160 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ in soybean; 0/40 – 40 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ in maize; 0/80 – 80 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ in maize; 0/120 – 120 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ in maize; 0/160 – 160 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ in maize; 90/30 – 90 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ in soybean and 30 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ in maize; 60/60 – 60 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ in soybean and 60 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ in maize; 30/90 – 30 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ in soybean and 90 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ in maize. The study evaluated grain yield, relative productivity (%) and agronomic efficiency (kg of grain per kg of P_2O_5 applied) and foliar P contents (sampled at full flowering in both crops). Results showed that system yield was highest when P application ranged from 80 to 160 kg ha^{-1} of P_2O_5 , regardless of whether it was applied to soybean or maize. When 120 kg $\text{P}_2\text{O}_5 \text{ ha}^{-1}$ was split between the two crops, system productivity remained similar regardless of the timing of P application. However, agronomic efficiency was higher when a larger proportion of P_2O_5 was allocated to soybean rather than maize. Additionally, soybean exhibited a stronger response to P fertilization than maize, as demonstrated by the P response and foliar P content curves.





PO6_14 NITRIC OXIDE, SILICON AND ZINC POLYPHENOL BOOST BEAN PHOTOSYNTHESIS AND YIELD

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1 - Goiano Federal Institute; 2 - FertiGlobal; 3 - Mosaic Company; 4 - Unicampo; 5 - Marambaia Sementes; 6 - Municipal Secretariat of Education of Rio Verde, Goiás

The common bean (*Phaseolus vulgaris* L.) is susceptible to biotic and abiotic stresses. Climate change and the need for biodiversity conservation pose challenges to modern agriculture. Consequently, resistance inducers, such as biostimulants, have been studied. Silicon enhances mechanical resistance, reduces transpiration, and increases photosynthesis. Nitric oxide (NO) activates systemic acquired resistance, while polyphenolic compounds and zinc boost antioxidant enzyme activity. This study aimed to evaluate the effects of silicon, nitric oxide, and zinc polyphenol on photosynthesis and yield of the black bean cultivar IPR-Urutau. The field experiment was conducted in Rio Verde, Goiás, Brazil, on an Rhodic Acrustox, equivalent to Latossolo Vermelho Acriférico in the Brazilian Soil Classification System. A randomised block design with five treatments and four replicates was used: Control, silicon (Si), nitric oxide (NO), Si+NO, and Zinc+Polyphenol (Zn+Poly). Semia® (13.6 g L⁻¹ N, 272 g L⁻¹ Zn, d = 1.36 g mL⁻¹) was applied at 0.3 L ha⁻¹ as the Zn+Poly source, potassium silicate (168 g L⁻¹ Si; 174.25 g L⁻¹ K, d = 1.4 g mL⁻¹, pH = 10.96) at 2 L ha⁻¹ as the Si source, and sodium nitroprusside p.a. at 200 µmol L⁻¹ as the NO source. Treatments with Si, NO, and Si+NO were applied at V3 and R8 stages, while Zn+Poly was applied at V3, V4-R, and R8. Photosynthetic pigments (ClorofiLog), chlorophyll a fluorescence (Fluorpen), and photosynthesis (IRGA) were assessed seven days after R8. At harvest, pod number, thousand-grain weight, and yield (13% moisture) were evaluated. Zn+Poly (Semia®) and Si+NO reduced chlorophyll a indices. Zn+Poly (Semia®) improved chloroplast ultrastructure, with lower MO and SM indices, resulting in higher probability of photon-induced electron movement from quinone A (ΦE0), increased maximum photochemical efficiency (ΦPMAX), and reduced energy dissipation as heat (DIO). Treatments with Si, NO, and Si+NO showed similar ΦPMAX, DIO, and net photosynthesis (A) values to Zn+Poly (Semia®). Grain yield and pod number were higher with Zn+Poly (Semia®) and Si, while NO, alone or combined with Si, reduced these parameters. In conclusion, Zn+Poly (Semia®) and Si enhance photochemical efficiency and photosynthesis, improving chloroplast ultrastructure, pod number, and yield compared to NO.





PO6_15 FIELD-BASED GENETIC AND MOLECULAR STUDIES TO DISSECT TOLERANCE MECHANISMS TO IRON TOXICITY IN RICE

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Iron (Fe) toxicity is a widespread soil nutrient stress that severely limits rice yield in many parts of Africa, Southeast Asia, and South America. Despite years of research identifying tolerant germplasm, genetic factors contributing to tolerance in field conditions remain largely unknown. In this study, we focused on the genotypic differences in tolerance levels between the popular variety IR64 and the tolerant landrace DJ123 from Bangladesh and investigated genetic factors that increase tolerance. To achieve this, we developed 48 chromosomal segment substitution lines carrying DJ123 introgressions in the IR64 genetic background and conducted screening experiments in hydroponics and farmers' fields in the Central Highlands of Madagascar. Three lines consistently showed tolerance to Fe toxicity in both conditions, and further fine-mapping showed these lines contained a common DJ123 introgression in a 300-kb region between 28-29 Mb on chromosome 1. Lines inheriting this region from DJ123 had high shoot Fe concentrations similar to IR64 but showed fewer Fe-toxicity symptoms and produced significantly higher grain yields than parent IR64 in the field, specifically under Fe toxic conditions.

RNA-seq analysis in leaf samples grown in hydroponic solutions with contrasting Fe levels suggested that the DJ123 allele at this locus mitigated the degree of transcriptional changes under Fe toxicity conditions; 73% of the genes that were expressed at lower levels in the line carrying the DJ123 allele compared to IR64 were Fe toxicity-inducible. To confirm this finding under field conditions, we developed a technique to facilitate gene expression analysis in field-grown plants without the need for cryogenics such as liquid nitrogen or dry ice. Using this method, we conducted an RNA-seq analysis in plants grown in Fe toxic fields in Madagascar to compare expression patterns between the sensitive IR64 and the Fe toxicity-tolerant breeding line KA-28, which likely carries the same allele as DJ123 at the chromosome 1 region. Remarkably, 2,687 genes that were expressed at lower levels in KA-28 compared to IR64 significantly overlapped with Fe toxicity-inducible genes, further suggesting that the tolerance allele confers insensitivity to high Fe concentrations.

Genetic segregation analysis indicated that the identified region confers tolerance to rice varieties grown in Fe toxic regions in Africa and Southeast Asia. Thus, these findings shed light on the genetic mechanisms underlying field-based Fe toxicity tolerance and highlight the potential for improving existing varieties sensitive to Fe toxicity. The results of ongoing field studies and physiological analyses will be also discussed.





PO6_16 INITIAL GROWTH AND CHLOROPHYLL LEVELS IN GRAIN SORGHUM GROWN IN THE FIELD WITH NITROGEN FERTILIZATION RATES

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Sorghum (*Sorghum bicolor* L.) is an important source of nutrients for both animal and human nutrition, contributing to animal protein production and ensuring global food security. The cultivation of this crop requires extensive study to optimize productivity and achieve the best fertilizer application efficiency throughout the plant's growth cycle. In this context, the objective of this study was to evaluate the response of nitrogen fertilization rates on the initial growth and leaf chlorophyll content of grain sorghum grown in the field. The experiment was conducted in the field at the University of São Paulo, Brazil, using a Randomized Block Design (RBD). The treatments consisted of five nitrogen fertilization rates: D0 = 0, D1 = 75, D2 = 150, D3 = 225, and D4 = 300 kg ha⁻¹ of nitrogen (N), with four replications. The evaluated parameters included plant height, stem diameter, number of leaves, and leaf chlorophyll content, measured using a chlorophyll meter (SPAD) at the V4 growth stage. Plants that did not receive nitrogen fertilization (D0) exhibited chlorosis in an inverted “V” shape, a typical symptom of N deficiency, which impacted plant growth. Plant height responded significantly to nitrogen fertilization rates following a quadratic model ($y = -0.0000005x^2 + 0.0074x + 38.4$), with lower heights observed in plants that did not receive nitrogen fertilization (D0 and D1). Stem diameter and number of leaves showed no statistical differences among the nitrogen levels. Leaf chlorophyll content varied significantly ($p < 0.05$) with nitrogen application, also following a quadratic model ($y = -0.00000005x^2 - 0.0015x + 45.5$), with readings ranging from 45 to 52. Therefore, it is concluded that increasing nitrogen fertilization promotes initial height growth and enhances leaf chlorophyll content in sorghum plants. However, it does not initially affect stem diameter or the number of leaves.





PO6_17 NITROGEN BALANCE IN SOYBEAN CROP PRODUCTION SYSTEMS IN THE BRAZILIAN SAVANNAH

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1 - Fundação MT; 2 - Universidade Federal do Rio Grande do Sul - UFRGS; 3 - Yara International

Soybean production can result in negative partial N balance (PNB), where more N is exported than biologically fixed (BNF). Nitrogen supply via fertilization is not recommended as it harms BNF. Therefore, crop diversification can be an alternative to increase BNF and favor positive or neutral PNB. This study investigates the influence of different production systems (e.g. monoculture, succession and crop rotation) on soybean PNB. The study was conducted in Itiquira, Mato Grosso, Brazil, within the savannah (Cerrado biome), which has a tropical climate. The soil is classified as Oxisol (60% clay). The experiment was established in the 2008/2009 season (17 years ago) using a randomized block design with four replications across eight production systems. The treatments included: soybean monoculture (M); Crop Succession (SC) SC1-soybean/millet; SC2-soybean/ruzigrass; SC3-soybean/corn second season; SC4-soybean/ruzigrass with 9 years with tillage and 7 years with no-tillage and with ruzigrass; Rotation (R) R1: year 1-soybean/millet, year 2-soybean/crotalaria, year 3-corn intercropped with ruzigrass; R2: year 1-soybean/crotalaria, year 2-corn intercropped with ruzigrass; R3: year 1-soybean/crotalaria, year 2-soybean/corn second season intercropped with ruzigrass, year 3-ruzigrass. The analyses in this study were conducted during the 2022/2023 and 2023/2024 growing seasons. Soybean plants were collected at the R6 phenological stage to determinate total dry mass, N-BNF ($\delta^{15}\text{N}$ natural abundance method) and grain yield (GY). The PNB was calculated as the difference between N accumulated via BNF (N-BNF) and N exported in GY. Data were subjected to analysis of variance (ANOVA), and when significant ($p < 0.05$), means were compared using the Scott-Knott test ($p < 0.05$). In season 2022/2023, the treatments with the lowest N-BNF were M, SC4 and R2, showing 42% reduction compared to the other systems. GY was 31% higher in treatments with continuous plant cover compared to M (3,099 kg ha⁻¹). The treatments with the highest PNB were SC1, SC2, R1 and R3, which were 131% higher than SC4, the treatment with the lowest PNB. In season 2023/2024, the lowest N-BNF values were M, SC2, SC4, R1 and R2. GY ranked in decreasing order with statistical differences were: SC1=SC3=R3>SC4=R1=R2>SC2>M. The highest PBN values were found in treatments M, SC1, SC2, SC4, R1 and R3, which had 288% higher PNB than SC3 and R2. In long term trial where the system provides nitrogen (either through fertilization and/or crop rotation with legumes), N-BNF decreases without reducing GY, resulting in a more balanced PNB (close to zero).





PO6_18 NUTRITIONAL AND PHYSIOLOGICAL PERFORMANCE OF ACAI (EUTERPE OLERACEA) IN RESPONSE TO ORGANIC COMPOST AND DOLOMITIC LIMESTONE

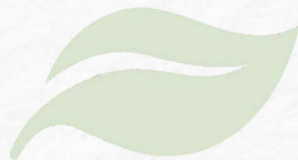
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The acai (*Euterpe oleracea* Mart) is a prominent Amazonian specie known for its rich characteristics, including high antioxidant capacity and its edible fruits, which serves as a staple food for the Amazonian population. In the state of Pará, there is a significant demand for organic products, particularly in agricultural production, making it essential to analyze the effect of organic inputs on acai fruit production. The objective of this research was to evaluate the effect of doses of compost associated with dolomitic limestone on the nutritional and physiological state of acai plants in organic farming, contributing to the sustainable living in the Amazon. The experiment was conducted with the acai variety BRS Pai d'égua, in Campo Limpo community in the municipality of Santo Antônio do Tauá/PA. A randomized block design with 7×2 factorial scheme was used with six replicates, where seven doses of organic compost (0, 2, 4, 6, 8, 10 and 12 kg) crossed with the presence or absence of liming (1.85 t ha⁻¹ of dolomitic limestone). Nutritional and physiological variables were assessed, such as macronutrients, micronutrients and gas exchange. In general, the organic compost provided the best results when doses of 8 and 10 kg/plant were combined with liming. Organic nutritional management significantly enhanced mineral nutrition, with nutrient content in tissue ranked as N > S > Ca > K > P > Mg (macronutrients) and B > Mn > Fe (micronutrients). Additionally, it boosted relative chlorophyll content by 38.8% and positively influenced net CO₂ assimilation rate, stomatal conductance, transpiration, intercellular CO₂ concentration and water use efficiency.





PO6_19 **PHYSIOLOGICAL INSENSITIVITY TO HIGH LEAF FE UNDERLIES TOLERANCE TO FE TOXICITY IN RICE**

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Iron (Fe) toxicity is a major nutrient stress that severely limits lowland rice yield in various regions of Southeast Asia, Sub-Saharan Africa, and South America. While tolerant rice varieties have been identified, their specific physiological factors underlying the tolerance remain unclear. This study aims to elucidate physiological mechanisms that contribute to field-based Fe toxicity tolerance by conducting field experiments and a hydroponic experiment. Field trials were conducted at Fe-stressed hotspot alongside control sites in Indonesia. Three contrasting lowland Indica rice genotypes were used: Ciherang (sensitive), IR42 (tolerant), and a breeding line KA-28 (tolerant) derived from a cross between Ciherang and IR42. In the field experiment, Ciherang exhibited the most severe leaf bronzing, biomass reduction, and >50% yield loss, whereas IR42 and KA-28 maintained higher yields (>80% of control) with less symptoms. Both tolerant genotypes increased Fe content in the shoot at the same rate as the sensitive Ciherang, suggesting that their tolerance is due to a shoot-based mechanism rather than the exclusion of excess Fe. The larger biomass of IR42 diluted Fe concentrations across tissues, while KA-28 exhibited tolerance despite having similar Fe concentrations as Ciherang in all tissues, suggesting that the tissues of KA-28 were less affected by the same levels of Fe. The hydroponic study also confirmed the “tissue-based” tolerance mechanisms of KA-28, as it showed significantly lower degrees of leaf symptoms than Ciherang despite having similar tissue Fe concentrations with excess Fe supply. Both genotypes showed reduced photosynthetic rate capacity in response to the increased concentration of Fe in young leaves as a result of Fe toxicity, but the reduction was more pronounced in Ciherang compared to KA-28. Expression patterns of Fe-responsive genes showed stronger induction of OsVIT2, a vacuolar Fe transporter, in Ciherang than in KA-28. These findings collectively suggest that physiological insensitivity to increased levels of Fe underlies the tissue-tolerance mechanism in KA-28. This study provides valuable insights for breeding Fe toxicity-tolerant rice and underscores the need for integrating field and hydroponic screening to identify robust tolerance indicators.

In addition, we found the first evidence that grain Zn concentrations, an important trait for addressing widespread children’s malnutrition in Indonesia, significantly increased under Fe toxicity conditions in the field experiment. Further testing with a broader range of genotypes (including improved varieties, landraces, and breeding lines) confirmed this finding, suggesting the need for further investigation.





PO6_20 GENOTYPIC VARIATION IN RICE FE TOXICITY TOLERANCE AND THE ATTRIBUTABLE TRAITS DURING GERMINATION AND ESTABLISHMENT

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Poor seedling establishment under Fe-toxic conditions hinders the widespread adoption of direct-seeded rice cultivation in Fe-enriched soil environments. To date, only a few studies have investigated the genotypic variation in Fe tolerance in rice during the pre-establishment period. The objectives of this study were to elucidate the effect of excess Fe on germination and the seedling vigor under various Fe levels, and to identify the tolerant rice genotypes and the physiological attributes. Nineteen genotypes were evaluated for Fe tolerance under hydroponic conditions, by imposing Fe stress from 0 to 15 days after sowing. Seed germination was not affected by high Fe stress (500 mg Fe²⁺ L⁻¹) in any genotype. However, exposure to 50 mg Fe²⁺ L⁻¹ retarded and reduced both shoot and root growths and 200 mg Fe²⁺ L⁻¹ resulted in partial plant mortality, whereas 400 mg Fe²⁺ L⁻¹ was completely lethal to plants. There was a significant genotypic variation in the shoot growth under Fe stress. The rank correlation in Fe tolerance was not significant between the pre-establishment and the vegetative stages. During the pre-establishment period, two indica genotypes, 'Pokkali' and 'Cilamaya Muncul', were shown to be tolerant to moderate to high Fe stress. Their Fe toxicity tolerance was attributable to their ability to limit Fe accumulation in shoots, mainly through a high root Fe retention capacity. 'Pokkali' also exhibited high Fe content in the root Fe plaque per unit root dry weight under the moderate Fe stress, suggesting the strong formation of the root Fe plaque potentially contributes to Fe toxicity tolerance in rice during establishment. Those results imply that the root-based mechanism is primarily important for Fe tolerance during the pre-establishment period in direct-seeded rice cultivation.

Acknowledgement

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PO6_21 MORPHOLOGICAL COMPOSITION OF UROCHLOA HYBRID CV. MULATO II TILLERS UNDER NITROGEN FERTILIZATION LEVELS

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Nitrogen fertilization provides changes in the levels of leaf chlorophyll, forage mass, and the weight of its morphological components in pasture systems, influencing the appearance and mortality of tillers. The objective of this study was to evaluate leaf chlorophyll content using a chlorophyll meter (SPAD), as well as the effects of nitrogen fertilization on the morphological composition of tillers of Urochloa hybrid cv. Mulato II, in two cuts. The experiment was conducted in the field at the University of São Paulo, using a Randomized Block Design. The treatments were: 0 (D0), 20 (D20), 40 (D40), and 60 kg.ha⁻¹ of Nitrogen (N) (D60), 4 blocks, with 2 cuts. For morphological composition analysis, evaluations took place at 7 and 37 days after forage uniformization (DAU). Ten tillers were randomly collected from each plot, and their morphological components (leaves, stem, and dead material) were separated. They were then dried in an oven to determine the dry mass of each component and calculate Relative Production (%) and Mass Proportion (% leaves, % stem, % dead material). For the chlorophyll meter, evaluations occurred at 50 and 60 DAU, where 10 randomly selected fully expanded young leaves were analyzed. The data were analyzed using Tukey's test at 5% probability. The dry mass of leaves from the 10 tillers responded to nitrogen fertilization doses according to positive quadratic models, being lower in the tillers that did not receive nitrogen, in both cuts. The dry mass of dead material from the 10 tillers also responded to nitrogen doses, following a positive quadratic model in the first evaluation and a negative quadratic model in the second evaluation. Therefore, the dry mass of dead material was lower in plants that received fertilization. The relative production of the 10 tillers responded according to positive quadratic models for the nitrogen doses. The proportion of leaves in the 10 tillers was higher at 7 DAU, while the proportion of stems was higher at 37 DAU. Chlorophyll meter readings showed significant effects ($p < 0.05$), with a linear effect at 50 DAU and a quadratic effect at 60 DAU. Chlorophyll levels in the plants at 50 DAU were lower than at 60 DAU, and lower in plants that did not receive nitrogen. It can be concluded that nitrogen fertilization has a positive effect on leaf chlorophyll content and the increase in dry mass of the morphological components of tillers of Urochloa hybrid cv. Mulato II.





PO6_22 EFFECT OF POST-HEADING TEMPERATURE ON INORGANIC ARSENIC ACCUMULATION IN RICE GRAINS

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Rice, a staple food crop, is commonly cultivated under flooded conditions, which enhance yield and mitigate continuous cropping disorders. However, flooding increases the solubility of inorganic arsenic (iAs) in soil, potentially leading to its accumulation in rice grains. Because iAs is a known carcinogen and rice is a major dietary source of iAs exposure, understanding the factors influencing its accumulation is crucial for ensuring food safety.

Analysis of rice cultivated in the same paddy field for approximately 20 years revealed a correlation between higher temperatures during the weeks following heading and increased iAs concentrations in rice grains (1). A similar trend was observed in rice grown at approximately 3,000 sites across Japan over three years, as investigated by the Ministry of Agriculture, Forestry, and Fisheries of Japan (2).

To elucidate the underlying mechanism, we conducted controlled greenhouse experiments where rice was grown under four different temperature regimes. We examined the timing of iAs absorption and accumulation in grains and analyzed the relationship between temperature and carbohydrate translocation to grains. Our findings suggest elevated temperatures reduce carbohydrate translocation to grains, diminishing the dilution effect and consequently increasing iAs concentration in rice grains.

As global warming continues to raise temperatures, iAs levels in rice may further increase. Therefore, it is essential to implement water management strategies that suppress iAs uptake, such as temporary drainage of paddy fields at appropriate times, while maintaining rice yield.

1. Arai, T., T. Makino, A. Kawasaki, I. Akahane, and N. Kiho. 2018. Effect of air temperature after heading of rice on the arsenic concentration of grain. *Soil Science and Plant Nutrition*. 64: 433-437.

2. Ministry of Agriculture, Forestry and Fisheries of Japan. 2019. Survey of arsenic in paddy fields in Japan. https://www.maff.go.jp/j/syouan/nouan/kome/k_as/attach/pdf/maff_kome-2.pdf (in Japanese) (accessed February 5, 2025).





PO6_23 BIOMETRIC AND PRODUCTIVE PARAMETERS OF GRAIN SORGHUM SUBJECTED TO NITROGEN FERTILIZATION LEVELS IN A GREENHOUSE

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The sorghum crop (*Sorghum bicolor* L.) plays a significant role in ensuring global food security, serving as an important source of nutrients for both animal and human consumption. Proper crop nutrition is essential to maintain productivity, optimize fertilizer use, enhance the efficiency of operational systems, and ensure sustainability in the use of natural resources. This study aimed to evaluate the biometric and productive parameters of grain sorghum (*Sorghum bicolor* L.) subjected to nitrogen fertilization rates in a greenhouse. The experiment was conducted in 5-liter pots in a greenhouse. The treatments consisted of 5 nitrogen fertilization levels (D0=0, D1=75, D2=150, D3=225, and D4=300 kg/ha of N). The experimental design was completely randomized with 4 replicates. The parameters evaluated included plant height, stem diameter, number of leaves, shoot dry mass (SDM), and the relative yield of the crop at three evaluation periods (7, 14, and 28 days after transplanting into the pots – DAT). Visual symptoms of nitrogen deficiency were initially observed on the older leaves of plants subjected to D0 and D1 doses, showing chlorosis followed by necrosis in an inverted “V” shape. A reduction in plant growth due to nitrogen omission was evident from the evaluated biometric parameters. SDM and relative yield showed increasing linear trends as nitrogen rates increased, according to significant statistical models ($P<0.05$). Stem diameter and the number of leaves responded significantly ($P<0.05$) to increased nitrogen fertilization following quadratic models across all evaluation periods, with the lowest values observed in plants that did not receive nitrogen fertilization. Plant height exhibited a quadratic model response to nitrogen rates only at 14 DAT, with no significant differences observed at 7 and 28 DAT. In conclusion, the increase in nitrogen fertilization significantly influenced the biometric and productive parameters of sorghum plants, showing quadratic models for plant height, stem diameter, and number of leaves, and increasing linear models for shoot dry mass and relative yield.





PO6_24 **CONTRIBUTION OF AZOSPIRILLUM BRASILENSE AND BACILLUS BACTERIA ASSOCIATED WITH NITROGEN FERTILIZATION WITH ^{15}N ISOTOPIC IN THE PRODUCTION AND USE OF FERTILIZER BY PALISADEGRASS MARANDU**

Reges Heinrichs (Brazil)¹; Gabriela da Silva Freitas (Brazil)¹; Maurício Bruno Prado da Silva (Brazil)¹; Matheus Haruichi Okazuka (Brazil)¹; Flaviane Wanessa Lopes Fernandes (Brazil)¹; André Rozetti Cristovão (Brazil)¹; Fabiano Martins de Almeida (Brazil)¹; Lucila de Sousa Vilela (Brazil)¹; Camille Eichelberger Granada (Brazil)²; Raul Antonio Sperotto (Brazil)³; Fernando Shintate Galindo (Brazil)¹; Borja Velázquez Martí (Spain)⁴; Clelber Vieira Prates (Brazil)⁵; José Lavres Júnior (Brazil)⁵; Paulo Renato Matos Lopes (Brazil)¹

1 - São Paulo State University (Unesp), College of Agricultural and Technological Sciences, Dracena, Brazil; 2 - Federal University of Rio Grande do Sul, Genetics Department, Porto Alegre, Brazil; 3 - Federal University of Pelotas, Biology Institute, Pelotas, Brazil; 4 - Universidad Politécnica de Valencia (UPV), Departamento de Ingeniería Rural y Agroalimentaria, Valencia, Spain; 5 - University of São Paulo, Center for Nuclear Energy in Agriculture, Piracicaba, Brazil

For livestock sustainability, forage productivity requires greater quantity and quality, with reduced inputs and minimal environmental impact. The objective of this study was to evaluate the capacity of *Azospirillum brasilense* strain V5+V6 (AZ), *Bacillus* sp. strain S26 and *Bacillus* sp. strain N72, applied via foliar spraying, associated with nitrogen fertilization, in the production of Marandu palisadegrass and the use of nitrogen from the fertilizer, using the isotopic dilution technique with ^{15}N enriched to 1.19%. The experiment was carried out in the field on a dystrophic Oxisol. The experimental design was randomized blocks with four replications. The treatments were as follows: T1) fertilized with 20 kg ha⁻¹ N (urea), T2) fertilized with 40 kg ha⁻¹ N (urea), T3) T1 + foliar inoculation of AZ, T4) T1 + foliar inoculation of S26, T5) T1 + foliar inoculation of N72, T6) T1 + foliar inoculation of AZ+S26+N72. Mineral fertilizer (urea) was applied immediately after cutting and bacteria were sprayed 10 days after, to allow forage regrowth before application. For sampling and evaluations, the forage was cut 20 cm from the soil surface with a growth cycle of 33 days. The dry mass production was positively influenced by the application of AZ, N72, or the combination of AZ+S26+N72 when associated with 20 kg ha⁻¹ of mineral nitrogen. This yield was greater than that obtained with the exclusive application of 40 kg ha⁻¹ of mineral nitrogen. Using the ^{15}N isotope technique, it was observed that nitrogen recovery in the aerial part of the forage was significantly higher (16.08% until 19.46%) with the application of AZ and N72 compared to exclusive mineral fertilization, which ranged from 10.43% to 12.16% for 40 kg ha⁻¹ and 20 kg ha⁻¹ of nitrogen, respectively. The quantity of N from fertilizer (QNFF), in the aerial part of the forage, was directly proportional to the dry mass production. The lowest QNFF values (1.99 until 2.43 kg ha⁻¹) were recorded in treatments with 20 kg ha⁻¹ of mineral nitrogen alone or in combination with S26. In contrast, treatments with 20 kg ha⁻¹ of nitrogen combined with AZ, N72, AZ+S26+N72 or with 40 kg ha⁻¹ of mineral nitrogen showed the highest QNFF values (3.21 until 4.17 kg ha⁻¹). Under the study conditions, *Azospirillum brasilense* strain V5+V6 and *Bacillus* sp. strain N72 demonstrated the best results.





PO7_1 PHOSPHORYLATION OF METAL TRANSPORTERS MODIFIES ITS ACTIVITY OF TRANSPORTATION

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Heavy metal pollution poses serious risks to plants and human health through food chain contamination. Despite the understanding of metal tolerance mechanisms in plants, whether and how plants actively respond to metals and in turn restrict its uptake and accumulation remain elusive. Here, we identified a cell wall-associated receptor-like kinase 4 (WAKL4) involved in specific tolerance to Cd stress. Cd exposure specifically induced WAKL4 expression and led to its accumulation at the plasma membrane by enhancing transcription and preventing its vacuolar degradation. WAKL4 was found to phosphorylate NRAMP1 at the conserved Tyr488 residue. Subcellular localization and complementation tests with NRAMP1 variants revealed that the phosphor-dead mutant (NRAMP1Y488F) increased Cd sensitivity, whereas the phosphor-mimetic mutant (NRAMP1Y488E) reduced Cd accumulation. These findings indicate that Tyr488 phosphorylation limits Cd uptake by promoting NRAMP1 degradation through vacuolar targeting in roots. Furthermore, we showed that the WAKL4-NRAMP1 module is presumably conserved in Col-0 and Ws, but the differential expression of WAKL4 in response to Cd may lead to the different contribution of this module to Cd tolerance in these ecotypes. Very recently, we further identified another metal transporter that can specifically transport Ni/Co, and its activity is also regulated by a kinase dependent phosphorylation. Our findings therefore uncover the important role of phosphorylation in mediating the activity of metal transporters, informing the future molecular breeding of low metal accumulated crops or vegetables.





PO7_2 THE ROLE OF FRUIT MATURITY, PULP NITROGEN, AND CALCIUM IN POST-HARVEST QUALITY OF AVOCADO (CV. HASS)

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The post-harvest quality of Hass avocados is a key determinant of their marketability, yet storage-related disorders such as internal discoloration, stem-end rot, and side decay, continue to pose significant challenges. This study investigates whether the levels of dry matter, nitrogen (N), and calcium (Ca) in the pulp are primary factors influencing fruit quality and storage potential. Specifically, an optimal balance among these parameters is expected to enhance fruit integrity and extend shelf life, whereas deviations may increase susceptibility to post-harvest deterioration.

A large-scale field survey was conducted across approximately 130 experimental plots in major avocado-growing regions of Israel. Avocado pulp samples were collected, homogenized, and analyzed using traditional laboratory techniques (Dumas and ICP) provide precise but costly and time intensive measurements. Therefore, we also explored the potential of Near-Infrared (NIR) and X-ray Fluorescence (XRF) spectroscopy as rapid alternatives for predicting these critical parameters.

Our findings indicate that higher pulp N concentrations and elevated dry matter correlate with an increased likelihood of internal discoloration and pathogen susceptibility. In contrast, higher Ca concentrations appear to mitigate storage-related damage. Notably, an increased N to Ca ratio suggests that excess N is associated with modification of Ca partitioning within the tree, leading to lower Ca concentrations in the pulp.

These findings highlight the potential for developing a cost-effective, spectral-based method for real-time quality assessment in packing facilities. Such an approach would enable growers and exporters to optimize harvest timing, minimize post-harvest losses, and enhance the competitiveness of Hass avocados in international markets.





PO7_3 FEASIBILITY OF SOYBEAN CULTIVATION IN DENMARK FOR SUSTAINABLE PROTEIN AND OIL PRODUCTION

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The increasing demand for plant-based food production, particularly rich in protein, underscores the importance of exploring soybean cultivation for human consumption in Denmark. To align with the country's need for sustainable protein sources, there is an urgent need to investigate the feasibility of domestic soybean production. This study explores a diverse range of soybean varieties, initiated in 2021 with 19 soybean varieties from the NordGen seed bank and seven commercial varieties. Over the cropping seasons from 2021 to 2024, selection was based on crop development under Danish climatic conditions, yield potential, and grain protein and oil content. Since the NordGen varieties initially consisted of only 20–25 seeds per accession, several years were required for seed multiplication. By the 2024 cropping season, sufficient seed quantities were available for large-scale trials. In 2024, field study was conducted according to organic standards at AU Viborg, central Jutland, using a randomized complete block design with four replicates. Eight soybean varieties were sown in plots with no prior soybean cropping history, with seeds inoculated with *Bradyrhizobium* prior to sowing to enhance nitrogen fixation. At maturity, yields varied from 1.0 t ha⁻¹ (Fiskeby V) to 3.0 t ha⁻¹ (Merlin). The growing cycle differed significantly, with Fiskeby V maturing in 133 days and Merlin in 153 days. These variations influenced protein and oil content, with Fiskeby V containing 37.29% protein and 18.21% oil, while Merlin exhibited 42.42% protein and 21.92% oil. Protein and oil content were predicted using non-destructive near-infrared spectroscopy (Pertin IM 9500 grain analyzer, PerkinElmer). Further analyses are underway to assess macronutrient and micronutrient composition in harvested grains, as well as soil samples collected post-harvest. Overall, our findings highlight the potential for soybean cultivation under Danish conditions, contributing to reduced dependence on imported soybeans and promoting local protein production for a more sustainable food system.





PO7_5 ENHANCING PHOSPHORUS-USE EFFICIENCY IN CHICKPEA BY REDUCING SEED PHYTATE ACCUMULATION

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Low phosphorus (P) availability in soil is a major constraint to global agricultural productivity. Optimising P use is essential for sustainable agriculture, as insufficient P inputs limit yields, while excessive applications lead to resource depletion and environmental pollution. Chickpea (*Cicer arietinum* L.), the third most widely cultivated legume crop, is a key component of human diets and animal feed, particularly in developing countries. This study aims to enhance P-use efficiency (PUE) in chickpea by reducing seed P and phytate concentrations.

A glasshouse experiment was conducted in 2023 at the University of Western Australia, using 275 chickpea genotypes from the core germplasm collection, including cultivars, breeding lines, landraces, and six wild *Cicer* species. Plants were grown under mild P deficiency to assess genotypic variation in seed P and phytate concentrations. A strong positive correlation was observed between seed P and phytate concentrations ($R = 0.77$). Phytate levels ranged from 0.96 to 5.10 mg·g⁻¹, with an average of 71.8% of total seed P present as phytate. Kabuli genotypes exhibited lower total seed P but higher phytate concentrations than Desi, with phytate comprising a significantly greater proportion of total P in Kabuli (76.5%) than in Desi (70.8%, $P < 0.01$). Wild *Cicer* species displayed greater genotypic variation in both phytate and P concentrations. A genome-wide association study (GWAS) is underway to identify candidate genes regulating phytate metabolism and P cycling.

To further elucidate phytate accumulation dynamics, four genotypes with high and low seed P concentrations were selected for a follow-up experiment in 2024, grown under low-P (20 mg·kg⁻¹) and high-P (60 mg·kg⁻¹) conditions. Seed samples were collected at 10, 15, 20, 25, 30, 35, and 40 days after flowering (DAF) to investigate temporal patterns of elemental accumulation. Cryo-FESEM will be employed to visualise and quantify elemental co-localisation within developing seeds. This study aims to provide insights into the regulation of seed P accumulation and its interactions with other mineral elements, contributing to breeding efforts for low-phytate chickpea varieties with improved nutritional quality.





PO7_6 CHANGES IN THE ANTIOXIDANTS OF PEA SEEDLINGS BASED ON HOME-USE IN JAPAN

Yuki Tsuruoka (Japan)¹; Takahiro Hosoya (Japan)¹

¹ - Toyo university

Based on the modern health consciousness, microscale vegetables that are inexpensive, stably supplied, and have high nutritional and functional properties have attracted attention, and pea seedlings are particularly popular in Japan. Pea seedlings are young leaves of pea (*Pisum sativum* L.), which are inexpensive year-round, have been reported to have high nutritional value, and furthermore, have the characteristic of sustainability, which allows them to be cultivated once the edible parts are cut down. Although there are many reports on the functionality of peas, there are few on the functionality of pea seedlings as food ingredients. Limited reports are available examining the variations in functional components in actual usage by consumers. Therefore, the purpose of this study was to explore the functional components of pea seedlings and to clarify the changes in functionality at the component level during re-cultivation and cooking for home use.

In the search for functional components of pea seedlings, components were isolated using antioxidant activity by DPPH radical scavenging activity as an indicator, and kaempferol glycosides (1,2) and quercetin glycosides (3,4) were isolated using nuclear magnetic resonance (NMR) and mass spectrometry (MS) analysis of the isolated components.

Next, we examined the differences in antioxidant components due to re-cultivation and cooking for home use. In the re-cultivation study, the edible parts of the seedlings were cut off and re-cultivated under three different conditions: sunlight (sun), indoors (room), and shade (shade). The results showed that the highest antioxidant activity was observed in sun-cultivated plants, which was approximately twice as potent as that in room-cultivated plants. Next, each antioxidant component was quantified; component 2 was 2.7 times higher, and component 4 was 6.2 times higher in the sun than in the room.

During cooking, antioxidant activity was maintained during steaming, whereas it was significantly attenuated in the other heating methods. The thermal stability of the antioxidant components was examined. The stability of components 2 and 4 with p-coumaric acid was confirmed, and the attenuation by heating was suggested to be due to leaching into water because of the high water solubility of the antioxidant components.

This study revealed that the antioxidant components differed depending on the re-cultivation environment and cooking of the pea seedlings, suggesting the functionality of the pea seedlings and the possibility of maximizing their use.





PO7_7 APPLICATION TO QUALITY CONTROL BASED ON THE CONSTITUENTS IN MORINGA POWDER

Yuria Kurosu (Japan)¹; Takako Koriyama (Japan)¹; Takahiro Hosoya (Japan)¹

¹ - Toyo University

Moringa (*Moringa oleifera*) is a plant belonging to the family Moringaceae, which is widely cultivated in tropical and subtropical regions. In recent years, there have been many reports on the functional properties of moringa leaves, which have attracted increasing attention in Japan. In addition to teas made from moringa leaves, food products, such as cookies and curries, have been actively developed using moringa powder. We observed that adding moringa powder from Okinawa Prefecture to bread, which is a staple food worldwide, increases its nutritional value and functionality by increasing general components, such as protein, dietary fiber, potassium, and calcium. However, because moringa powder is currently grown and processed in various regions and is widely available in the market, differences in the baking results were observed when bread was prepared using these moringa powders. This suggests that the components and quality of moringa powder sold in the market may differ depending on the region. Therefore, this study was conducted to clarify the differences in composition and functionality, with the aim of developing quality control techniques for moringa powder. Moringa powder from 10 regions, including Japan, was used as the research sample for this study. For comparison with moringa powder, coloring were measured using a colorimeter, antioxidant activity was evaluated using the DPPH radical method, and the constituents were analyzed using liquid chromatography mass spectrometry (LC/MS). In the comparison of coloring, the difference between high and low a^* values was 11.31, and there were differences from region to region, ranging from bright green to brown. Moreover, the difference in antioxidant activity was 30 % by region. In addition to quercetin-3-glucoside (Q3G), the main antioxidant component of moringa, a derivative with a quercetin skeleton, was compared. Quercetin acetylglucoside (Q3AcG) was the second most abundant after Q3G. In addition, the greener the moringa powder, the more it contained Q3AcG, and lesser the content, it was closer to brown. Moringa powder was close to brown when heated and contained less Q3AcG. This suggests that Q3AcG content may affect the degree of processing and could indicate quality. In summary, in this study, we identified differences in the content of moringa powder by region and identified components that could be applied to the quality control of the powder.





PO7_8 SYNERGISTIC ENHANCEMENTS OF YIELD AND QUALITIES OF PEPPER FRUIT ON ACIDIC SOIL

Yuria Kurosu (Japan)¹; Takako Koriyama (Japan)¹; Takahiro Hosoya (Japan)¹

¹ - Toyo University

Moringa (*Moringa oleifera*) is a plant belonging to the family Moringaceae, which is widely cultivated in tropical and subtropical regions. In recent years, there have been many reports on the functional properties of moringa leaves, which have attracted increasing attention in Japan. In addition to teas made from moringa leaves, food products, such as cookies and curries, have been actively developed using moringa powder. We observed that adding moringa powder from Okinawa Prefecture to bread, which is a staple food worldwide, increases its nutritional value and functionality by increasing general components, such as protein, dietary fiber, potassium, and calcium. However, because moringa powder is currently grown and processed in various regions and is widely available in the market, differences in the baking results were observed when bread was prepared using these moringa powders. This suggests that the components and quality of moringa powder sold in the market may differ depending on the region. Therefore, this study was conducted to clarify the differences in composition and functionality, with the aim of developing quality control techniques for moringa powder. Moringa powder from 10 regions, including Japan, was used as the research sample for this study. For comparison with moringa powder, coloring were measured using a colorimeter, antioxidant activity was evaluated using the DPPH radical method, and the constituents were analyzed using liquid chromatography mass spectrometry (LC/MS). In the comparison of coloring, the difference between high and low a^* values was 11.31, and there were differences from region to region, ranging from bright green to brown. Moreover, the difference in antioxidant activity was 30 % by region. In addition to quercetin-3-glucoside (Q3G), the main antioxidant component of moringa, a derivative with a quercetin skeleton, was compared. Quercetin acetylglucoside (Q3AcG) was the second most abundant after Q3G. In addition, the greener the moringa powder, the more it contained Q3AcG, and lesser the content, it was closer to brown. Moringa powder was close to brown when heated and contained less Q3AcG. This suggests that Q3AcG content may affect the degree of processing and could indicate quality. In summary, in this study, we identified differences in the content of moringa powder by region and identified components that could be applied to the quality control of the powder.





PO7_9 HOLLOW STEM IN BROCCOLI AS AFFECTED BY CULTIVATION FACTORS AND CROP CHARACTERISTICS

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Broccoli is an economically important cruciferous vegetable worldwide. A considerable proportion of the harvest can be affected by hollow stem. This physiological disorder causes splitting of the stalk pith tissue. If the damage is severe and leads to discoloration or rot, the produce becomes unmarketable. The aim of an ongoing research project is therefore to develop cultivation strategies to prevent this quality degradation. It is known that factors promoting rapid and vigorous plant growth favor the development of hollow stems in broccoli. In this study, we examined the significance of nitrogen supply (100, 200, and 300 kg N ha⁻¹) and plant spacing (60 cm x 40 cm, and 30 cm x 20 cm) in this context. The field trial was conducted in northwest Germany with the broccoli varieties 'Parthenon' and 'Naxos' (n = 4). At harvest, plant characteristics such as hollow stem formation, head weight, and stem diameter were recorded. Furthermore, the nitrogen content in the dry matter of the broccoli heads and residual soil mineral nitrogen (0–60 cm depth) were determined.

The frequency and intensity of hollow stem formation were significantly influenced by plant density, nitrogen supply and the broccoli variety. With close planting, almost no hollow stems were observed. At wider plant density, the proportion of hollow broccoli heads increased with higher nitrogen supply. The variety 'Parthenon' proved particularly susceptible: 30 % (low nitrogen supply) to 70 % (high nitrogen supply) of the harvest showed this disorder. In the 'Naxos' variety, the proportion of hollow stems was significantly lower, ranging from 1 % (low nitrogen supply) to 28 % (high nitrogen supply). Overall, the occurrence of hollow stems closely correlated with stem diameter ($r^2 = 0.91$) and head weight ($r^2 = 0.72$). Broccoli with a stem diameter of less than 3.5 cm or a head weight of under 400 g was hardly hollow stemmed. A closer plant spacing reduced the average head weight. However, at medium to high nitrogen supply, it also led to a higher yield per unit area compared to wider plant density. There were no significant differences in head yield and nitrogen content of broccoli between the medium and high nitrogen supply levels. However, the residual soil nitrogen increased with higher nitrogen supply at the end of the growing period. The results of the study show that variety selection, optimization of plant density, and nitrogen fertilization can contribute to reducing hollow stem in broccoli.





PO7_10 ENHANCING SPINACH IRON CONTENT: EFFECTS OF GENOTYPE, SOIL PH, AND FOLIAR FERTILIZATION

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Iron deficiency is a widespread health problem worldwide, affecting women in particular. For example, in Germany, about three-quarters of women of childbearing age have lower iron intakes than recommended, according to the results of the latest nationally representative dietary survey. The bioavailability of iron in plant-based foods is markedly lower than that of animal-based foods containing heme iron. However, the utilization of non-heme iron in the human organism can be improved by the presence of ascorbic acid. Therefore, an ongoing research project aims to develop an approach for iron biofortification of spinach, a vitamin C-rich leafy vegetable.

Three field experiments were conducted in northern Germany to investigate how soil pH, spinach variety, and foliar iron fertilization affect the iron content of spinach leaves. Additionally, the tolerance of plants to aerial applications of various iron fertilizers, including chelates and ferrous sulfate, was evaluated at fertilization rates ranging from 0.05 to 0.45 kg Fe ha⁻¹. The foliar sprays were conducted with 500 L ha⁻¹ of water and with the addition of a wetting agent (BREAK-THRU® S 301).

Native iron content in spinach leaves ranged between 0.7 and 1.9 mg (100 g FM)⁻¹ depending on the site and cultivar. On average, spinach grown at soil pH 5.1 had a 27 % higher iron content than that grown at pH 6.2. Within a cultivation site, the iron content of the twelve spinach varieties examined varied by a factor of 2.1. In treatments with different forms of iron fertilizer, Fe-HEDTA proved to be the least tolerated by the plants. Here, even a single treatment with 0.05 kg Fe ha⁻¹ resulted in leaf necrosis. When Fe-IDHA and ferrous sulfate were applied, no leaf damage occurred with application rates up to 0.3 kg Fe ha⁻¹. Foliar sprays of Fe-EDDHA did not cause damage to leaves even when treated twice with 0.45 kg Fe ha⁻¹ per application. Subsequent field trials indicated that the occurrence of leaf damage after iron foliar sprays under summer conditions is significantly affected by the time of day. Treatments in the late evening hours were best tolerated by the plants. A single foliar fertilization with 0.3 kg Fe ha⁻¹ ten days before harvest approximately doubled the iron content of spinach leaves. The results indicate that spinach can be biofortified with iron by foliar fertilization, but appropriate application timing is crucial to avoid plant damage.





PO7_11 SOIL VERSUS FOLIAR FERTILIZATION AS A STRATEGY TO ENRICH APPLES WITH SELENIUM

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In regions with selenium-depleted soils, agronomic biofortification has proven to be an effective and safe means of ensuring an adequate selenium supply for the population. However, there is still limited knowledge regarding the application of this method to deciduous fruit. Thus, the aim of this study was to determine which fertilization technique is most suitable for increasing the selenium content in apples. In a field experiment conducted for this purpose in northwestern Germany, apple trees of the scab-tolerant variety 'Topaz' were repeatedly fertilized with two different forms of selenium (sodium selenate and sodium selenite), both through foliar sprays (twice, with a total of 0.75 kg selenium ha⁻¹) and soil drenches (nine times, with a total of 1.8 kg selenium ha⁻¹). The fruits were harvested at the end of September. The selenium content of the apples was analyzed in unwashed, washed, and peeled fruit samples. The intensity of leaf damage caused by selenium fertilization was assessed. In addition, the average individual fruit weight, fruit flesh firmness, and total soluble solids content of fruits were determined.

By means of foliar sprays, the selenium content in apples was increased to 16 µg (100 g FM)⁻¹, irrespective of the applied selenium form. With soil fertilization, selenium accumulation in the fruit was lower, despite the significantly higher selenium application rate. Selenate drenches increased the selenium content to 3 µg (100 g FM)⁻¹. With selenite drenches, it remained at 0.1 µg (100 g FM)⁻¹, equivalent to the unfertilized control. Washing the fruit under running water had no effect on the selenium content of the apples in any treatment. Peeling the fruit, on the other hand, reduced the selenium content by 42–65 %, depending on the distribution of selenium in the fruit. After foliar selenate sprays, approximately half of the biofortified selenium was detected in the fruit flesh. About one-fifth of the selenium accumulated through foliar sprays was detected in the core, suggesting some degree of translocation of selenium from the leaves into the fruit. The selenium biofortification had no impact on the average individual fruit weight, fruit flesh firmness, and total soluble solids content of the apples. Thus, leaf necrosis associated with aerial applications of selenite and selenate did not negatively affect fruit development. Foliar fertilization therefore seems to be a suitable approach for enhancing the nutritional value of apples with selenium.





PO7_12 APPLES – A SUITABLE FRUIT FOR IODINE BIOFORTIFICATION THROUGH FOLIAR FERTILIZATION

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Iodine is an essential micronutrient for humans that is not sufficiently absorbed through the diet in various regions of the world. Previous studies have indicated that fruit crops can be biofortified with iodine by foliar fertilization. The objective of this study was to investigate the suitability of this approach for two apple varieties, 'Jonagold' and 'Boskoop'. The field experiment was conducted in an orchard located in the northwestern part of Germany. The apple trees, approximately 2.0 m tall, were sprayed once, two weeks before harvest, with different iodine forms (potassium iodide and potassium iodate) and fertilizer rates (0, 0.5, 2.0, and 5.0 kg iodine ha⁻¹) using a handheld sprayer. The application was carried out with 2000 L ha⁻¹ of water and the addition of a wetting agent (BREAK-THRU® S 240). The fruits were harvested at the end of September. The iodine content of the apples was analyzed in unwashed, washed and peeled fruit segments. The intensity of leaf damage caused by iodine fertilization was assessed. In addition, the appearance of the fruits and their total soluble solids content were determined.

Iodine foliar sprays induced leaf necrosis ranging from slight at the lowest to severe at the highest fertilization rate. Nevertheless, none of the treatments had a negative impact on fruit appearance or total soluble solids content. The iodine content of apples increased with increasing iodine fertilization rates. While it was about 2 µg (100 g FM)⁻¹ in the controls, it reached 16–289 µg (100 g FM)⁻¹ in 'Jonagold' and 48–568 µg (100 g FM)⁻¹ in 'Boskoop' with iodine fertilization. For both varieties, applications with iodide proved to be more effective than applications with iodate. Between 45 % and 78 % of the biofortified iodine was found in the fruit peel. Iodide treatments resulted in greater penetration of iodine into the fruit flesh than iodate treatments. Washing the fruit under running water had no significant effect on its iodine content. Overall, the results of this study show that apples can be biofortified with iodine to a level appropriate for human nutrition by means of a single foliar spray shortly before harvest without compromising other fruit characteristics. Even small amounts of iodine fertilizer (0.5–2.0 kg ha⁻¹) are sufficient to provide at least half of the daily iodine requirement of an adult (200 µg) with just one apple.





PO8_1 RESPONSES OF CONTRASTING TOMATO GENOTYPES IN THEIR WATER AND NITROGEN USE EFFICIENCY

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Efficient use of water and nitrogen (N) is crucial for plant growth, development, and survival, especially in the face of increasing resource scarcity driven by climate change. To identify key morpho-physiological and biochemical responses related to improved resource use efficiency, studying contrasting genotypes under combined stress is of utmost importance. In this context, the present study focused on evaluating the morphological, physiological, and biochemical responses of two previously selected tomato genotypes — efficient (EF - RF21) and inefficient (INEF - RF216) — under four treatment conditions: control (10.5 mM N; 100% field capacity), N deficit (5.3 mM N), water deficit (50% field capacity), and combined N and water deficit (5.3 mM N and 50% field capacity). The results showed that the EF genotype maintained total dry weight under single deficit conditions but experienced a 30% reduction under combined deficit. In contrast, the INEF genotype showed greater TDW losses, ranging from 32% under water deficit to 53% under combined deficit. Also, the efficient genotype showed higher N and water use efficiency compared to the inefficient genotype (by 14% and 26%, respectively). The better performance of the EF genotype may be linked to a generally lower stomatal conductance (23%) compared to control conditions. Additionally, this genotype had a tendency for a lower leaf area ratio under water deficit conditions, as well as a generally and significantly lower proline accumulation—23% lower compared to the INEF genotype. Regarding the INEF genotype, a decrease in relative chlorophyll content was observed under all deficit conditions up to 20% and a higher lipid peroxidation under combined deficit (19%) compared to control conditions. These results highlight the relevance of characterizing genotypes with superior physiological and biochemical traits for improving resource use efficiency, offering valuable insights for breeding programs aimed at enhancing crop resilience under combined abiotic stresses.





PO8_4 SEQUENTIAL INJECTION ANALYSIS IN A MINI-COLUMN: SIMULATING RAINFALL TO STUDY NANOFERTILISER LEACHING

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Nanofertilisers show great potential to improve the delivery of critical nutrients, but their leaching behaviour in soils remains poorly understood, and requires testing with realistic conditions.

This study aimed to assess the retention and mobility of different iron chelate ($\text{Fe}(\text{dmpp})_3$)-loaded nanoparticles in soil layers after multiple rainfall events, by developing a flow-based system to simulate fertiliser leaching.

A sequential analysis system was connected to a mini-column containing artificial soil, linked to a container to collect leachates. Different types of $\text{Fe}(\text{dmpp})_3$ -loaded nanoparticles were added to the previously moistened soil, followed by consecutive additions of rainwater. Absorbance measurements were taken using a spectrophotometer to determine the iron chelate passage after each leaching event. The eluted $\text{Fe}(\text{III})$ was also quantified by reaction with SCN^- .

Results show different results for each nanoparticle type, with the ones labelled as “small” showing that the entirety of the iron chelate was leached in the first three leaching events, while $\text{Fe}(\text{III})$ ion was significantly more retained, with approximately 10.5%, 0.3%, 6.3%, 15.0% and 2.1% being leached in the five events, respectively. Regarding the “medium” nanoparticles, the iron chelate was more successfully retained within the soil, since only 66.7% were leached after the five events. $\text{Fe}(\text{III})$ was even more efficiently retained than for the “small” ones, with the percentages of leached ion being significantly lower, with a maximum of 35.0% on the third rainfall simulation. Finally, the application of “large” nanoparticles leaches the chelate more rapidly than the “medium” ones, with the five percolation events leaching 74.3% of the total compound. Regarding the ion, the nanoparticles seemed less effective in retaining it in the soil, as the percentage of leachate collected after nanofertiliser application was 39.6%, followed by 20.9%, 10.8%, 10.2%, and 7.0% after four rainfall events, respectively.

To sum up, the results reveal that “medium” nanoparticles have a better retention capacity in the soil, minimizing leaching losses and allowing for a better delivery of iron. “Small” nanoparticles leached the iron chelate more rapidly in the first three percolation events, while “large” nanoparticles behaved similarly to medium ones in terms of chelate leaching but were less effective in retaining $\text{Fe}(\text{III})$ in the soil.





PO8_5 HEAVY METAL TRANSFER TO SOIL AND NUTRIENT STOICHIOMETRY IN RYEGRASS: EFFECTS OF POULTRY MANURE AND ROCK PHOSPHATE AMENDMENTS

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In recent years, organic amendments such as poultry manure (PM) have been widely used as an alternative to synthetic fertilizers due to their ability to improve soil fertility and enhance nutrient cycling. However, PM can also introduce heavy metals into the soil, which may affect plant nutrient uptake and pose environmental risks. In ryegrass (*Lolium perenne*), heavy metal accumulation can interfere with root nutrient absorption, potentially reducing plant growth and productivity. The integration of PM with inorganic fertilizer sources such as rock phosphate (RP) may help optimize nutrient availability while mitigating heavy metal-associated risks. This study assess the effect of PM, RP, and their combination (PMRP) on ryegrass nutrient stoichiometry, soil nutrient availability, and heavy metal accumulation in moderately acidic and alkaline soils. Shoot K uptake increased significantly under PMRP, with an increase of 4.5-fold in acidic soil and 1.7-fold in alkaline soil compared to the control. Root K uptake followed a similar trend, increasing by 2.2-fold under PMRP in both soil types. Ca uptake was higher under RP in alkaline soil (2.6-fold increase in shoots), while PMRP was the most effective in acidic soil, leading to a 1.9-fold increase in shoot Ca uptake. Mg uptake was maximized under PM in alkaline soil, increasing by 3.2-fold in roots. Na uptake was significantly elevated under PMRP, increasing by 2.5-fold in shoots and 3.1-fold in roots in alkaline soil. Heavy metal accumulation varied across soil types. Zn and Cu concentrations increased under PM application, particularly in alkaline soil, by 3.4-fold and 2.9-fold, respectively. In acidic soil, metal accumulation was lower, suggesting reduced mobility under lower pH conditions. The C:N:P stoichiometry differed across treatments and soil types. In LUV soil, PM and PMRP reduced the shoot C:P ratio by 36% and 44%, respectively, while RP decreased the shoot C:N ratio by 48%. In NEO soil, PM and PMRP lowered the shoot C:P ratio by 21% and 12%, respectively, with similar trends in root stoichiometry. PCA analysis showed that PMRP was associated with increased nutrient availability and lower heavy metal accumulation. The combined application of PM and RP enhances nutrient stoichiometry and uptake efficiency while minimizing heavy metal accumulation, particularly in acidic soils. These findings highlight the potential of integrating organic and inorganic amendments for sustainable nutrient management in forage production systems. Further research should explore long-term soil health effects and optimization of amendment ratios for diverse soil types.





PO8_6 NITROGEN CONTENTS IN THE DIAGNOSTIC LEAVES OF MARANDU GRASS AFTER UREA APPLICATION

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Nitrogen (N) restitution is essential to increase pasture longevity and productivity. It is one of the nutrients most demanded by plants and one of the most used in agricultural fertilization, the application of N is considered a key factor for pasture management. The objective of this study was to evaluate the concentration of N in the diagnostic leaves of *Brachiaria brizantha* cv. Marandu, after the application of urea rates, in the second year of the experiment. The research was conducted in an experimental area of UFMT, in Barra do Garças-MT, Brazil. The experimental design used was randomized blocks with six N rates (0, 60, 120, 180, 240 and 300 kg ha⁻¹) using urea as a source (46% N) and four replications, in plots of 30 m² and useful area of 1.0 m². The five doses of N were divided into applications of 60 kg ha⁻¹ of N each, and the treatment with 60 kg ha⁻¹ of N was all in the first application. After each application, the height of the Marandu grass was monitored with the help of a tape measure and when the average height reached 35 cm, the cut was made. Five cuts were made. The diagnostic sheets (freshly expanded leaf blades) were separated after each cut, dried in a forced air circulation oven at 65°C, until constant weight. Subsequently, they were ground in mills and analyzed for N content. The data were submitted to statistical analysis by the F test and, when significant at 5% probability, the regression test was performed. All five cuts responded significantly to the N rates applied. The highest N content in the diagnostic leaves of Marandu grass was observed in the third cut with 26 g kg⁻¹ of N at the dose 300 kg ha⁻¹ of N and the content of 16 g kg⁻¹ of N in the control treatment in the same cut, presenting a linear adjustment in this evaluation. And the lowest levels were observed in the fourth cut with a minimum of 8 g kg⁻¹ of N in the control treatment and a maximum of 11 g kg⁻¹ in the treatment with 300 kg ha⁻¹ of N, adjusting to the second-degree polynomial model. Marandu grass showed significant responses in the N contents in the diagnostic sheets according to the application of N rates.





PO8_7 MICRONUTRIENT APPLICATIONS ALLEVIATE THE SYMPTOMS OF CITRUS GREENING DISEASE (HUANGLONGBING)

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Citrus Greening Disease (also known as HLB; Huanglongbing) is a pervasive bacterial disease that has spread across the globe. The bacterium “*Candidatus Liberibacter asiaticus* (CLas)” is transmitted by an insect vector, the psyllid *Diaphorina citri*, and resides in the phloem of infected trees. Treating this bacterium presents significant challenges. In most regions, infected trees are removed to halt propagation of the pathogen. The symptoms shown by HLB-infected trees can be similar to chlorosis, and there have been reports of micronutrient deficiencies in elements such as Fe, Zn and Mn¹⁾. Continuous ferrous ion (Fe²⁺) supply has been observed to alleviate the symptoms of HLB, while other chelating agents such as Fe-EDTA have not shown this effect²⁾.

In the most recent IPNC (2022), we reported the outcomes of a field experiment that revealed that foliar application of Fe²⁺ supplying materials increased the yield of HLB-infected citrus in Florida. We hypothesize that HLB infection in the phloem by CLas disrupts the homeostasis of micronutrients within the plants, and continuous supply of micronutrients enhances the growth of HLB-infected citrus trees.

The present study details an experiment conducted to assess the efficacy of foliar application of micronutrients in conjunction with a novel chelating agent. Proline-2'-deoxymugineic acid (PDMA), an analog of a phytosiderophore³⁾, forms a complex with Fe (Fe-PDMA) that can be transported via YSL (YS1-like transporter), which is present in all higher plants and plays a role in micronutrient homeostasis. The experimental design entailed monthly foliar applications of Fe and Zn with PDMA, as well as micronutrients including Fe²⁺ with an organic acid, in the field in Florida. The results demonstrated that both treatments enhanced the yield of HLB-infected citrus while quantitative PCR (qPCR) revealed no significant difference in the amount of CLas between the treated and untreated groups.

These findings imply that the application of readily available micronutrients can serve as a strategy to recover from disease-induced micronutrient deficiencies, thereby promoting growth and yield.

¹⁾ Masaoka et al. (2011) Jpn. Agric. Res. Q., 45, 269-275

²⁾ Inoue et al. (2020) Int. J. Mol. Sci., 21, 4033

³⁾ Suzuki et al. (2021) Nat. Commun., 12, 1558





PO8_8 UREA FERTILIZATION IN ACIDIC VOLCANIC SOILS IN SOUTHERN CHILE MITIGATES THE EFFECTS OF ALUMINUM TOXICITY IN NON-BEARING BLUEBERRIES PLANTS

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Ammonium- and urea-based fertilizers are widely used in blueberry orchards in southern Chile, as ammonium is the preferred nitrogen (N) source for blueberries. However, long-term application to soils can decrease soil pH due to ammonium nitrification and plant uptake of N in ammonium form, intensifying aluminum (Al) phytotoxicity. This study aimed to study the effect of N fertilization rate and source under different soil acidity conditions on the vegetative growth and physiological performance of Blue Ribbon® blueberries plants during their first growing season in acidic volcanic soil in southern Chile. A split-split-plot field experiment was established with three replicate blocks. Soil liming (CaCO₃, MgO and no liming) was the main plot, N source (urea and nitrate) the sub-plot, and N rate (0, 20 and 40 kg N ha⁻¹) the sub-sub-plot. Vegetative growth variables (shoot length, plant height and shoots emerged from crown) and physiological variables (stomatal conductance, chlorophyll fluorescence, and chlorophyll content in leaves) were periodically assessed. Soil chemical characteristics were evaluated through soil analysis, and plant nutritional status via foliar analysis. Regardless of the lime source, soil liming increased pH and reduced Al availability to safe levels for blueberries. Vegetative growth was only affected by soil liming with no interaction with N source and rate. Blueberries growing in plots limed with CaCO₃ or MgO had longer shoots than those in unlimed plots. However, the net shoot emergence from the crowns remained similar across liming levels. Unexpectedly, foliar Al concentration was not affected by soil liming but was influenced by N source. Plants fertilized with urea had lower foliar Al concentration (Figure 1) and higher chlorophyll content than those fertilized with nitrate. However, none of the experimental factors significantly affected chlorophyll fluorescence or stomatal conductance. Foliar N concentration increased with N rate (Figure 1), regardless of the N source, while foliar Ca and Mg concentrations decreased. Higher Ca and Mg availability in soil of limed plots was not reflected in foliar concentrations. Our results indicate that blueberry plants have a low N demand during the first growing season, which was fully met by N mineralization from the organic matter-rich volcanic soil. This explains the lack of response to N source. Additionally, urea fertilization appeared to mitigate Al phytotoxicity under moderate acidity conditions.





PO8_10 PREVENTION OF MANGANESE DEFICIENCY IN CEREALS THROUGH A TARGETED CHOICE OF COVER CROPS

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Background and aims:

Manganese (Mn) is an essential plant micronutrient with an indispensable function in photosynthesis. Even so, Mn deficiency frequently occurs without visual leaf symptoms, thereby masking the distribution and dimension of the problem. Manganese deficiency is a widespread nutritional disorder, particularly in cereals, and constitute a serious problem in plant production worldwide. The deficiency yearly results in marked yield losses and reduced grain quality. Thus, this emphasizes the importance of investigating new ways to prevent Mn deficiency in the field.

Cover crops are important for the sustainable intensification of plant production systems through their impact on nutrient cycling for the sufficient availability of essential nutrients to the following crop, while reducing the pollution of terrestrial and aquatic environments from agriculture. Different species of cover crops sequester and accumulate nutrients at various levels, but their release to the subsequent cash crop is also highly variable. Nutrient release is influenced by various processes, including the timing of crop termination and soil incorporation, which must be optimized to ensure maximum nutrient availability for the subsequent crop.

Here we explored and compared the capacity of different cover crop species to accumulate Mn in the shoot biomass and their ability to release and supply Mn to the following main crop.

Methods:

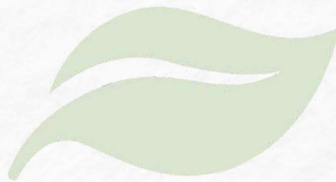
A total of 12 different cover crop species were explored for their Mn accumulation in the shoot biomass. The cover crops were either undersown in spring barley (6 species) or established after harvest (6 species) in two organic field trials. In addition, six of these cover crop species were grown in a pot experiment under controlled conditions in a growth chamber. The effect of cover crop species on Mn release and supply to the following spring barley crop was measured by chlorophyll a fluorescence and ICP-OES elemental analyses of the youngest fully developed leaves.

Key results:

Lupins had particularly larger Mn concentrations in the shoot biomass compared to all other cover crop species, even when grown in marginal soils prone to Mn deficiency. In the field, yellow lupin accumulated 137 µg Mn/g DW, which was significantly more than all other tested cover crops, and 5 times more than that of buckwheat at the time of sampling.

Conclusions:

Our results highlight the potential of cover crops in Mn cycling and management in organic crop production systems, with the potential to develop multi-functional cover crop mixtures that will contribute to the plant nutrition.



PO9_1 EXPLORING WHEAT ENDOPHYTIC PSEUDOMONAS SPP. FOR PLANT GROWTH PROMOTION UNDER NUTRITIONAL DEFICIT

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Wheat (*Triticum aestivum*) is among the most widely consumed crops worldwide and increasing its nutrient use efficiency is highly relevant to promote sustainable agrifood production systems. Plant growth promoting bacteria (PGPB) have been pointed out as effective alternatives to chemical fertilizers, but further studies are needed to better explore a wider range of potential microorganisms namely endophytic ones. This study, which integrates the European Project 'Wheatbiome', mainly aims to explore the potential of endophytic *Pseudomonas* spp. isolated from wheat plants cultivated under different agricultural practices, soil types, and different genotypes, as biofertilizers to enhance fertilizer efficiency use. Roots, leaves and wheat grain were collected from organic and conventional fields (irrigated and non-irrigated) in Spain, as well as from different cultivars and soil types in the Netherlands. The samples were surface-disinfected, macerated, and cultured in LB medium. Morphologically distinct colonies were purified and subjected to 16S rRNA gene sequencing. The genus *Pseudomonas* was typed by BOX-PCR and sequenced by *rpoD*. Of the 127 isolates of this genus, 45 non-pathogenic species, including *P. tritici*, *P. fluorescens* and *P. paracarnis*, were selected and tested for phosphorus solubilization (PSI), nitrogen fixation, and production of indole-3-acetic acid (IAA). Moreover, the 10 best performing isolates were considered for further analysis, including for urease production, tolerance to acid and alkaline pH conditions, tolerance to water and salinity stress, motility, ACC deaminase activity and siderophore production. We found that, 38 from 45 isolated *Pseudomonas* spp. were able to solubilize phosphorus (PSI between 1.1 and 3.2), of which 13 had $PSI > 2$. Furthermore, 39 isolates showed to be able to fix atmospheric nitrogen, and 20 to produce $IAA \geq 50 \mu\text{g/mL}$. Most of isolates showed to produce urease and to grow at acid and alkaline medium. These results indicate that the evaluated *Pseudomonas* spp. have significant potential for the promotion of plant growth under limited fertilizers, such as phosphorus and nitrogen. And they demonstrate the ability to stimulate the development of the root system, favouring the absorption of nutrients leached in depth, even in acidic or basic soils, reinforcing the potential of these isolates for application as biofertilizers in sustainable agricultural systems. As next steps, the best-performing isolates will be used separately and combined in plant trials under abiotic stress conditions to assess their actual impact on plant growth promotion.

Acknowledgments

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PO9_2 WHEAT NATIVE ENDOPHYTIC BACILLACEAE: EXPLORING GROWTH PROMOTING TRAITS TOWARDS SALT TOLERANCE AND NUTRIENT USE EFFICIENCY

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As recognized by the European Union's 'Farm to Fork' strategy, climate change increases the need for sustainable agricultural solutions. Wheat (*Triticum aestivum*), a staple crop crucial for global food security, is highly sensitive to soil salinity, which can hinder growth, yield, and nutrient acquisition. In this context, endophytic microorganisms, particularly bacteria from the family Bacillaceae, are gaining attention for their potential to enhance nutrient uptake and plant resilience to abiotic stress. This study, conducted in the scope of the EU-funded Wheatbiome project, evaluates the role of endophytic *Bacillus*, *Paenibacillus*, *Peribacillus*, and *Terribacillus* strains in promoting plant nutrition and salt tolerance in wheat. Wheat plants were collected at milky stage from different farming systems in Spain (conventional irrigated, non-irrigated, and organic fields) and across varied soil types and different cultivars in the Netherlands. Roots, leaves, and grains were surface-sterilized and macerated for bacterial isolation. A total of 60 endophytic isolates were selected based on their endospore-forming morphology and molecularly identified as Bacilli through sequencing of the 16S rRNA and *gyrB* genes. Phylogenetic analysis identified strains as *Bacillus pumilus*, *B. velezensis*, *B. halotolerans*, *B. licheniformis*, *Paenibacillus nuruki*, *P. amylolyticus*, *P. pabuli*, *Peribacillus frigiditolerans* and *Terribacillus saccharophilus*. Functional screening of these isolates focused on key plant growth-promoting traits, including indole-3-acetic acid (IAA) and siderophore production, phosphorous solubilization, nitrogen fixation, urease activity, motility and salt tolerance. Nearly all Bacillaceae isolates produced IAA, with *Paenibacillus pabuli* exceeding 70 $\mu\text{g mL}^{-1}$, supporting root development and nutrient absorption. Several strains demonstrated swimming motility and potential for biofilm formation, critical for stable root colonization. Notably, *Bacillus pumilus*, *B. velezensis*, and *B. licheniformis* exhibited both salt tolerance (>12% NaCl) and urease activity, enhancing nitrogen bioavailability. This highlights the noteworthy role of endophytic Bacillaceae in supporting plant nutrition. Their ability to convert urea and phosphate into plant-available forms of nitrogen and phosphorus, respectively, along with IAA and siderophore production and salt tolerance, places them as promising bioinoculants for sustainable wheat production in salt-affected and nutrient-deficient environments. The best-performing isolates will be further used in plant trials to assess their potential as bioinoculants, capable of enhancing nutrient uptake and salinity tolerance for climate-resilient agriculture. This study provides one of the few cross-regional studies to identify and characterize the diversity of native endophytic Bacillaceae in wheat.

Acknowledgments

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PO9_5 FROM FEN TO POT: EVALUATING PROCESSED CATTAIL AS A PEAT SUBSTITUTE IN HORTICULTURAL GROWING MEDIA

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Broadleaf cattail (*Typha latifolia*) harvested from rewetted lowland fens could serve as a sustainable input material for horticultural growing media. This study aimed to assess the impact of different processing methods on the suitability of broadleaf cattail as a substrate component. The following treatments were applied: chopping, defibration, composting, and fermentation. The processed materials were then mixed with white peat at proportions of 10 %, 30 %, and 50 % (v/v). Two vegetation experiments with petunia were conducted, using cattail harvested from different sites in Germany and the Netherlands. Pure white peat served as the control in both trials, which were arranged in randomized block designs with four replications. Plant growth, nutrient content in shoot dry matter, and various chemical and physical substrate parameters were analyzed.

In the first trial, plant growth declined as the proportion of cattail in the substrate increased. At 30 % (v/v), the fresh mass yield of petunias was, on average, about a quarter lower than in pure peat. When the substrate contained 50 % (v/v) cattail, fresh mass yield was reduced by more than half. Substrate and plant analyses suggested that growth impairments were primarily due to initial nitrogen immobilization (particularly in cattail fibers) and high potassium content (especially in composted cattail, with up to 2125 mg K₂O L⁻¹). Yield reductions occurred when the nitrogen content in the shoot dry matter dropped below 5 % (w/w) at the intermediate harvest after 17 days of cultivation or when the potassium content in the shoot dry matter exceeded 5 % (w/w) at the end of cultivation.

The cattail used in the second trial contained significantly less potassium, with a maximum of 529 mg K₂O L⁻¹ in the composted material. Additionally, plants received 50 % more nitrogen fertilizer than typically required for adequate petunia nutrition. In this experiment, plants in all treatments grew comparably to those cultivated in pure peat, even at the highest cattail proportion. No differences were found in flower formation either. All plants achieved marketable quality. The nitrogen content in the shoot dry matter did not differ significantly between the variants. These findings suggest that the suitability of cattail as a substrate component depends more on its origin and composition than on the processing method. Increased nitrogen immobilization in cattail-containing substrates can be counteracted by appropriately adjusted fertilization during plant cultivation.





PO9_6 DYNAMICS OF BORON IN ORGANIC GROWING MEDIA: INFLUENCE OF FERTILIZER FORM AND ITS IMPLICATIONS FOR PLANT GROWTH

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For the cultivation of horticultural crops in organic growing media, a boron concentration of 0.2–1.0 mg (L substrate)⁻¹, determined using the calcium chloride/DTPA (CAT) extraction method according to DIN EN 13651:2002-01, is recommended. However, this reference range is based on a limited number of pot experiments with boric acid as a boron fertilizer. Previous investigations indicate that the concentration of CAT-extractable boron in growing media rapidly decreases after boron fertilization. To date, little is known about whether this decline affects plant growth. Therefore, the objective of this study was to determine the dynamics of boron in a peat-based growing medium and its impact on plant growth. The substrate was base-dressed with different boron fertilizer forms, each at three concentration levels (0.1, 0.5, and 2.0 mg B (L Substrat)⁻¹), and adjusted to pH (CaCl₂) 5.0 and 6.0. Subsequently, the substrate was used for a pot experiment with basil (*Ocimum basilicum* cv. 'Gustosa'), either immediately after boron fertilization or following a nine-week storage period.

Directly after the base dressing, on average, 76 % of the boron applied as boric acid and borax was detected in the growing medium using CAT extraction. The recovery rate increased with decreasing substrate pH and increasing boron supply. When fertilizing with calcium borate, less than one-third of the applied boron was recovered in the substrate. During storage, the boron concentration in the substrate declined by a further 56 % on average. However, this reduction was only marginally influenced by substrate pH, boron fertilizer form, and application rate. In the pot experiment, the boron content in the dry matter of basil shoots was closely correlated with the CAT-extractable boron concentration in the growing medium ($R^2 = 0.95$). The suitability of the CAT method for predicting the phytoavailable boron concentration in growing substrates can thus be confirmed for potted basil and the three tested boron fertilizer forms. Optimal plant growth was achieved at 0.05, 0.06, and 0.28 mg boron (L substrate)⁻¹ when fertilizing with calcium borate, borax, and boric acid, respectively. Storage of the substrate prior to planting reduced basil shoot fresh matter yield by about 2 %. Apparently, even relatively low boron base dressings were sufficient to meet the boron demand of basil, even in stored growing media. Overall, the findings indicate that potted basil plants are adequately supplied with boron at a CAT-extractable boron concentration of 0.3 mg (L substrate)⁻¹.





PO9_7 INOCULATION OF BROCCOLI SEEDLINGS WITH DIAZOTROPHIC BACTERIA – AN APPROACH TOWARDS REDUCING NITROGEN FERTILIZATION?

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The use of biostimulants based on diazotrophic bacteria is proposed as a sustainable approach to reducing mineral nitrogen fertilization in crop production. However, data on the efficacy of these products in vegetable cultivation are limited. To address this knowledge gap, a greenhouse experiment was conducted with broccoli plants grown under different nitrogen supply levels and treated with two diazotrophic bacterial species. The study aimed to evaluate the effects of bacterial inoculation on plant growth and nitrogen efficiency-related traits.

The experiment followed a randomized block design with four replicates and was conducted over a period of 15 weeks. Broccoli plants (*Brassica oleracea* var. *italica*, cv. 'Parthenon') were cultivated in 12-liter containers filled with a peat-based growing medium and received one of three nitrogen supply levels (3.5, 5.7, or 7.9 g N per plant). Calcium nitrate was applied as fertilizer at four time points throughout the cultivation period. The bacterial inoculation treatments included two different species, *Methylobacterium symbioticum* and *Azotobacter salinestris*, which were applied either once (cultivation week 1) or twice (cultivation weeks 1 and 3). Plant growth, SPAD values, fresh and dry biomass, and nitrogen content of the individual shoot organs (inflorescence, leaves, and basal stem) were determined. Based on these parameters, nitrogen uptake efficiency, nitrogen utilization efficiency, and overall nitrogen use efficiency were calculated for each plant organ.

In general, bacterial inoculation did not result in a consistent improvement in plant performance, with sporadic positive effects observed. Under high nitrogen supply, two applications of *M. symbioticum* led to a statistically significant 3.3 % increase in shoot yield. At medium nitrogen supply, all twice-treated variants produced broccoli heads exceeding 500 g, whereas some control plants did not reach the minimum weight required by the German food retail. Across all nitrogen levels, the proportion of nitrogen allocated to the inflorescence relative to the other shoot organs increased with the number of bacterial applications. The enhanced nitrogen translocation into the inflorescence also promoted its share of the shoot fresh mass. However, bacterial inoculation had little impact on nitrogen efficiency parameters in broccoli shoots. Only the inflorescence showed a slight trend towards improved nitrogen uptake efficiency and nitrogen use efficiency following two applications of *M. symbioticum*. Both efficiency traits correlated closely with inflorescence fresh mass.

Further research under field conditions is necessary to assess the potential of biostimulants based on diazotrophic bacteria in broccoli production.





PO9_11 OPTIMIZING NITROGEN APPLICATION RATES IN CEREALS THROUGH THE IDENTIFICATION OF KEY PARAMETERS – DATA FROM 38 YEARS OF FIELD TRIALS

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1 - SEGES Innovation

In Denmark, nitrogen (N) fertilizer application is regulated based on economic optimum principles for specific crops and soil types, forming the foundation of the N norm system. These norms are derived from data from field experiments investigating yield response to increasing N application rates, which have been conducted since 1987. SEGES Innovation maintains comprehensive databases, including results from 472 and 283 field trials with winter wheat and spring barley, respectively, along with additional trials with other cereal crops, silage maize, grass seed, and potatoes.

The aim of this study was to refine the model for determining N requirements by conducting an advanced statistical analysis of trial datasets. Specifically, we quantified the effects of key parameters affecting N demand and production functions. These parameters include pedoclimatic and management variables such as soil texture, humus content, total soil N, yield potential, manure applications and cropping history. Rather than proving a predetermined outcome, this study identified and quantified relationships that contribute to optimized N rate recommendations. To achieve this, we analyzed data from long-term N application curves, focusing particularly on winter wheat and spring barley. The statistical approach accounted for variations in soil conditions, crop rotations, and previous nutrient inputs, hence allowing for a more precise determination of the economically optimal N application rates.

Preliminary results indicate that we can significantly improve the parameterization of soil and management factors which influence N demand. For example, we found that information about previous manure applications and previous crops, holds a legacy effect for the N needs of the succeeding crop. These findings contribute to a more nuanced understanding of N requirements, supported by a model that accounts for site-specific variations rather than one-size-fits-all approaches.

Considering these refined insights, this research enhances the precision of N recommendations and optimizes fertilizer use efficiency in Danish agriculture. The long-term dataset provides a robust foundation for improving N management practices, ensuring both economic and environmental sustainability in cereal production.





PO9_12 MITIGATION OF AMMONIA AND GREENHOUSE GAS EMISSIONS IN COMPOSTING PROCESS THROUGH THE APPLICATION OF A POLYHALITE-BASED ADDITIVE AND NITRIFICATION INHIBITORS

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Composting is a widely recognized, effective, and established bioprocess that transforms organic waste effluents from agro-industrial sources, among others, into compost, stable soil amendment rich in humic substances and essential nutrients. However, while composting efficiently stabilizes organic matter, eliminates pathogens, and enhances the preservation and transportability of the final product, it also produces significant emissions of ammonia and greenhouse gases (GHG).

Different strategies are being investigated to minimize the environmental impact associated with greenhouse gas emissions. Among them, the use of mineral additives in the composting process not only helps on mitigating the GHG and ammonia emissions but also enhances the quality of the final product by minimizing the loss of nutrients in the form of gas.

The present work aims to evaluate the mitigation of GHG and ammonia emissions generated during the pig manure composting process through the application of a polyhalite-based additive with or without an added nitrification inhibitor (Dicyandiamide, DCD). Polyhalite is a natural mineral, it is certified for organic agriculture and has a very low carbon footprint of 0.0029 kg CO₂eq/kg product.

An analytical monitoring has been carried out during the active phase of the composting process as well as during the maturation phase, which lasted 4 and 3 weeks respectively. The evolution of the physico-chemical parameters of the materials in the piles, temperature, GHG and ammonia emissions have been measured throughout the process. Regarding the mitigation of emissions, a flux chamber was used to collect and monitor NH₃ and GHG emissions.

The results reveal a positive effect on the treated piles during the composting process, being more noticeable in the maturing stage of the process. The integration of the polyhalite-based additive in the composting pile has not only mitigated GHG emissions but also the ammonia emissions were reduced. The mitigation performance of the treatments was similar for ammonia and nitrous oxide, achieving reductions of 21–25% and 43–46%, respectively. However, methane mitigation was more effective with the sole addition of the polyhalite-based additive, reducing emissions by about 85%, while the combined addition of the polyhalite-based additive and DCD has not exceeded 67%. Overall, incorporating the polyhalite-based additive into the composting process reduced the carbon footprint by up to 72% compared to the conventional composting system. Another trial is being conducted to support these findings.

These results suggest that incorporating the polyhalite-based additive into composting practices can enhance environmental sustainability by reducing harmful emissions and improving nutrient retention in the final compost product.





PO9_13 NITROGEN FERTILIZATION AND CO-INOCULATION WITH PLANT GROWTH-PROMOTING BACTERIA IN MAIZE IN THE BRAZILIAN CERRADO

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Nitrogen (N) is the most required nutrient for maize (*Zea mays* L.) and represents one of the main costs of its production. Management strategies that reduce dependence on nitrogen fertilizers are essential for environmental sustainability and food security. Among these strategies, the use of plant growth-promoting bacteria (PGPBs) has shown promise. However, there is limited information on the effects of co-inoculation with different PGPBs combined with nitrogen fertilization in grasses. This study aimed to evaluate the effects of PGPBs inoculation and co-inoculation on maize development and productivity in combination with different N doses. The experiment was conducted in Rhodic Hapludox soil with a clayey texture under a no-tillage system, at the experimental area of the Faculty of Engineering of Ilha Solteira, in Selvíria – Mato Grosso do Sul, Brazil. The experimental design was a randomized block design in a 4 × 5 factorial scheme, with four replications. The treatments consisted of: (1) inoculation with *Azospirillum brasilense*; (2) co-inoculation with *A. brasilense* + *Pseudomonas fluorescens*; (3) co-inoculation with *A. brasilense* + *Bacillus subtilis*; and (4) a control without inoculation, combined with five N doses (0, 50, 100, 150, and 200 kg ha⁻¹), applied as urea in covering at the V3 stage of the maize crop. The productive components, SPAD index, ear length, and N content in the grain and plant did not differ significantly among inoculation treatments. However, the SPAD index varied significantly with N doses, showing a linear increasing trend, with the lowest value at the zero dose and the highest at 200 kg ha⁻¹. The N content in the grain followed the same trend, while the N content in the straw showed no significant differences. Additionally, the number of grains per row, grains per ear, and ear length increased with higher N doses. The highest yield was observed in the co-inoculation treatment with *A. brasilense* + *B. subtilis* (10.63 t ha⁻¹), although it did not differ statistically from the control or the co-inoculation with *A. brasilense* + *P. fluorescens*. The lowest yield was obtained with *A. brasilense* alone (9.62 t ha⁻¹). Regarding N doses, a quadratic trend was observed, with the optimal fertilization dose being 147.86 kg ha⁻¹ of N, regardless of inoculation. The results suggest that co-inoculation may be a viable strategy to enhance maize growth, but responses vary depending on the treatment, highlighting the need for further studies in this area.





PO9_14 SUSTAINABLE NITROGEN MANAGEMENT IN STARCH AND TABLE POTATOES: MAXIMIZING YIELD AND EFFICIENCY

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Nitrogen (N) fertilization is essential for potato production but often leads to environmental losses. This study, conducted within the research project POTENZIO^N ("Potentials for Increasing Nutrient Efficiency and Reducing Nitrogen Emissions in Starch Potatoes"), evaluated the effects of different N fertilization levels on tuber yield, quality parameters, and nitrogen use efficiency (NUE) in two starch potato cultivars (Eurotonda, Avamond) and one table potato cultivar (Milva) grown in Northern Germany. A field experiment was conducted at the Reinshof experimental farm (Göttingen) using a split-plot design with three fertilization levels (N0: 0 kg N ha⁻¹, N1: 120 kg N ha⁻¹, N2: 160 kg N ha⁻¹). Before fertilization, the initial soil mineral nitrogen (N_{min}) content was determined at 60 kg N ha⁻¹ across all treatments. Various agronomic and physiological parameters were assessed, including yield, starch content, nitrogen uptake, and NUE, alongside soil N_{min} dynamics throughout the growing season. Yield responses varied among cultivars. Eurotonda achieved its highest yield at 50.2 t ha⁻¹ under N1, while Avamond benefited from increased fertilization, peaking at 52.0 t ha⁻¹ under N2. Milva reached its maximum yield at 56.0 t ha⁻¹ under N1, suggesting that moderate fertilization was optimal. Starch content declined with increasing N application, confirming the dilution effect. In Eurotonda, starch content dropped from 23.0% (N0) to 20.1% (N2), while Avamond showed a more stable response (22.1% to 22.7%), and Milva exhibited the most pronounced decrease (16.0% to 14.9%). NUE declined with rising N supply, ranging from 108.9% (N0) to 69.0% (N2) in Eurotonda, 87.9% to 72.7% in Avamond, and 103.1% to 69.8% in Milva, indicating reduced efficiency under higher fertilization rates. Post-harvest soil N_{min} levels varied among cultivars. Milva retained the highest residual soil nitrogen (53.8–65.1 kg N ha⁻¹), suggesting incomplete N uptake under higher fertilization rates, whereas Eurotonda showed the lowest values (30.6–36.6 kg N ha⁻¹), indicating prolonged N uptake. These findings highlight the need for variety-specific N management strategies to optimize NUE while minimizing environmental losses. Reducing N fertilization from 160 kg N ha⁻¹ to 120 kg N ha⁻¹ maintained high yields while improving NUE and reducing residual soil N, particularly in Eurotonda. By adopting targeted fertilization strategies, starch and table potato production can achieve a sustainable balance between yield maximization and environmental protection.





PO9_15 METHYL JASMONATE (MEJA) REGULATES AUXIN LEVELS INDUCING ORGANIC ACIDS IN RESPONSE TO WATER DEFICIT AND ALUMINUM STRESS IN VACCINIUM CORYMBOSUM L.

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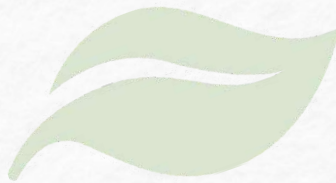
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The combined stress of water deficit and aluminum toxicity (WD+Al) is a major challenge that affects plants. Recent findings suggest that foliar application of methyl jasmonate (MeJA) could mitigate the detrimental effects of these stresses. Therefore, the objective was to reveal the auxin and organic acids interaction in response to MeJA application in *Vaccinium corymbosum* cultivars with contrasting resistance to aluminum (Al) under combined WD+Al stress. The cultivars Star (Al-sensitive) and Legacy (Al-resistant) were subjected to seven treatments: (1) control (80% field capacity, low Al saturation), (2) water deficit (WD; 50% field capacity), (3) Al toxicity (85% Al saturation), (4) WD+Al combination (50% field capacity, 85% Al saturation), (5) Al+MeJA, (6) WD+MeJA, (7) WD+Al+MeJA for 7, 14 and 21 days. The following measurements were performed: Al concentration, water potential (Ψ_w), relative growth rate (RGR), net photosynthesis (P_n), stomatal conductance (gs), transpiration (E), organic acid accumulation and exudation, and auxins (IAA). Under WD+Al, MeJA application reduced Al accumulation, particularly in Legacy roots (decrease up to 57%), and improved RGR (increase up to 1.5-fold), Ψ_w (increase up to 2.1-fold), P_n (increase up to 1.3-fold), gs (increase up to 1.5-fold), E (increase up to 2.1-fold) with respect to the combined WD+Al stress without MeJA, reaching the values of control plants. MeJA induced organic acid accumulation and organic acid exudation, especially oxalic and malic acids. MeJA application increased auxin concentrations in the Al-resistant cultivar under combined WD+Al stress, which correlated directly with malate exudation. These results confirm that foliar MeJA application improves the resistance of plants, effectively mitigating the effects of WD+Al stress in *V. corymbosum* cultivars, especially the Al-resistant cultivar, through enhancing auxin regulation.

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PO9_16 USING PHOSPHORUS-STORING MICROALGAE AS RECYCLED PHOSPHORUS FERTILIZER

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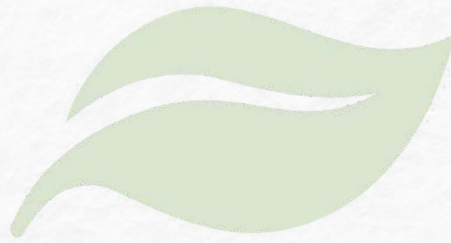
1 - Gilat Research Center, Agricultural Research Organization, Israel; 2 - Ben-Gurion University of the Negev, The Jacob Blaustein Institute for desert research

Phosphorus (P) is an essential nutrient for plant growth, commonly applied in agriculture through fertilizers to achieve optimal crop yields. However, conventional P-fertilizers are derived from rock phosphate, a non-renewable resource, reflecting the need for sustainable alternatives. Wastewater, containing 12–30 mg P L⁻¹, offers a sustainable alternative, with microalgae like *Coelastrella* sp. efficiently absorbing and storing P as polyphosphate (Poly-P). Since Poly-P must be hydrolyzed before plant uptake, its availability largely depends on soil microbial activity. Arbuscular mycorrhizal fungi (AMF) are known to enhance P acquisition, yet their role in facilitating Poly-P utilization remains unclear. This study evaluates *Coelastrella* sp. as a P-biofertilizer and examines AMF's contribution to P uptake from synthetic Poly-P and biofertilizers in tomato (*Solanum lycopersicum*) and lettuce (*Lactuca sativa*) cultivation.

Three experiments were conducted using calcareous soil: (i) an incubation experiment assessing P availability from ortho-P, synthetic poly-P, and a biofertilizer over 84 days; (ii) a pot experiment using tomato as a model plant to evaluate poly-P, ortho-P, and an algae-based biofertilizer in autoclaved soil inoculated with AMF; and (iii) a pot experiment examining lettuce response to biofertilizer versus conventional ortho-P fertilizer. In the incubation experiment, available P concentrations were initially lower with biofertilizer compared to conventional ortho-P fertilizer during the first 21 days. However, from day 21 onward, biofertilizer provided significantly higher available P levels until day 84. In the tomato pot experiment, AMF colonization was highest in plants fertilized with biofertilizer, followed by synthetic poly-P and ortho-P. Increased AMF colonization correlated with improved plant biomass and P uptake, particularly in biofertilizer-treated plants, likely due to enhanced organic matter supporting microbial activity. Lettuce grown with biofertilizer outperformed conventional ortho-P fertilization in yield, P uptake, and the uptake of other nutrients (N, K, Ca, S, Mg, Mn). AMF colonization in lettuce roots was also significantly higher with biofertilizer than with ortho-P. Interestingly, combined ortho-P and biofertilizer application resulted in equal or lower yield and nutrient uptake compared to biofertilizer alone, highlighting the benefits of the slow P release from poly-P in the biofertilizer.

These findings emphasize AMF's critical role in facilitating poly-P hydrolysis and uptake, particularly from biofertilizers. The results suggest that integrating AMF with alternative P sources, such as algae-based biofertilizers, could enhance P-use efficiency and plant growth while reducing reliance on conventional fertilizers. Further studies are needed to explore long-term soil-microbial interactions and optimize biofertilizer formulations for sustainable agriculture.





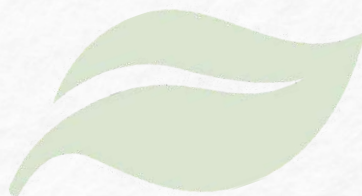
PO9_17 **KNOWNs AND UNKNOWNs IN THE SEARCH FOR MITIGATING CLIMATE-RELEVANT NITROUS OXIDE EMISSIONS**

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Nitrous oxide (N₂O) emissions from agricultural soils account for almost 50% of the global anthropogenic emissions of this climate-relevant trace gas. N₂O emissions are closely linked to the use of nitrogenous fertilisers. Of these N sources, after application to soils, on average about 1.2% is microbially converted to N₂O. However, the proportion is highly variable and depends primarily on environmental conditions and the management and timing of crops, mineral and organic fertilizers, and all kinds of organic residues. N₂O reduction to elemental nitrogen N₂ also plays an important role. Attempts to develop effective mitigation measures depend essentially on detailed knowledge of influencing factors such as soil moisture, temperature, crop growth, soil nitrate concentration and the availability of electron donors, i.e. the provision of organic carbon compounds in the soil. In a number of field and controlled-condition studies, we evaluated nitrous oxide emissions and their controls. As in intensively farmed systems denitrification is the major source of N₂O and as this process produces more gases than N₂O, novel tools like intramolecular isotope signatures and novel N₂-flux quantification methodologies provide relevant new information on the microbial origin and the product stoichiometry, i.e. the N₂:(N₂+N₂O) ratios in the generated gases. Overall, studies show how nitrous oxide emissions can be aggravated or reduced, particularly by managing soil nitrate levels, crop residues and organic matter such as intercrop biomass. Conflicting objectives of reducing other N losses such as nitrate leaching and ammonia emissions are addressed. With a focus on intensively managed land use systems in temperate regions, the contribution presents examples of successful approaches, and looks at knowledge gaps e.g. in the field of freeze-thaw related N₂O emission events.





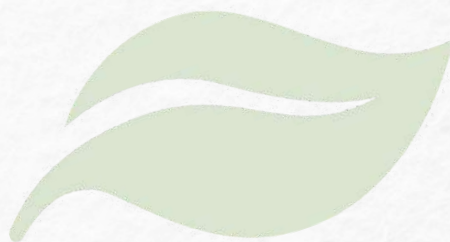
PO9_21 INOCULATION WITH PHOSPHATE-SOLUBILIZING BACTERIA IMPROVES COMMON BEAN PRODUCTION UNDER REDUCED PHOSPHATE FERTILIZATION

Marcelo de Almeida Silva (Brazil)¹; Victor Hugo Araújo Bonduki (Brazil)¹; Raissa Aparecida de Almeida Zorzi (Brazil)²; Lukas Yujii dos Santos (Brazil)²; Anelisa de Aquino Vidal Lacerda Soares (Brazil)²; Rosemary Marques de Almeida Bertani (Brazil)²; Cristiani Kano (Brazil)³; Ivan Herman Fischer (Brazil)²; Angelo Mansur Mendes (Brazil)³; Rafael Marcelino (Brazil)⁴

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The use of phosphate-solubilizing bacteria has emerged as a sustainable alternative to increase phosphorus availability in the soil, thereby promoting higher yields in grain production. In this context, an experiment was conducted in a protected environment at APTA/URPD Bauru, SP, Brazil, with the objective of evaluating the effects of applying phosphate solubilizing microorganisms (*Bacillus subtilis* BMF 2484 and *Bacillus megaterium* BRM 119) and phosphorus doses on common bean (*Phaseolus vulgaris* L.) production. The IAC 2051 cultivar was used in soils with high (Presin = 84 mg dm⁻³) and low phosphorus content (Presin = 8 mg dm⁻³). The experimental design was a randomized block with six treatments, including (T1) absolute control without inoculation and phosphorus fertilization (AC); (T2) 50% recommended phosphate fertilization (AF50B0); (T3) full-dose phosphate fertilization (AF100B0); (T4) 2.7 mL kg⁻¹ of BiomaPhos® (AF0B27); (T5) 50% phosphate fertilization + 2.7 mL kg⁻¹ of BiomaPhos® (AF50B27); and (T6) 100% phosphate fertilization + 2.7 mL kg⁻¹ of BiomaPhos® (AF100B27), inoculated in the seeds, and four replications. The phosphorus source used was triple superphosphate, with a full dose of 40 kg ha⁻¹ of P₂O₅. For the soil with high phosphorus content, the production of beans was influenced by the interaction between phosphorus doses and the solubilizer, with treatment AF50B27 yielding 16.57 g per plant, compared to 13.26 g per plant in treatment AF100B0, representing a 24.98% increase. In the soil with low phosphorus content, grain production was influenced by the main effects, represented by the doses of P₂O₅ and inoculation with BiomaPhos®. Inoculation with the bacteria alone increased grain production (8.10 g per plant), whereas without the inoculant, the production was 6.70 g per plant. Phosphorus doses also significantly influenced production, with the treatments receiving 50% (average of 8.70 g per plant) and 100% of the recommended phosphorus dose (average of 9.32 g per plant) being more productive compared to the treatment without phosphate fertilization, which produced 4.14 g per plant. It is concluded that the use of phosphate solubilizing microorganisms (*Bacillus subtilis* and *Bacillus megaterium*) combined with a 50% reduction in the recommended phosphorus dose for the common bean crop can reduce production costs and dependence on imported phosphate fertilizers, as seen in Brazil, thus promoting a more sustainable production system.





PO9_22 SUSTAINABLE MANAGEMENT PRACTICES TO MITIGATE GREENHOUSE GAS EMISSIONS IN CITRUS FARMING

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1 - Centro de Citricultura Sylvio Moreira, Instituto Agronômico (IAC), Brazil; 2 - Centro de Solos e Recursos Ambientais, Instituto Agronômico (IAC), Brazil; 3 - Yara Fertilizantes; 4 - FortCitrus

The Brazilian citrus industry is important in global orange production and juice exports. Companies that sell fresh oranges and/or orange juice need to estimate the carbon footprint of their products to inform consumers of the environmental impact generated, either in terms of CO₂ equivalent emitted into the atmosphere or how it contributes to carbon (C) recovery and consequently the reduction of this footprint during the different stages of production. In this context, the Centro de Citricultura Sylvio Moreira/IAC, in partnership with Yara Fertilizers, carried out a study with the aim of (i) measuring soil organic C content and stocks and; (ii) monitoring carbon dioxide (CO₂), nitrous oxide (N₂O) and methane (CH₄) emissions in a Pêra sweet orange orchard grafted onto Rangpur lime, subjected to different managements: (i) orchard intercropped with *Urochloa ruziziensis*, managed with an ecological mower, where the mown phytomass is directed to the citrus planting rows, and (ii) orchard intercropped with *U. ruziziensis*, managed with a conventional mower, where the mown phytomass is maintained in the inter-rows; and their interaction with four nitrogen (N) fertilizer sources in the row: (i) ammonium nitrate-NA, (ii) calcium nitrate-NC, (iii) urea-U and (iv) no N. The following were evaluated: *U. ruziziensis* phytomass, soil C dynamics, greenhouse gas (GHG) emissions, soil fertility, plant nutritional status, citrus canker incidence, and orange trees' vegetative and productive development. The research was conducted at Fazenda Cachoeira in Mogi Guaçu, São Paulo State, Brazil, which is part of the Fruit Resilient project, by Solidaridad Foundation. Integrating ecological mowing and NC application resulted in greater C retention in the soil and lower global warming potential (GWP). Over the course of 313 days, the study showed that the ecological mowing treatment significantly reduced GHG emissions per ton of orange produced. Management with ecological mowing increased orange productivity by approximately 12%, regardless of nitrogen fertilization, and the greatest productivity gain (29%) was obtained with the combined use of ecological mowing and NC, which also resulted in a lower incidence of citrus canker. These findings highlight the potential of management with ecological mowing to reduce the carbon footprint of Brazilian citriculture while maintaining competitiveness in the international market.





PO9_23 **PHYSIOLOGICAL EFFECTS OF FOLIAR-APPLIED MAGNESIUM SALTS ON STOMATAL REGULATION IN MAGNESIUM DEFICIENT FABA BEANS**

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Foliar fertilization is an effective strategy for improving crop nutrition, particularly when root nutrient supply is restricted due to poor soil conditions, high nutrient losses, or restricted translocation to critical plant organs (Fernández et al., 2013). While nutrient absorption occurs through the leaf cuticle, stomatal pores are also considered important pathways for foliar nutrient uptake (Eichert and Burkhardt, 2001). This suggests that stomatal regulation influences the efficiency of foliar nutrient uptake. However, more research is needed to understand how foliar-applied salts affect stomatal regulation and if changes in stomatal aperture affect the absorption of foliar-applied nutrients into the leaf

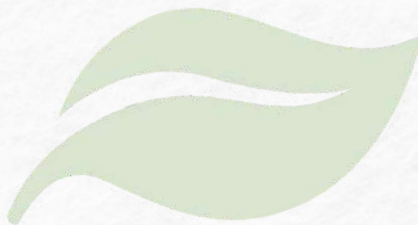
Foliar application of magnesium (Mg) salts is a common strategy to alleviate emerging Mg deficiency, restoring photosynthetic performance and thereby reflecting the efficiency of foliar Mg fertilization. Various Mg salts are available, differing in their companion anion, such as chloride, sulfate, or nitrate. The accompanying anion affects the physicochemical, osmotic, and ionic properties of the salt solution, which must be considered when evaluating its physiological effects on the plant. We hypothesize that the anions in foliar-applied fertilizer solutions affect the stomatal aperture differentially, thereby influencing the overall effectiveness of foliar nutrient uptake, particularly through the stomatal pathway. Furthermore, we use the physiological responses to the different Mg salts as indicators of the efficiency of foliar nutrient uptake in addition to direct nutrient uptake measurements.

To investigate these effects, we examined the impact of foliar-applied Mg salts on stomatal aperture in *Vicia faba* using in vivo light microscopy under controlled environmental conditions. Concurrently, the pH in the mesophyll apoplast is monitored to track changes in plasma membrane H⁺-ATPase activity associated with ion uptake into the cytosol. To quantify the ion translocation into the leaf apoplast, we extracted apoplastic wash solution to monitor the increase in ion concentration following foliar salt application. Additionally, we assessed the physiological responses in Mg-deficient plants by measuring photosynthesis, chlorophyll content, and chlorophyll fluorescence to evaluate nutrient uptake efficiency. Combining the physiological responses provides deeper insights into how stomata react to different companion anions in foliar fertilizers, ultimately influencing nutrient absorption efficacy. This improves our understanding of effective and sustainable foliar fertilization.

References:

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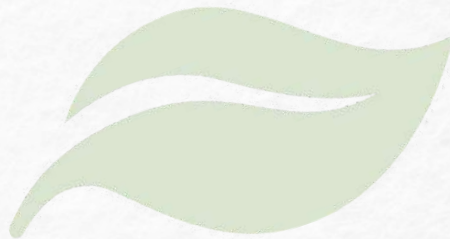
PO9_24 WOOD VINEGAR FOLIAR SPRAY ENHANCES COMMON BEAN YIELD

Carlos Ribeiro Rodrigues (Brazil)¹; Tatiana Michlovská Rodrigues (Brazil)¹; João Ricardo Cruz Crispim (Brazil)¹; José Carlos Bento (Brazil)¹; Gustavo Castoldi (Brazil)¹; Leandro Carlos (Brazil)¹; Vinicius Ferreira Souza (Brazil)¹; Maria Emília Antunes de Rezende (Brazil)²; Rebeca Martins da Silva Fernandes Oliveira (Brazil)¹; 3; Crislene de Oliveira Pereira (Brazil)¹; 4; Alfredo Silva de Brito (Brazil)¹

1 - Goiano Federal Institute; 2 - Biocarbo; 3 - Mosaic Company; 4 - Municipal Department of Education of Rio Verde, Goiás

Increasing food production and ensuring food security depend on agricultural inputs. The use of natural products, such as wood vinegar (pyroligneous extract), can reduce external inputs and enhance plant stress adaptation. Rich in polyphenolic compounds, wood vinegar induces plant resistance. However, there is limited information on its application timing and effects on plant photochemistry and yield. As common bean (*Phaseolus vulgaris* L.) is a staple food globally, this study evaluated the effects of foliar-applied wood vinegar (Biopiról®) at different growth stages on photosynthetic pigments, chlorophyll a fluorescence, and yield of cv. IPR Urutau. The experiment was conducted in Rio Verde, GO, Brazil, on a Rhodic Acrustox (equivalent to Latossolo Vermelho Acriférico), using a randomized block design with four treatments (control; vegetative; reproductive; vegetative + reproductive) and four replicates. Biopiról® was applied at 1 L ha⁻¹ (1% in spray solution). Vegetative applications occurred at V3 and V4, reproductive at R6 and R7, and combined at V3, V4, R6, and R7. Photosynthetic pigments and chlorophyll a fluorescence were analyzed seven days after R7. At harvest, pod number, thousand-grain weight, and yield (13% moisture) were evaluated. The application of Biopiról® during the vegetative stage of common bean resulted in the highest levels of photosynthetic pigments (chlorophyll a, b, and total). The chlorophyll a:b ratio remained unchanged across treatments. Plants treated with Biopiról® during both vegetative and reproductive stages exhibited the lowest energy loss as fluorescence, along with the highest electron transport rates from PSII reaction centers (RC/PSII), maximum photochemical efficiency, and reduced energy loss in non-photochemical quenching (NPQ), regardless of application timing. Leaf nutrient content was altered only for P, K, and Mn. The highest P and K levels were observed with Biopiról® application, particularly during the vegetative + reproductive stages, while Mn levels decreased under the same conditions. Biopiról® increased total pod number, especially during the reproductive stage, but also raised the number of empty pods. Thousand-grain weight remained unchanged. Yield was highest with combined vegetative and reproductive application, followed by reproductive application alone. The yield increase with combined application was 614.01 kg ha⁻¹ compared to the control. In conclusion, Biopiról® application during vegetative and reproductive stages increased grain yield by 18%, with higher pod numbers, attributed to improved photochemical efficiency and reduced energy loss in NPQ.





PO9_26 INTERACTION BETWEEN THE WEATHERING OF GLACIAL ROCK FLOUR AND ROOT GROWTH: A RHIZOBOX TRIAL

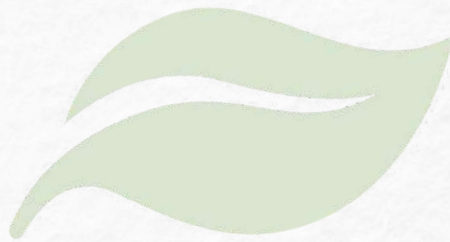
Saulo Augusto Quassi de Castro (United States)¹; Charlotte Vermeiren (Denmark)²; Lars Stoumann Jensen (Denmark)²

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Glacial rock flour (GRF) is a soil amendment consisting of ultrafine silicate minerals naturally produced by glacial movement. GRF has a large reactive surface area and is considered suitable for enhanced rock weathering, releasing Si, K, and Mg to the soil. These elements can be available to the plants and have sparked an interest in GRF's use for improving nutrient availability and crop health in agriculture. Positive effects on crop yield and/or nutrient contents have been observed, but little is known about the contribution of roots to these effects. We hypothesized a dual interaction effect, with roots enhancing GRF weathering by soil acidification and exudate production, while the method of GRF application can affect root architecture and growth. To test this, a six-week rhizobox trial was carried out in a two factorial scheme, with plant species as first factor, i.e., leguminous (soybeans) or non-leguminous crop (maize), and the second factor being different GRF application methods (all at 50 ton ha⁻¹), as well as a positive and a negative control (with or without K-fertilizer only). GRF application method was either "mixed" throughout the top zone of the rhizobox, placed in a "spot" to test if high local nutrient concentrations attracted roots, or applied as a "layer" at the bottom of the top zone to test for barrier effects. The rhizoboxes were filled with an acidic sandy clay loam (pH 5.4) soil with low K availability.

Roots appeared to be indifferent to the presence of GRF in the soil; they were neither attracted to the GRF "spot" placement with elevated nutrient availability, nor were they blocked by GRF "layer" amendment. The greatest effects in both plant and soil were observed when GRF was mixed in the top zone of the rhizobox. This yielded a significant soil pH increase with both plant species, though greatest for maize, up to 0.5 pH units. The concentration of exchangeable K was elevated compared to the negative control in the "mix" treatment with maize, while "layer" and "spot" did not differ from the negative control. Therefore, "mixed" GRF was able to alleviate K deficiency in maize, to a similar extent as the positive control, contributing significantly to crop K requirements. Moreover, GRF also increased maize Si concentrations. As Si is known for its beneficial effects on plants under stress, this suggests another positive effect of using GRF as an amendment in agriculture, however, further investigations are needed.





PO9_28 **EVALUATION OF LIQUID ORGANIC FERTILIZER ON GARNEM (PRUNUS PERSICA × PRUNUS AMYGDALUS) ROOTSTOCK GROWTH IN NURSERY**

Mehdi Ben Mimoun (Tunisia)¹; Haïfa Benmoussa (Tunisia)¹

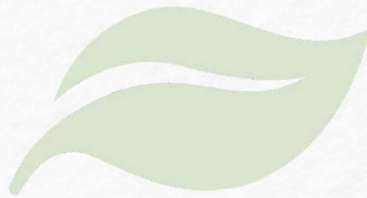
¹ - University of Carthage, National Agronomic Institute of Tunisia (INAT), Laboratory GREEN-TEAM; LR17AGR01, 43 Avenue Charles Nicolle, 1082 Tunis, Tunisia

Plant quality from nursery is crucial for fruit production. As a result improving plant growth in nurseries with an adequate mineral nutrition is a key point. Among alternatives to chemical fertilizers, manure tea, an organic solution, could supports the development of young plants, enhances soil nutrient availability, and stimulates microbial activity. This study assesses the effect of manure tea “Solorga Ghbar” on the growth of Garnem (*Prunus persica* × *Prunus dulcis*) plants on nursery. In 2023, 60 potted Garnem plants were placed in a glass greenhouse equipped with shading net and cooling system. The plants received two to three irrigations weekly based on their needs and temperature conditions. Four treatments were implemented with 15 replicates each: T0 (control with water only), T1 (0.2% manure tea), T2 (0.5% manure tea), and T3 (1% manure tea). Six applications were made every 15 days over three months. The manure tea used contains beneficial microorganisms, with nutrients including nitrogen, potassium, phosphorus, calcium, and magnesium, as well as a dry matter content of 1.4% and organic matter. Plant parameters such as height, diameter, leaf number, and SPAD Chlorophyll Index were monitored every 15 days. At the end of the experiment, measurements were taken for leaf area, root system volume, and dry weight of leaves, stems, and roots. One-way ANOVA was conducted for analysis.

Results indicated significant treatment effects on plant height and diameter at all monitoring dates and in leaf numbers except at Day +30 with T3 treatment improving plant height. By the end of the experiment, treatment effects were significant for leaf area, root volume, dry weight of stems and leaves, and the dry weight ratio of the aerial part to the roots. The T3 treatment enhanced root volume, dry weights of stems and leaves, and the aerial-to-root dry weight ratio compared to the control, while T1 showed improvements in leaf area compared to T2 and T3.

SPAD Chlorophyll Index values exhibited notable differences at Days +15, +75, and +90, with the highest values recorded for T0 and T2, and with no nitrogen deficiency in Garnem leaves for all treatments.





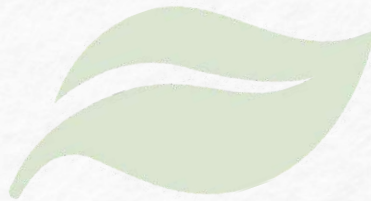
PO9_29 BACTERIAL INOCULATION ENHANCES GAS EXCHANGE AND SOIL PHOSPHORUS AVAILABILITY IN COMMON BEAN UNDER REDUCED PHOSPHATE FERTILIZATION

Marcelo de Almeida Silva (Brazil)1; Hariane Luiz Santos (Brazil)1; Rosemary Marques de Almeida Bertani (Brazil)2; Victor Hugo Araújo Bonduki (Brazil)1; Mirele Lopes da Silva (Brazil)1; Cristiani Kano (Brazil)3; Ivan Herman Fischer (Brazil)2; Anelisa de Aquino Vidal Lacerda Soares (Brazil)2; Ricardo Henrique Casini Chiarelli (Brazil)4

1 - São Paulo State University (UNESP), School of Agricultural Sciences, Laboratory of Ecophysiology Applied to Agriculture (LECA), Botucatu, SP, Brazil; 2 - São Paulo Agribusiness Technology Agency, Bauru, SP, Brazil; 3 - Embrapa Territorial, Campinas, SP, Brazil; 4 - Cati Regional, Botucatu, SP, Brazil

Phosphorus (P) is the most limiting nutrient for common bean productivity in Brazilian soils, playing an essential role in cell division, metabolism, energy storage, and transfer. In this context, bacteria contribute to the solubilization and mineralization of P in the soil, processes that are fundamental to its biogeochemical cycle. This study aimed to evaluate gas exchange and leaf P content in common beans, as well as P availability and microbial activity in the soil under bacterial inoculation and different phosphate doses. The interaction between plants and microorganisms is influenced by the availability of carbon sources derived from photosynthesis, which support microbial growth and survival. The experiment was conducted in a randomized block design using a 3×3 factorial scheme, with three inoculation treatments [No inoculation (NI); *Bacillus megaterium* BRM 119 and *Bacillus subtilis* BMF 2484 (BiomaPhos) – 4×10^9 CFU mL⁻¹; BiomaPhos + *Rhizobium tropici* SEMIA 4077 – 2×10^9 CFU mL⁻¹ + *Azospirillum brasilense* Ab-V5 and Ab-V6 – 2×10^8 CFU mL⁻¹ (BRA)], and three P doses (100%, 50%, and 0% of the recommended dose), applied as triple superphosphate, with four replicates. Data were subjected to analysis of variance, and means were compared using Tukey's test ($p \leq 0.05$). Stomatal conductance and transpiration increased by 23.8% and 12.1%, respectively, under 100% P compared to 0% P. Intercellular CO₂ concentration was lower with BiomaPhos compared to NI and decreased under 50% and 100% P. Under 0% P, BiomaPhos increased net CO₂ assimilation, water use efficiency, and carboxylation efficiency by 42.1%, 39.8%, and 50.9%, respectively, compared to the NI control. Increasing P doses enhanced fluorescein diacetate (FDA) activity under NI but reduced it under BiomaPhos, possibly due to the high P availability in the soil. BiomaPhos increased β -glucosidase activity by 12.7% compared to NI. In contrast, phosphatase activity decreased with BiomaPhos, especially under 100% P, a pattern also observed for BRA. Overall, inoculation increased soil P content, although the highest values were recorded under 100% P. Additionally, BiomaPhos increased foliar P content by 11% compared to NI, showing results similar to those obtained with NI under 100% P. However, the combined inoculation of *Bacillus*, *Rhizobium*, and *Azospirillum* did not significantly improve photosynthetic, nutritional, or microbiological parameters compared to BiomaPhos. Thus, it is concluded that *B. megaterium* BRM 119 and *B. subtilis* BMF 2484 enhanced gas exchange and soil health, even under reduced phosphate doses, contributing to increased foliar P content.





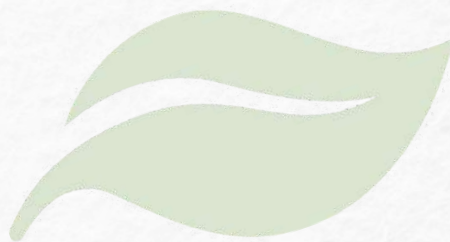
PO9_30 CO-INOCULATION OF AZOSPIRILLUM BRASILENSE AND BACILLUS SUBTILIS ASSOCIATED WITH NITROGEN FERTILIZATION ON NUTRIENT UPTAKE AND WHEAT YIELD

Marcelo Carvalho Minhoto Teixeira Filho (Brazil)¹; Arshad Jalal (Saudi Arabia)²; Carlos Eduardo da Silva Oliveira (Brazil)³; Edson Cabral da Silva (Brazil)¹; Guilherme Carlos Fernandes (Brazil)¹; William Cesar Nishimoto Ito (Brazil)¹; Fernando Shintate Galindo (Brazil)⁴; Thiago Assis Rodrigues Nogueira (Brazil)⁵; Karina da Silva Souza (Brazil)¹

1 - São Paulo State University (UNESP), Campus of Ilha Solteira; 2 - Center of Excellence for Sustainable Food Security, Division of Biological and Environmental Sciences (BESE), King Abdullah University of Science and Technology (KAUST); 3 - State University of Mato Grosso do Sul (UEMS); 4 - São Paulo State University (UNESP), Campus of Dracena; 5 - São Paulo State University (UNESP), Campus of Jaboticabal

Optimization of nitrogen (N) rates is always appreciated to obtain high-quality grains and yields of wheat crops. Despite this, the introduction of inoculants with plant growth-promoting bacteria (PGPB) is increasing day by day due to the high cost of fertilizers and increasing awareness of sustainable and pollution-less agriculture. These PGPB are contributing to the improvement of nutrient availability and absorption as well as promoting plant growth. However, there are practically no studies about the effect of co-inoculation with *Azospirillum brasilense* and *Bacillus subtilis* on wheat quality and yield improvement. In this context, the objective of this research was to evaluate the effect of seed inoculation and co-inoculation with *A. brasilense* and *B. subtilis* and rates of N in coverage, on macronutrients uptake, yield components and yield of irrigated wheat in two consecutive cropping seasons, after soybean crop. The experiments were developed in a Rhodic Haplustox soil with a clayey texture under a no-tillage system at Selvíria, State of Mato Grosso do Sul, Brazil. The experiments were designed in a randomized block with four replications in a 4 x 5 factorial scheme. The treatments consisted of control (non-inoculation), seeds inoculation with *A. brasilense* (strains AbV5 and AbV6) or with *B. subtilis* (strain CCTB04) and co-inoculation with *A. brasilense* + *B. subtilis*, and five N rates (0, 40, 80, 120 and 160 kg ha⁻¹ in the form of urea) applied at wheat tillering stage, between the cultivation lines of this cereal. Total shoot nutrient uptake followed the decreasing order of N > K > Ca > S ≥ P > Mg in the 1st year and N > K > P > S > Ca ≥ Mg in the 2nd year. Inoculation with *B. subtilis* and especially co-inoculation with *A. brasilense* and *B. subtilis* improved plant nutrition by promoting higher total shoot macronutrients uptakes, straw dry biomass, and grain yield. Regardless of inoculation with PGPB, the increasing N rates had positively influenced uptakes of all macronutrients in total shoot plants, in both cropping seasons, except for the Ca and Mg total shoot uptake in the first year. Nonetheless, the increasing rates of N alone or associated with PGPBs inoculations had little influence on the biometric and yield components, and grain yield of wheat. Therefore, seeds co-inoculation with *A. brasilense* and *B. subtilis* is recommended for more sustainable cultivation of wheat crop in Brazilian Cerrado.





PO9_31 **ORGANIC MATTER MODULATES THE ACTION OF BACILLUS VELEZENSIS UFV 3918 ON THE MICROBIOTA AND PHOSPHORUS AVAILABILITY IN SOILS WITH DIFFERENT TEXTURES**

Hariane Luiz Santos (Brazil)¹; Maria Eduarda da Silva Benevente (Brazil)¹; Michael Douglas dos Santos Arildo (Brazil)¹; Lusiane de Sousa Ferreira (Brazil)¹; Melina Rodrigues Alves Carnietto (Brazil)¹; Isadora Malveira Costa Frederico (Brazil)¹; Marcelo de Almeida Silva (Brazil)¹

¹ - São Paulo State University (UNESP), School of Agricultural Sciences, Laboratory of Ecophysiology Applied to Agriculture (LECA), Botucatu, SP, Brazil

Brazil is the world's largest sugarcane producer. Phosphorus (P) is essential for plant metabolism but has the lowest use efficiency among macronutrients due to its strong soil retention. This limitation reduces sugarcane yield and longevity, leading to intensive use of synthetic phosphate fertilizers. An alternative approach involves phosphate-solubilizing bacteria (PSB) combined with less soluble phosphate fertilizers and filter cake (FC). Certain bacterial strains hydrolyze insoluble organic and inorganic P, making it available to plants. PSB releases metabolites that solubilize inorganic P and mineralize organic P, while FC provides organic matter that supports soil microbial activity. This research evaluated soil chemical and microbiological responses to *Bacillus velezensis* UFV 3918 (Bv) inoculation, applied alone or with Bayóvar reactive phosphate rock (RPR) and FC in two contrasting environments (E2 and B1). A randomized block design (2×5 factorial) tested Bv presence/absence and five RPR-FC combinations: absolute control (AC – no RPR or FC), positive control (PC – 100% recommended RPR dose), 75% RPR + 25% FC, 50% RPR + 50% FC, and 25% RPR + 75% FC, with four replicates. Data were analyzed using ANOVA (F-test) and Tukey's test ($p \leq 0.05$). Overall, PC benefited the least from Bv inoculation. In E2, Bv increased acid phosphatase (6.6%), β -glucosidase (14.5%), arylsulfatase (18.1%), fluorescein diacetate (FDA) hydrolysis (27.1%), and urease (22.4%) activities, with the highest values under 25% RPR + 75% FC, which performed similarly to or better than PC, regardless of inoculation. Bv also increased soil organic matter (SOM) in AC and 75% RPR + 25% FC and significantly raised soil P levels, particularly in AC, at 0–20 cm (46.9%) and 20–40 cm (231%) depths. In B1, Bv increased β -glucosidase (5.5%), arylsulfatase (18.3%), FDA hydrolysis (7%), and urease (16.4%), with the highest activities under 50% RPR + 50% FC, which performed similarly to or better than PC. Bv improved SOM and soil P content, especially in AC, 50% RPR + 50% FC, and 25% RPR + 75% FC at 0–20 cm (41.2%, 19.7%, and 38.1%, respectively) and in AC at 20–40 cm (74.3%). Thus, *B. velezensis* UFV 3918 improved soil health and P content, but soil texture and chemistry influenced bacterial activity, likely due to FC's organic material.





PO9_32 PLANT GROWTH-PROMOTING EFFECT OF A CYANOBACTERIUM ENRICHED CULTURE AND ITS AGRONOMIC BIOFERTILIZER POTENTIAL

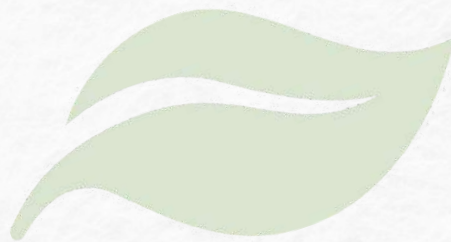
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Biofertilizers based on microalgae and cyanobacteria are regarded as valuable resources for sustainable agricultural practices. These organisms are abundantly present in soils and play significant roles in soil fertility and health. However, their biotechnological potential has yet to be thoroughly investigated, with only a few species recognized for their agricultural applications. In this study, a non-axenic culture, composed mainly of a filamentous cyanobacterium (hereafter named *Tildeniella* sp.), was extensively characterized, and an in-depth evaluation of its effect on plants was carried out to determine its agronomical potential. A metagenomic analysis of the culture for identification and functional characterization was conducted. Furthermore, the effect of the cyanobacterium culture on plant growth was evaluated by co-cultivation with lettuce plants followed by plant biometric and biochemical analyses.

Metagenomic analysis showed that Cyanobacteria is the most abundant phylum in the culture and suggests that the most representative MAG corresponds to a novel cyanobacterial species, most likely belonging to the *Tildeniella* genus. Functional metagenomics assigned the capability of the cyanobacterium to fix N₂, revealed by the presence of several *nif* genes. Further characterization of the cyanobacterium revealed a filamentous and non-heterocystous organism with straight to slightly curved trichomes surrounded by a colourless sheath. Concerning the phycobiliproteins, *Tildeniella* sp. contains phycocyanin but not phycoerythrin and is capable of producing siderophores and auxins. Co-cultivation of lettuce plants with the cyanobacterium culture increased plant growth, both in pots and in commercial hydroponic systems, highlighting its potential for agronomic applications. The culture enriched in *Tildeniella* sp. exhibited a strong positive effect on plant carbon and nitrogen metabolism, increasing photosynthesis, carbohydrate, and pigment content, and the activity of nitrogen-related enzymes (Nitrate Reductase and Glutamate Dehydrogenase). Additionally, it influences plant anatomy by promoting root length and stimulating the formation of lateral roots, probably due to its capability to modulate plant auxin metabolism, as observed using auxin-GUS *Arabidopsis* reporter plants. This study contributes to a better understanding of the molecular mechanisms underlying the interaction between nonsymbiotic cyanobacteria and plants and reveals the potential of novel species for use in sustainable hydroponic cultivation strategies.

This research was supported by national funds through FCT – Foundation for Science and Technology within the scope of UID 05748: GreenUPorto - Centro de investigação em Produção Agroalimentar Sustentável.



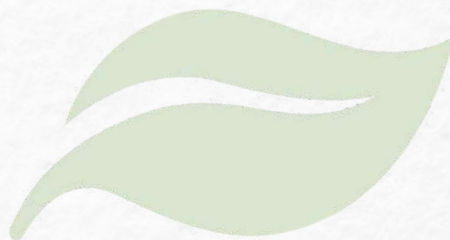
PO9_33 OPTIMIZING NITROGEN, POTASSIUM, AND BORON MANAGEMENT FOR SUSTAINABLE COTTON PRODUCTION IN CONTRASTING SOIL CONDITIONS

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Proper nutrient management is crucial for optimizing cotton yield, reducing costs, and enhancing the sustainability of fertilizer use. In Brazil, particularly in the Midwest, nitrogen (N) and potassium (K) are often overapplied, which can lower nutrient use efficiency and affect boron (B) uptake. This study evaluated the effects of different N, K, and B rates on cotton nutrition and yield. The research was conducted during 2020/2021 growing season in São Paulo state at two locations: Presidente Bernardes, with a tropical climate, rainfed agriculture, and poor sandy soil, and Paranapanema, with a subtropical climate, irrigation, and fertile clayey soil. The treatments included B at 1.5 and 3.0 kg ha⁻¹ (ulexite); N applied at 0, 70, 140, and 210 kg ha⁻¹ (urea) and K at 0, 50, 100, and 150 kg ha⁻¹ (potassium chloride). Leaves were collected at full bloom to determine the concentration of N, K, and B in plant tissue. The leaves were washed, dried, and analyzed using standard laboratory techniques. At harvest fiber yield was determined. N and K rates interacted significantly in influencing nutrient concentrations, except for B in sandy soil. In these environments, N leaf content plateaued at 140 kg ha⁻¹, while in clay soils, it increased to 240 kg ha⁻¹ when K was absent, and B was high. High N reduced K uptake, especially under high B availability, leading to a 50% decrease in leaf K in sandy soils and 60% in clay soils. Fiber yield in sandy soil peaked at 70 kg ha⁻¹ of N when 3.0 kg ha⁻¹ of B was applied, reducing the K requirement. In clay soil, the highest yields (2500–3000 kg ha⁻¹) were obtained with moderate K (50–100 kg ha⁻¹) and N (70–140 kg ha⁻¹), with little benefit from additional B. No yield increase was observed with 210 kg ha⁻¹ N in any environment. These findings highlight the complex interactions between N, K, and B in cotton nutrition. Balanced fertilization strategies tailored to soil texture and nutrient availability can enhance efficiency, maximize yield potential, and reduce unnecessary fertilizer applications, promoting economic and environmental sustainability in cotton production.





PO9_34 MAIZE AND COMMON BEAN CROP PERFORMANCE IS AFFECTED BY THE CHOICE OF NITROGEN SOURCE IN A TEN-YEAR STUDY IN THE TROPICS

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Urea is the most utilized form of nitrogen (N) as fertilizer, representing 62% of the total N-consumption in Brazil. Although it is economically attractive, the main disadvantage of urea is the high potential for N losses due to NH_3 volatilization, when applied to the soil surface. However, research suggests that the same environmental conditions that promote NH_3 volatilization also favor soil N mineralization. As a result, in some cases depending on the soil type, the advantages of using more stable N sources may not be evident in short-term studies. Therefore, evaluating N sources in medium and long-term studies is a reliable approach to assess how N ion forms impact soil parameters and indirectly influence crop performance. In this study, we evaluated the long-term effects of continuous applications of urea, calcium ammonium nitrate (CAN) and ammonium sulfate on nitrogen use efficiency (NUE) and the grain yield of maize and common bean crop. The field experiment was conducted for ten growing seasons (2013/14 to 2022/23) at Capivara Farm, located at the municipality of Santo Antônio de Goiás, Brazil. The experiment consisted of a randomized block design with five replicates and two factors - N sources (calcium ammonium nitrate - CAN and urea) and three N rates (50%, 100% and 150% of the recommended N rate for the crop) and two additional treatments (ammonium sulfate at 100% of the recommended N rate and a control without N application). N fertilizers were broadcasted as topdressing onto the same plots each season. The effects of N fertilization on maize and common bean yields, both in terms of rates and sources, were influenced by time. Over an average of ten years, maize yield with CAN at a rate of 135 kg N ha^{-1} remained 1.9% higher than the yield obtained with 205 kg N ha^{-1} of urea. Regardless of the N rate, CAN outperformed urea for the common bean. When ammonium sulfate was included in the comparison at the recommended N rate, its performance was 19% lower than CAN, while the yield reduction with urea was 11%. From the 2018/19 season onwards, common bean yields in plots with ammonium sulfate declined to levels similar to those in the N unfertilized plots. In conclusion, continuous CAN application resulted in higher maize and common bean grain yields. The cumulative N losses as NH_3 from urea and soil acidification caused by ammonium sulfate reduced the NUE of these fertilizers.





PO9_35 **BLACK LIQUORS AND THEIR DERIVATIVES AS IRON COMPLEXING AGENTS FOR FERTILIZATION**

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The search for sustainable fertilizers is a priority in modern agriculture to reduce environmental impact and improve nutrient absorption efficiency¹. A promising alternative is the use of biodegradable complexing agents and the valorization of industrial by-products, allowing the substitution of fossil-based compounds with renewable carbon sources. In the wood industry, lignin extraction undergoes two main processes: the sulfite process, which produces lignosulfonates (LS) with a significant complexing capacity^{2,3}, and the Kraft process, producing a black liquor whose complexing capacity and plant application have yet to be explored. Advances in the chemical modification of LS extraction methods have led to the development of new derivatives with different properties and applications in plant nutrition than LS. This study aimed to evaluate the complexation capacity of products derived from the Kraft process, as well as those obtained through modifications in the sulfite extraction process. Additionally, their effectiveness as iron (Fe) fertilizers was assessed in hydroponic cultivation.

The complexation capacity of two Black Liquor (BL) types was evaluated: Black Liquor Kraft (BLK), obtained from Kraft extraction process, and Black Liquor Bisulfite (BLB) derived from modification of the LS extraction method. The BLB showed a higher complexation capacity, with 12.3% soluble Fe by dry weight, compared to 5.3% in BLK. Consequently, BLB was selected as the base material, and its modifications, along with those of humic Kraft lignins (LKB), were studied, allowing for comparison with LS.

The preparation of the Fe complexes was carried out by assessing the complexation capacity of BL derivatives⁴ (BLB, BLBox, LKB, LKBox), using LS and its modifications (LSNH₄⁺ and LSsulf) as controls. Plant experiments were then conducted, first inducing Fe chlorosis in the plants, and then studying the plant recovery with the mentioned complexes at the dose of 30 µM Fe. Additionally, two root fertilization controls were included: a positive control (C⁺) with a full nutrient solution with 30 µM Fe-EDTA, and a negative control (C⁻) under complete Fe deprivation conditions.

This work will demonstrate the potential of chemically enhanced materials as Fe fertilizers with potential applications in crop production.

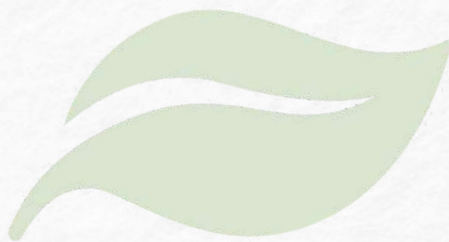
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2. DOI: 0.1002/jsfa.4197
3. DOI: 10.3389/fpls.2016.01767
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PO9_36 **COPPER POLYPHENOL AND HORMONES INCREASE BEAN GROWTH AND YIELD**

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1 - Goiano Federal Institute; 2 - FertiGlobal Company; 3 - Marambaia Sementes; 4 - Municipal Secretariat of Education of Rio Verde, Goiás

Common bean (*Phaseolus vulgaris* L.) is a key source of protein, vitamins, and minerals. Enhancing its productivity requires balancing agronomic efficiency, environmental sustainability, and resource optimization. The crop's vigorous vegetative growth necessitates plant growth regulators to manage development and reduce foliar diseases, as excessive foliage creates microclimates favoring pathogens. Current disease control relies on frequent fungicide applications, but an alternative approach combines copper with plant resistance inducers. This study evaluated the effects of copper, alone or combined with cytokinin and polyphenols, on photosynthesis, growth, and yield of common bean, cultivar IPR Urutau. The experiment was conducted in Rio Verde, Goiás, Brazil, in the Cerrado biome, on a Rhodic Acrustox soil. A randomized complete block design was used with five treatments: copper (Cu), cytokinin (Cyt), Cu + cytokinin (Cu+Cyt), copper + polyphenol (Mantus®), and propiconazole. Applications were made at the V2 and V5 growth stages, with Mantus® receiving an additional application at R7. Copper was applied at 88.8 g ha⁻¹ (CuSO₄·5H₂O p.a.), cytokinin (Maxcell®, 20 g L⁻¹ N₆-benzyladenine) at 500 mL ha⁻¹, copper + polyphenol (Mantus®, 14 g L⁻¹ N, 280 g L⁻¹ Cu) at 300 mL ha⁻¹, and propiconazole (Tilt®, 250 g L⁻¹ Propiconazol) at 500 mL ha⁻¹. Photosynthetic pigments and chlorophyll fluorescence were measured seven days after V2 and V5 applications using a ClorofiLog and FluorPen portable devices. Photosynthesis (IRGA) and aboveground dry mass were assessed during the second evaluation. At harvest, pod number, thousand-grain weight, and grain yield (13% moisture) were measured, and agronomic efficiency was estimated. During vegetative stages, Propiconazole and Mantus® treatments showed superior performance in photosynthetic pigments, except for the A:B ratio, which was lower with Propiconazole. In the reproductive stage, chlorophyll A and total chlorophyll were higher with Propiconazole and cytokinin. No differences were observed in photosynthesis, dry mass, pod number, or stems among treatments. Mantus® outperformed others in yield, thousand-seed weight, and agronomic efficiency. In conclusion, while no treatment altered photosynthesis, Cu, Cit, and Cu+Cit improved photochemical efficiency, and Mantus® and Propiconazole enhanced photosynthetic pigments, pod number, and grain yield.





PO9_37 PRE- AND POST-STRESS BIOSTIMULANT APPLICATION RESTORES NUTRIENT HOMEOSTASIS AND MITIGATES OXIDATIVE STRESS IN DURUM WHEAT

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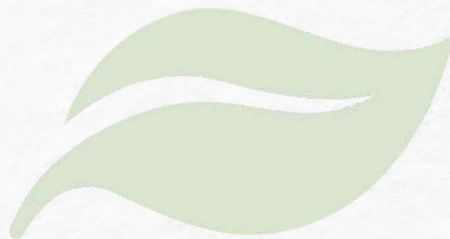
Durum wheat (*Triticum durum* Desf.) is critical for global food security, particularly in the Mediterranean. Climate change and population growth are intensifying agricultural challenges in this region, making drought-tolerant, high-yielding varieties essential.

Drought stress not only diminishes crop yields but also profoundly disrupts plant nutrient dynamics. Specifically, it impairs the ability of plants to absorb and assimilate essential nutrients, resulting in nutritional deficiencies and a substantial decline in crop quality, even in soils with adequate fertilization. This occurs due to reduced soil moisture, which limits nutrient diffusion and transport to the roots, and also affects nutrient distribution within the plant.

This research aimed to evaluate the efficacy of a novel biostimulant, formulated with glycine-betaine, vaterite, and *Pseudomonas protegens*, in preventing or curing the detrimental effects of water stress on durum wheat. Plants were grown hydroponically for 15 days, with water stress induced by 10% PEG in the nutrient solution for the final eight days. The biostimulant was applied foliarly either four days before (pre-treatment, for prevention) or four days after (post-treatment, for cure) the stress imposition, enabling a comparative analysis of its protective and restorative potential. The biostimulant's impact on plant physiology and stress response was assessed through a comprehensive analysis of biomass, chlorophyll, protein, root architecture, ionomics, stress markers (proline, MDA, antioxidant enzyme activity), and drought-related gene expression.

Drought significantly reduced growth of wheat seedlings, mainly by inducing oxidative stress. However, biostimulant application effectively mitigated these detrimental effects, resulting in increased shoot and root biomass and favoring root morphological adaptations. Notably, both pre- and post-stress biostimulant treatments significantly enhanced nutrient concentrations in shoots and roots of stressed plants. Specifically, biostimulant application restored the nutrient accumulation pattern in stressed tissues to levels comparable to unstressed control plants, regardless of application timing. These findings suggest that the biostimulant may improve nutrient use efficiency, reducing the need for fertilizers' use, thus contributing to more sustainable agricultural practices by reducing yield losses and minimizing the environmental impact of excessive fertilization. However, further research is needed to elucidate the specific mechanisms underlying these beneficial effects and evaluate the biostimulant's performance under field conditions, to fully assess its potential for sustainable agriculture in drought-prone regions.

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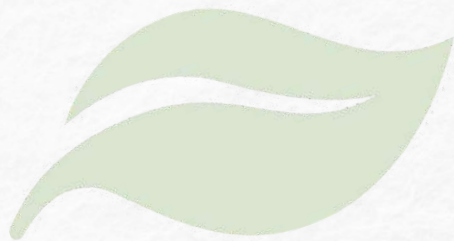
PO9_38 THE IMPACT OF NPK FERTILIZATION ON ENERGY CANE YIELD

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Efficient management of mineral nutrition is essential to maximize agricultural productivity while avoiding fertilizer waste and environmental impacts. This study was conducted in Piracicaba, São Paulo, Brazil. the objective of this study was evaluate the effect of NPK fertilization on stalk productivity in the Vertix 3 variety of energy cane cultivated for five months under full irrigation. The field experiment was conducted under full irrigation (100%), based on the soil water holding capacity (θ_{cc}). The methodology followed the Response Surface approach to assess the effects of independent variables on the response variable. The experimental design was a randomized block design with three replications, evaluating the effects of three doses of nitrogen (N), phosphorus (P), and potassium (K) in a $3 \times 3 \times 3 + 1$ factorial scheme on stalk productivity. The tested doses were 60, 180, and 300 kg ha⁻¹ of N, P₂O₅, and K₂O in the form of urea, triple superphosphate, and potassium chloride. An additional control treatment received no fertilization. Stalk productivity was evaluated in the fifth month of cultivation. With fixed N doses (60, 180, and 300 kg ha⁻¹) while varying P₂O₅ and K₂O doses, stalk productivity ranged from 40 to 110 tons ha⁻¹ for 60 and 300 kg ha⁻¹ of N and from 45 to 85 tons ha⁻¹ for 180 kg ha⁻¹ of N. With fixed P₂O₅ doses (60, 180, and 300 kg ha⁻¹) while varying N and K₂O doses, stalk productivity varied from approximately 30 to 90, 50 to 130, and 40 to 110 tons ha⁻¹, respectively. With fixed K₂O doses (60, 180, and 300 kg ha⁻¹) while varying N and P₂O₅ doses, stalk productivity varied from 40 to 100 tons ha⁻¹ when using 60 and 180 kg ha⁻¹ K₂O, and from 45 to 85 tons ha⁻¹ when using 300 kg ha⁻¹ K₂O. Conclusions: The findings indicate that the most efficient fertilization strategy in this study stage was 300 kg ha⁻¹ of N and 180 kg ha⁻¹ of P₂O₅ and K₂O, leading to the highest productivity increments. In contrast, 300 kg ha⁻¹ of P₂O₅ and K₂O may not be advantageous, potentially reducing energy cane stalk productivity. The balance between nutrients is more important than the indiscriminate increase in doses, as an excess of one nutrient can have limiting effects on the absorption and utilization of others.





PO9_39 ENERGY CANE YIELD AS AFFECTED BY NPK FERTILIZATION AND WATER AVAILABILITY

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Soil fertility and water availability are key factors influencing agricultural productivity. Therefore, understanding the interactions between different doses of nitrogen (N), phosphorus (P), and potassium (K) is essential for optimizing the production of energy cane. The objective of this study was to evaluate the effect of NPK fertilization on the stalk productivity of two energy cane varieties under full and deficit irrigation conditions in greenhouse. Four experiments were conducted: (1) Vertix 3 with 50% water replacement (water deficit), (2) Vertix 3 with full irrigation (100%), (3) Vertix 2 with 50% water replacement, and (4) Vertix 2 with full irrigation (100%). The experiments were carried out in 167 dm³ pots. After transplanting pre-sprouted seedlings, the plants were cultivated for 12 months. A randomized block design was used, with three replications, evaluating the effects of three doses of N, P, and K in a 3×3×3+1 factorial scheme on stalk productivity. The tested fertilization rates were 60, 180, and 300 kg ha⁻¹ of N, P₂O₅, and K₂O in the form of urea, triple superphosphate, and potassium chloride. An additional treatment was left unfertilized. There was an interaction for all effects (N×P, N×K, P×K, and N×P×K) in experiments 2, 3, and 4, and (N×K, P×K, and N×P×K) in experiment 1. In experiment 1, productivity increased from 71 t ha⁻¹ (unfertilized) to 122 t ha⁻¹ when fertilized with 180 kg ha⁻¹ of N and P₂O₅ combined with 300 kg ha⁻¹ of K₂O. In experiment 2, productivity increased from 136 t ha⁻¹ (unfertilized) to over 163 t ha⁻¹ with the application of 180 kg ha⁻¹ of N and P₂O₅ combined with 180 or 300 kg ha⁻¹ of K₂O. In experiment 3, productivity increased from 60 t ha⁻¹ (unfertilized) to 138 t ha⁻¹ when fertilized with 60, 180, and 300 kg ha⁻¹ of N, P₂O₅, and K₂O. In experiment 4, productivity increased from 48 t ha⁻¹ (unfertilized) to 200 t ha⁻¹ when fertilized with 180 kg ha⁻¹ of N and P₂O₅ combined with 300 kg ha⁻¹ of K₂O. The application of 180 kg ha⁻¹ of N, with higher doses of P₂O₅ and K₂O, resulted in the highest stalk productivity. The interaction between NPK rates is essential for optimizing fertilization and maximizing energy cane yield. Full irrigation increased productivity compared to water deficit conditions, highlighting the crop's sensitivity to stress. The optimal fertilization rates recommended for energy cane cultivation are higher than those recommended for conventional sugarcane.





PO9_40 INTERPLAY OF IRON AND NITROGEN FORMS IN GRAPEVINE: SPATIAL ELEMENTAL DISTRIBUTION IN FERCAL ROOTSTOCK

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Iron (Fe) deficiency is one of the major concerns in viticulture, especially in vineyards grown on calcareous-alkaline soils where tolerant grapevine rootstocks (e.g., Fercal and 41B) are commonly used, as they display a prompt activation of the Fe acquisition mechanism. Moreover, the Nitrogen (N) form applied can influence Fe bioavailability for plants uptake. This study aimed at evaluating the interplay between N- and Fe-nutritional pathways providing a spatial insight into nutrients' distribution in different grapevine tissues to reveal the effects of N-forms on modulating Fe acquisition and allocation. Rooted woody cuttings of Fercal rootstock were grown hydroponically with either nitrate or ammonium-nitrate applied in combination with 10, 50 or 100 μM of FeNa(III)-EDTA for two weeks. Then, in the further three weeks, half of the pots were kept in Fe deficiency (-Fe). Depending on the N-form applied and Fe levels, significant effects on the morphological and physiological responses of Fercal were observed. Under Fe deficiency, nitrate-fed plants display in general lower Fe concentration than nitrate-ammonium fed plants, in both roots and leaves. Additionally, other elements like K, Mg, Mn, P, Cu and S increased in the 10 μM /-Fe in nitrate-fed plants, whereas Zn levels increased across all treatments. To enhance our understanding in spatial elemental distribution among the treatments, Micro X-ray fluorescence analysis at PETRA III at DESY (P06 beamline) synchrotron was performed on root and leaf cross-sections. The imaging of leaf cross-sections revealed a differential distribution of Mn among tissues. Additional physiological analysis showed combination of both N-forms resulted in lower chlorophyll losses in young leaves under all Fe-deficient conditions, particularly in 100 μM /-Fe treatment, leading to reduced chlorosis symptoms. Moreover, Fercal showed a remarkable ability to enhance root biomass under 10 μM /-Fe and 50 μM /-Fe treatments when both N forms were present. This was accompanied by an increased activity of ferric chelate reductase, which can help in the remobilization of Fe precipitates occurring in the apoplast of epidermal cells, as indicated by a less fluorescent intensity in -Fe treatments. These findings provide valuable insights into the interplay of Fe and N in grapevine rootstocks, enhancing our understanding of elemental localization patterns and their potential role in Fe deficiency response.

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PO9_43 OPTIMIZING MAIZE GROWTH IN LOW-PHOSPHORUS ACIDIC SOILS: A STUDY OF RECYCLED FERTILIZERS AND BIOSTIMULANT INTERACTIONS

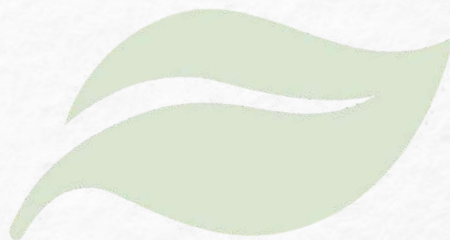
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Using recycled phosphorus (P) fertilizers and biostimulants in agriculture is an emerging issue. With global phosphate rock reserves projected to peak by 2030 and environmental concerns over mining and nutrient runoff escalating, the need for sustainable alternatives for P fertilization is requested. In a rhizobox experiment, we aimed to explore the effect of recycled fertilizers such as Struvite and sewage sludge ash (SSA) combined with biostimulants like Seaweed, humic substances, and chitosan on maize biomass, growth indicators, and soil P acquisition. This study investigated the combined effects of biostimulants and different phosphorus sources on acidic soils with high aluminum concentrations. The study aimed to assess of influence phosphorus acquisition, soil conditions, and plant growth indicators. A six-week factorial rhizobox experiment was conducted using a randomized block design with maize (*Zea mays* var. Ronaldinho). The study was conducted in a low P (Class A, VDLUFA) acidic soil (pH (CaCl₂): 5.9) with a moderately high aluminum concentration (19,000 mg/kg). Phosphorus was applied at four levels (Control, Soluble P, Struvite, and sewage sludge ash). Biostimulants (control, humic substances, seaweed, chitosan) were applied as powders on the planting date and twice in liquid form.

Applying humic substances led to a significant decrease in rhizosphere pH, whereas seaweed application resulted in the highest pH values. Regarding biomass, both soluble P and struvite significantly promoted growth. However, humic substances induced the most substantial biomass increase among the biostimulants. Soluble P and struvite enhanced P use efficiency (PUE) by approximately 100% compared to SSA; however, the overall efficiency remained low. Applying humic substances and chitosan also resulted in higher PUE than the control and seaweed treatments. Struvite enhanced P CAL by 42.8% compared to soluble P. This rhizobox experiment demonstrated the potential of recycled phosphorus fertilizers and biostimulants to increase maize growth and phosphorus acquisition in acidic, aluminum-rich soils. While all phosphorus sources improved biomass compared to the control, struvite and soluble phosphorus exhibited superior PUE and plant-available phosphorus (P CAL). Notably, humic substances emerged as highly effective biostimulants, significantly increasing biomass and improving PUE, likely through their influence on rhizosphere pH. Its ability to lower pH in these conditions may have increased phosphorus availability.





PO9_44 THE EFFECT OF MELATONIN ON PHOTOSYNTHETIC TRAITS OF CHILEAN COMMON BEAN LANDRACES GROWN UNDER DIFFERENT PHOSPHORUS CONDITIONS

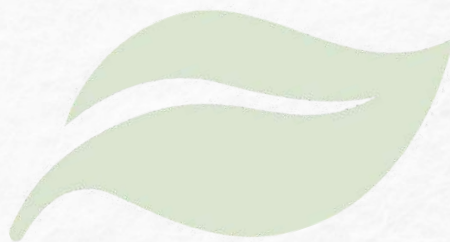
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Common bean (*Phaseolus vulgaris* L.) is one of the most important pulses for human consumption worldwide. Nevertheless, low soil phosphorus (P) availability is one of the main limiting factors for its production. Chilean common bean landraces have important cultural and economic significance for smallholder farmers and consumers, highlighting the need to increase their production. In recent years, melatonin, a well-known animal hormone, has emerged as an important player in plant biology, regulating various physiological, biochemical and molecular processes. In addition, melatonin also improves tolerance to several environmental stresses, including P deficiency. Therefore, the aim of this study was to evaluate the effect of melatonin application on photosynthetic features of two Chilean common bean landraces (Manteca and Juanita) grown under contrasting P conditions. For this purpose, a pot experiment was carried out with two P levels (Low P; 6 mg kg⁻¹ Olsen-P and Optimal P; 50 mg kg⁻¹ Olsen-P). Ten days after sowing (DAS), two doses of melatonin (0 and 150 µM) were irrigated for each P treatment. After 30 DAS, photosynthetic parameters such as CO₂ assimilation (A), stomatal conductance (g_s), transpiration rate (E) and leaf intercellular CO₂ concentration (C_i) were measured using a portable photosynthesis system (TARGAS-1). Compared to optimal P supply, both common bean landraces showed a significant reduction in A in response to P limitation, irrespective of melatonin treatment. In P-stressed plants, no significant changes in E and g_s were observed in either genotype after exogenous melatonin application. In contrast, under sufficient P supply, melatonin supplementation increased E and g_s parameters by about 19% and 30.5%, respectively, in Juanita. Interestingly, at P deficiency, C_i increased by 20.8% after melatonin application in Manteca, whereas no significant differences were found in Juanita. Under optimal P supply, melatonin reduced C_i in both genotypes. Taken together, our study has demonstrated differential photosynthetic traits of Chilean common bean landraces in response to melatonin and P status. These preliminary results may provide an opportunity to use melatonin as a novel tool to improve the performance of common bean grown in P-deficient soils.

Acknowledgments: FONDECYT Projects N° 11240769, 11240738, and 1241718, ANID, Chile.





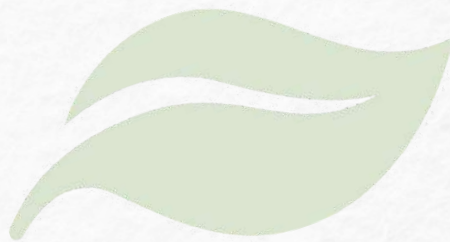
PO9_46 **ENHANCING PHOSPHORUS AVAILABILITY AND MODIFYING IRON DISTRIBUTION IN MAIZE USING NITRIFICATION INHIBITORS**

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Phosphorus (P) availability constraints crop productivity in over 40% of arable soils due to fixation with iron (Fe), aluminium (Al), and calcium (Ca), necessitating innovative strategies to enhance nutrient uptake and plant growth in low-P environments. This study aimed to determine whether nitrification inhibitors (Nis), specifically 3,4-dimethylpyrazole with fulvic acid (DMPFA) and DMPP, combined with plant growth-promoting microorganisms (PGPM), can improve P solubilization and enhance maize (*Zea mays* L.) growth in P-limited soil. It was hypothesized that Nis-driven rhizosphere changes and microbial synergy increase nutrient use efficiency. Two rhizobox experiments were conducted in a greenhouse using a silty loam soil (P CAL: 8.7 mg kg⁻¹, pH (CaCl₂) 6.4): the first assessed Nis effects on nutrient dynamics with treatments including ammonium, nitrate, and rock phosphate (RP) across ten treatments, while the second evaluated DMPFA-PGPM synergy with five treatments incorporating *Bacillus atrophaeus* ABi05. Measurements included rhizosphere pH, phosphatase activity, biomass, root length, nutrient content, and phytohormones. In the first experiment, Nis reduced rhizosphere pH by 0.5–0.8 units and increased acid phosphatase activity significantly. DMPFA + RP achieved a nitrogen recovery efficiency (NRE) of 63.38 g/g versus 24.44 g/g in nitrate without P. Nis shifted nutrients in shoot and root distribution, especially iron. Treatments using nitrification inhibitors result in 60% of the iron content accumulated in the shoots, compared to 38% with ammonium alone and 31% with nitrate. In the second experiment, DMPFA increased shoot biomass by 27.6% and total root length by 204.3% compared with control, while DMPFA + PGPM raised shoot P content by 20.2%. Nitrate treatments resulted in less micronutrient (Zn, Mn, Fe) transport to the shoot than Nis's. Phytohormone levels of zeatin and jasmonic acid increased by 79.1% and 53.6%, respectively, in DMPFA + PGPM treatments, and P use efficiency (PUE) increased by 7.0–7.59%. These findings indicate that Nis, in combination with humic substances and PGPM, optimize P availability and Fe translocation in maize by acidifying the rhizosphere and boosting microbial activity, offering a sustainable approach to improve crop productivity in low-P soils. This strategy reduces reliance on chemical fertilizers, enhances nutrient efficiency, and calls for field-scale trials to validate its agricultural potential.





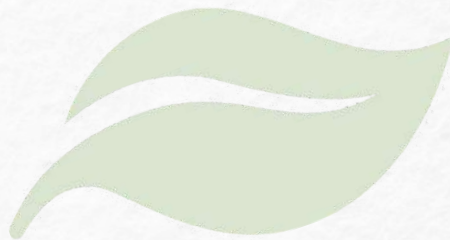
PO9_47 BORAX PROMOTES FERTILITY OF BRASSICA NAPUS BETTER THAN OTHER BORON SPECIES AT SUBOPTIMAL SUPPLY

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The incidence of boron (B)-deficiency in crop production has increased in recent years because of more commonly experienced drought conditions in soil leading to reduced plant B availability. Continuous and sufficient B supply is essential for achieving maximum seed yield in *Brassica napus*. Therefore, an optimal fertilization management that considers availability of the applied nutrient in water-limited as well as water-sufficient conditions is critical. Different B fertilizer formulations (B species) exist, which release B at different rates. The aim of this study was to evaluate the potential of different B species to sustain growth and fertility of *B. napus* plants during flowering in growth conditions below the B-sufficiency level, and in combination with water-limitation. Focus of the study is on the effects of different B species and B availability on the nutritional status of inflorescences, and the ability of plants to develop asymptomatic inflorescences. The effects of two highly soluble/fast-release (boric acid, borax) and three slow-release (colemanite, ulexite, zinc borate) B species on plant development and B nutritional status in the shoot head, flowers and remaining shoot were investigated before and during flowering on B-sufficient, moderate or severe B-deficient levels in well-watered or water-limited conditions in a soil-substrate. When supplied to the substrate at identical concentrations at sowing in a simulated spring drought and under water-sufficiency, plant performance under B-deficiency decreased in the following order: borax > boric acid > ulexite > colemanite or zinc borate. Under well-watered conditions, the application of borax led to more vigorous (e.g. larger shoot length) and fertile (e.g. higher number of asymptomatic flowers) plants with higher tissue B concentrations and whole shoot B content compared to the other B species even under severe B-deficient conditions. This beneficial effect of borax on plant performance was also observable in the water-limited treatment, albeit only on moderate B-deficient conditions. Independent of the B species, root length of plants correlated positively with shoot B content, and shoot head B concentration before flowering correlated positively with the number of asymptomatic flowers. In summary, floral development and fertility of *B. napus* plants depends on the available B levels in soil directly at the flowering stage, which is driven by the B availability of the supplied B species and the soil water status, with borax application being the most favorable compared to other B species. Further testing in field environments under various B and water availabilities is needed.





PO9_48 FOLIAR PHOSPHORUS UPTAKE IN FIELD-GROWN POTATO: INVESTIGATING THE EFFECTS OF SURFACE TENSION ON ORTHOPHOSPHATE AND NANOHYDROXYAPATITE UPTAKE

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Phosphorus (P) deficiency is a global challenge in high demanding crops like potatoes. Conventional soil fertilization strategies are often inefficient in potato, due to the poor root development and high P requirements. Foliar fertilization has the potential to improve P use efficiency as it bypasses the soil and root processes limiting P uptake. However, it remains a challenge that mineral orthophosphate ions (Pi) in classical foliar P fertilizers lead to leaf scorching when used in the required quantities. As an alternative, P nanofertilization has shown to be able to overcome these limitations. Here, we analyzed the factors controlling foliar uptake and translocation of P containing nanoparticles in field grown potato.

The uptake and translocation of P from both Pi and nanohydroxyapatite (nHAP) was studied under varying droplet surface tensions using radioactive ³³P, and by elemental analysis. It was found that leaf P concentrations were extremely dynamic and depended on leaf age. During tuber initiation, P concentrations declined from 8000 ppm in the youngest leaves to 2000 ppm in the oldest. Within just seven days, P levels dropped by 25–33% due to P translocation to tubers. By the tuber bulking stage, leaf P concentrations were below the critical threshold of 2200 ppm in all leaf positions.

Foliar P uptake efficiency was highly dependent on surface tension (γ) and P speciation. At $\gamma \leq 40 \text{ mN m}^{-1}$, Pi uptake reached 30–40%, with most P accumulating in tubers, whereas at $\gamma 50 \text{ mN m}^{-1}$, recovery dropped to 10%. In contrast, nHAP exhibited an opposite trend, with uptake below 20% at low γ , but reaching 50–60% at $\gamma 50 \text{ mN m}^{-1}$, with most P translocated to tubers. This highlights that foliar P uptake is influenced by γ and P speciation. The differences are likely related to the fact that droplets at low γ spread and cover a larger area, forming a thin film that also dries quickly, while droplets at moderate γ spreads less and retains moisture longer. This indicates that readily available Pi are absorbed relatively fast, whereas nHAP requires more time to diffuse in the water film continuum from the cuticle to the mesophyll before dissolving. At tuber bulking stage, when leaves become P-depleted, most foliar applied P is rapidly remobilized to tubers. The results obtained, show that nanofertilization is an efficient approach for P fertilization of potato provided proper optimization of foliar spray formulation.





PO9_49 TRANSFORMING PLASTIC WASTE INTO GREEN SOLUTIONS: ISOSORBIDE AS A POTENTIAL BIOSTIMULANT FOR ENHANCING GROWTH IN ARABIDOPSIS THALIANA

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Innovative solutions for sustainable agriculture have become crucial as global agriculture faces challenges to achieve its goal, i.e., increasing food production while decreasing its negative effects on the environment. In order to mitigate the adverse effects of conventional methods such as excessive fertilizer use, which contributes to soil degradation and environmental contamination, sustainable agricultural practices are essential. There is a strong demand for novel approaches that combine waste recycling with agricultural sustainability in the context of the growing concerns regarding the accumulation of plastic waste. The "plastics to fertilizers" concept is a promising approach that have recently reported (Abe et al., 2021, Green Chemistry). The concept underlying this innovative approach is to turn poly(isosorbide carbonate) (PIC), a bio-based polymer made from plastic waste, into urea, a well-known nitrogen fertilizer, and isosorbide, a compound with promising potential as a plant bio-stimulant, through ammonolysis. While urea's role in plant nutrition is well-reported, isosorbide's impact on plant growth and development remains largely unexplored. This study investigates the effects of exogenous isosorbide treatment on *Arabidopsis thaliana*, aiming to unveil its potential as a biostimulant. Plants were grown in normal media with varying concentrations (0 to 10 mM) of isosorbide. After 8 days of growth, the primary root lengths were measured from the taken picture using ImageJ, and after 15 days, shoot biomass was measured. Based on the optimum isosorbide dose determined from the enhancement of shoot biomass and primary root length, several parameters such as carbon and nitrogen content, carbon-to-nitrogen (C/N) ratio, nitrogen use efficiency (NUE), ionome, transcriptomes, and stress resilience were analysed. Our results demonstrate that isosorbide treatment significantly boosted plant growth with a significant increase in shoot biomass, an improved C/N ratio, and NUE. In addition, ionome analysis revealed alteration of essential and non-essential elements' distributions in shoots and roots, indicating isosorbide's influence on nutrient uptake and allocation. Besides that, it also shows growth enhancement under nitrogen deficiency and salt stress. Further transcriptomic analysis identified 447 differentially expressed genes (DEGs) in the shoots and 327 in the roots, with pathways related to stress adaptation, metabolism, and hormonal regulation being significantly impacted. Together our results provide novel insights into isosorbide's potential as a biostimulant, highlighting its robust effect in enhancing plant growth and stress resilience while offering an innovative link between polymer recycling and sustainable agriculture.





PO9_50 **RESPONS-OMICS OF TOMATO PLANTS: INTERPLAY BETWEEN N FORM (UREA, AMMONIUM OR NITRATE) AND FE SUPPLY**

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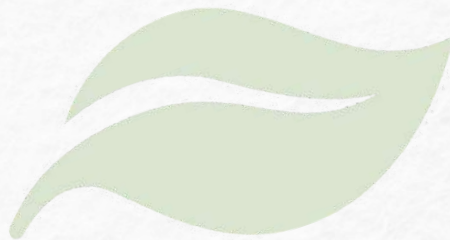
In soils, the bioavailability of nitrogen (N) and iron (Fe) is often insufficient to meet plant demand, making these nutrients two of the main constraints for crop production. Despite their importance, there is a significant knowledge gap regarding how different forms of N influence Fe nutritional pathways in plants. This study addressed this gap by examining the reciprocal relationship between Fe availability and N forms— as nitrate (Nit), ammonium (A), or urea (U)— using a multi-omic approach (metabolomic, “exudomic”, transcriptomic, ionomic analyses^{1,2}). The research revealed that resupplying Fe along with different N-forms to Fe-deficient plants triggered distinct transcriptional responses. After just four hours, RNA sequencing showed significant changes in gene expression in roots: 967 genes were modulated when Nit was used, 1891 by U, and 1315 by A compared to control (-Fe-N). By 24 hours, metabolomics analyses highlighted treatment-dependent modulations of root metabolism. The form of N significantly influenced phytohormone profiles and N-containing metabolites. Notably, the simultaneous application of Fe with N led to the accumulation of secondary metabolites like phenylpropanoids and primarily when urea was used. The concentration of Fe in roots varied based on the applied N form: Nit resulted in higher levels than U or A. Nitrate-treated plants showed improved root Fe concentrations and displayed the highest expression level of the *SLIRT1* gene responsible for Fe uptake. The supply of urea along with Fe maintained up-regulated genes of Strategy-I, such as *SIFRO1*, *SIFER*, *SLOPT3*, *SINRAMP1*, whereas nitrate and ammonium reduced their expression after 24 hours². Data integration revealed a positive correlation between early transcriptional responses at 4 hours and later metabolic adjustments at 24 hours. Key genes involved in both Fe deficiency response and N acquisition pathways suggested synergistic effects that enhance nutrient availability. Further analyses indicated that tomato plants adjust their response to Fe deficiency based on specific organs and N forms used. These findings contribute significantly to understanding how N influences Fe nutritional pathways by highlighting metabolic reprogramming dependent on the type of N form applied. Overall, this study bridges existing knowledge gaps about interactions between N and Fe nutritional pathways by demonstrating complex interplay between these essential nutrients for plant growth under varying conditions.

¹<https://doi.org/10.1016/j.plaphy.2024.108666>

²<https://doi.org/10.3389/fpls.2024.1408141>

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PO9_51 THE SYNTHETIC PHYTOSIDEROPHORE ANALOG, PDMA, FACILITATES MORE EFFICIENT UPTAKE OF FE IN COMPARISON TO CONVENTIONAL CHELATORS IN VARIOUS PLANT SPECIES

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Poaceae plants secrete phytosiderophores termed “mugineic acid family phytosiderophores (MAS)” from their roots into the rhizosphere for the uptake of iron (Fe) as a complex via YSI/YSL transporters. Poaceae plants with elevated MA secretion exhibit greater tolerance to Fe deficiency. Recently, synthetic proline-2'-deoxymugineic acid (PDMA) has been developed by replacing the four-membered ring of 2'-deoxymugineic acid (DMA) with a five-membered ring¹⁾. The characteristic properties of PDMA, such as its role in metal transport and its constant stability to metals, are very similar to those of natural MAS^{1), 2), 3)}. Fe(III)-PDMA complexes are absorbed by Poaceae via the YSI/YSL transporter from their roots^{1), 2)}, while non-Poaceae plants absorb Fe²⁺ via the IRT after reduction of Fe(III)-PDMA⁴⁾. Additionally, it has been proposed that non-Poaceae plants may absorb Fe-PDMA directly using their YSL transporters⁵⁾.

In this study, we examined the impact of PDMA on Fe deficiency recovery compared with other conventional chelates using a range of plant species. In maize, the soil application of 10 μ M Fe-PDMA as soil solution significantly enhanced the recovery of Fe deficiency in SPAD values when compared to the use of 90 μ M Fe-EDTA in calcareous soil. Furthermore, hydroponic experiments revealed that the use of chelated Fe with higher stability constants was less effective in supplying iron. In radish, a non-Poaceae plant, the soil application of 3 μ M Fe-PDMA exhibited greater efficacy in ameliorating Fe deficiency compared to Fe-EDDHA in calcareous soil.

These findings suggest that PDMA enhances the absorption efficiency of iron nutrition in both Poaceae and non-Poaceae plants.

¹⁾ Suzuki et al. (2021) Nat. Commun., 12, 1558

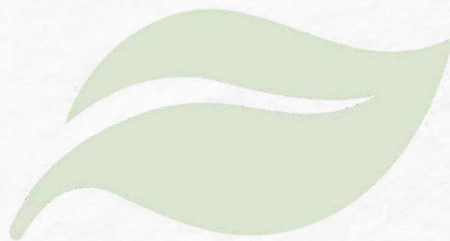
²⁾ Yamagata et al. (2022) Nat. Commun., 13, 7182

³⁾ Evers et al. (2024) Biometals, 37, 1599-1607

⁴⁾ Ueno et al. (2021) Plant Soil, 46, 239-250

⁵⁾ Wang et al. (2023) Plant Cell, Environ., 46, 239-250





PO9_52 ASSESSMENT OF NITROGEN UTILIZATION RATES OF COMBINED RETURN OF ¹⁵N LABELED MAIZE STRAW AND ITS RELATION TO MICROORGANISMS UNDER AN INTERCROPPING SYSTEM

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Intercropping leguminous and gramineous crops represents a sustainable strategy to optimize nutrient cycling and enhance soil fertility in agricultural production. While most studies on straw returning to field focus on monoculture systems, research on mixed decomposition has predominantly been conducted in forest ecosystems, leaving its potential in diverse farmland systems largely unexplored. This study investigated nitrogen utilization rates of maize straw by subsequent crops through ¹⁵N-labeled maize straw incorporated into soil and integrated high-throughput sequencing to identify key driving microorganisms. Four kinds straw incorporated into soil treatments were designed: maize straw alone (M), 1:1 mixture of soybean and maize straw (MS), soybean straw alone (S), and without straw (CN). Following combined straw returning, the average utilization rate of maize straw ¹⁵N by maize and soybean increased by 9.40% and 51.14%, respectively, compared with maize straw returning to field alone. Under the M and MS treatments, the utilization rate of maize straw ¹⁵N by maize increased by 51.23% and 38.74%, respectively, under intercropping compared with monocropping. Intercropping significantly enhanced soil microbial diversity, network complexity, and straw degradation potential compared with monocropping. Soil key bacterial genera such as *Sphingomonas* was enriched, which accelerated straw decomposition in soil, thereby boosting nitrogen utilization efficiency of maize straw in MS treatment. Functional prediction analyses revealed that microbial activities associated with cellulose degradation, aromatic compound metabolism, and nutrient cycling were enhanced. The findings of this study offer new ideas into enhancing the nutrient utilization efficiency of maize straw through mixing decomposition effects in diversity cropping system.





PO9_53 INCREASED TOLERANCE IN LAGENARIA SICERARIA BY USING BACTERIA ISOLATED FROM COASTAL ENVIRONMENTS IN CHILE: SEARCHING FOR THE IMPROVEMENT OF ROOTSTOCKS FOR CUCURBITS PRODUCTION UNDER DROUGHT

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The increasing frequency of drought events poses a significant challenge to global agricultural productivity, particularly for high-demand crops such as cucurbits. Utilizing drought-tolerant rootstocks, such as *Lagenaria siceraria*, in grafting systems has demonstrated promise for enhancing crop resilience under water-limited conditions. Additionally, plant growth-promoting microorganisms (PGPMs) offer a complementary strategy to improve drought tolerance by supporting physiological and biochemical plant processes.

This study evaluated the effects of four PGPMs—*Bacillus* sp. (BS), *Streptomyces kanamyceticus* (SK), *Streptomyces endophyticus* (SE), and *Staphylococcus succinus* (SS)—on two Chilean drought-tolerant genotypes of *L. siceraria* (V23-Osorno and V25-Illapel) under well-watered (WW: 100–90% WHC) and drought-stressed (WD: 50–40% WHC) conditions in a controlled greenhouse setting. The selected microorganisms were isolated from drought-prone coastal regions and demonstrated growth-promoting traits, including auxin production, siderophore activity, phosphate solubilization, and nitrogen fixation.

Results showed that PGPM application significantly improved plant performance under drought stress in both genotypes, with strain-specific effects. In the Illapel genotype, *Bacillus* sp. (BS) showed the best performance, while *Staphylococcus succinus* (SS) was most effective in the Osorno genotype. Despite these differences, both genotypes exhibited significant enhancements in photosynthetic parameters, including net photosynthesis, stomatal conductance, and internal CO₂ concentration, following inoculation. Additionally, inoculated plants under drought conditions reached shoot biomass levels comparable to those of non-inoculated, well-watered plants and showed increased total chlorophyll content. PGPMs also improved the soluble solids-to-starch ratio, highlighting their role in enhancing sugar reserves under water stress.

Proline accumulation was consistently higher across both genotypes with PGPM application, underscoring its role in osmotic adjustment, while BS uniquely reduced malondialdehyde (MDA) levels, indicating decreased lipid peroxidation. Furthermore, BS and SS inoculation resulted in reduced phenolic content and antioxidant activity (TEAC) under drought stress, reflecting a metabolic shift favoring growth and stress tolerance. These findings confirm that PGPMs not only mitigate drought-induced damage but also sustain physiological performance in *L. siceraria*, with BS and SS showing the most notable effects depending on the genotype.

In conclusion, PGPMs offer a sustainable approach to enhance drought tolerance in *L. siceraria*, supporting its role as a resilient rootstock for cucurbit production under climate change scenarios. Future research should focus on optimizing rootstock-microorganism combinations to further improve drought resilience and promote sustainable agricultural practices in water-scarce regions. The authors thank the Regional Government of O'Higgins for funding this study through the FCIDER11927 project. Partial support was provided by ANID/FONDECYT/1230587 (Ruiz Antonieta).



PO9_54 ARBUSCULAR MYCORRHIZAL FUNGI ENHANCE NUTRIENT ABSORPTION AND ANTIOXIDANT DEFENSE TO IMPROVE SALT STRESS TOLERANCE IN TOMATO PLANTS

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Arbuscular mycorrhizal fungi (AMF) are ubiquitous soil microorganisms that form symbiotic associations with plant roots, including approximately 90% of agriculturally important plants. This symbiosis plays a crucial role in promoting plant growth under stress conditions by enhancing water and nutrient uptake, leading to greater photosynthetic efficiency, maintenance of nutrient balance, and positive regulation of antioxidant systems. In this study, we evaluated the functional contribution of two AMF strains, *Diversispora celata* and *Funneliformis mosseae*, isolated from the Atacama Desert, in improving salt stress tolerance through the enhancement of nutrient absorption and the modulation of antioxidant defense mechanisms in tomato plants (*Solanum lycopersicum* cv. Limachino and Maulino). After 50 days of growth, various parameters were assessed in tomato plants subjected to salinity stress (150 mM NaCl), including mycorrhizal colonization, biomass production, nitrogen and phosphorus content, oxidative damage, proline content, photosynthetic parameters, and the activity and antioxidant capacities of phenolic compounds. The results indicate that mycorrhizal colonization by *D. celata* and *F. mosseae* varies depending on the cultivar and salinity conditions, influencing biomass production and nutrient content. Colonization in the Limachino cultivar was more sensitive to salinity, showing a marked reduction under saline conditions, whereas the Maulino cultivar exhibited higher and more stable colonization by *D. celata* and a smaller decrease with *F. mosseae*. Consequently, salinity reduced both foliar and root biomass in both cultivars, with a stronger effect on non-inoculated Limachino plants. However, inoculation with *D. celata* improved aerial and root biomass in Limachino, while in Maulino, it had no significant impact. Salt stress also reduced nitrogen content in both cultivars. However, *D. celata*-inoculated Limachino plants exhibited higher nitrogen levels than their non-inoculated counterparts, whereas no significant differences were observed in Maulino. Similarly, phosphorus content decreased across all treatments, with no variations between inoculated and non-inoculated plants. The observed improvements in biomass and nutrient content were associated with reduced oxidative damage, increased proline synthesis, greater photosynthetic efficiency, and enhanced production and antioxidant activity of phenolic compounds, which play a crucial role in neutralizing reactive oxygen species. The modulation of salt stress tolerance in tomatoes through AMF colonization is achieved by improving nitrogen content and adjusting antioxidant systems, ultimately reducing oxidative damage and promoting plant growth. These findings suggest that AMF application, through targeted inoculation with efficient fungal strains, can enhance crop resilience and improve agricultural yields, particularly in saline environments.

The work in the current research line was funded by ANID/FONDECYT/11240859; ANID/FONDAP/1523A0001.



PO9_55 **DESIGNING THE NEXT GENERATION OF BIOINOCULANTS: TRIPARTITE PLANT GROWTH PROMOTING CONSORTIA OF BACTERIA, YEAST, AND ARBUSCULAR MYCORRHIZAL FUNGI TO ENHANCE DROUGHT STRESS TOLERANCE IN LETTUCE (*LACTUCA SATIVA* L) PLANTS.**

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Drought is a critical factor that negatively impacts food production and poses one of the greatest challenges to global food security, particularly with the continuous growth of the human population. One of the most promising strategies to enhance plant tolerance to drought stress is the use of beneficial rhizosphere microorganisms. However, within the rhizosphere, microbial communities establish diverse interactions, both among themselves and with host plants, which can either enhance or hinder drought tolerance. Given this complexity, leveraging microorganisms that occupy distinct ecological niches to collectively improve plant resilience to drought may provide the foundation for developing the “Next Generation of Bioinoculants.”

This study aimed to formulate a bioinoculant composed of plant growth-promoting bacteria, yeast, and arbuscular mycorrhizal fungi for the cultivation of *Lactuca sativa*. A total of 27 different microbial consortia were inoculated into lettuce plants subjected to drought stress for 40 days. Based on superior biomass production, four consortia were selected for further evaluation in agricultural soil under drought conditions. Various physiological and biochemical parameters were assessed, including biomass production, proline and malondialdehyde (MDA) content, photosynthetic activity, antioxidant enzyme responses, phenolic compound profiles, and nitrogen (N), phosphorus (P), and potassium (K) uptake.

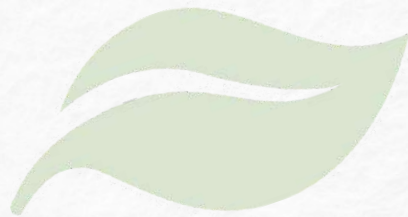
The results demonstrated that the consortium composed of *Claroideoglomus lamellosum* (Cl), *Naganishia albida* (Na), and *Burkholderia caledonica* (Bc) enhanced biomass production by 43% under drought stress. This improvement was primarily attributed to increased proline accumulation, higher levels of photosynthetic pigments, and enhanced activity of the antioxidant enzymes catalase (CAT) and ascorbate peroxidase (APX), leading to reduced oxidative damage. Additionally, lettuce plants inoculated with the Cl-Na-Bc consortium exhibited significantly improved nutrient uptake under drought conditions, with phosphorus and nitrogen absorption increasing by 129% and 66%, respectively, compared to non-inoculated plants.

These findings highlight the potential of species-specific microbial consortia as effective tools for enhancing drought tolerance in crops, contributing to more sustainable agricultural practices in water-limited environments.

ACKNOWLEDGMENTS:

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PO9_56 EFFECTIVENESS OF BIOLOGICAL TESTS IN PREDICTING CORN NITROGEN RESPONSIVENESS: PRELIMINARY FINDINGS FROM BRAZIL

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The recommendation of nitrogen (N) fertilization in most crops has historically been challenging due to the low predictability of soil N availability during the crop season. Some biological tests (CO₂ burst; Franzluebbers, 2018; and potentially mineralizable N; McDaniel et al., 2020) have recently been proposed in the US to better predict corn N response. Additionally, we hypothesized that certain soil enzymes, already used as indicators of soil health and nutrient cycling, could also serve as potential predictors. Our aim was to evaluate biological and chemical tests as predictors of corn responsiveness to N under tropical conditions. Nitrogen response trials included 24 site-years across three states in Brazil. All trials were conducted with corn as a double crop, with most following soybean. Nitrogen rates ranged from 0 to 220 kg N ha⁻¹, applied in six increments. Four composite soil samples (ten cores each) were collected from a depth of 0-10 cm just prior to planting. The soils were analyzed for 16 chemical and biological tests. When the grain yield data showed at least one significant regression model, the site was considered responsive to N. Subsequently, the biological and chemical soil tests were compared between the two responsiveness classes using analysis of covariance and Student's t-test, with the clay content as the covariate. Corn responded to N in 42% of the sites. Among the biological attributes, four were effective in distinguishing responsive soils from non-responsive ones: mineralizable N after 14 days of aerobic incubation, β -glucosidase, arylsulfatase, and mean specific enzymatic activity ($((\beta\text{-glucosidase/SOC}) + (\text{arylsulfatase/SOC})) / 2$). The following biological tests were not effective: CO₂ burst, microbial biomass carbon, and N-acetylglucosaminidase. Interestingly, for total N, mineral N (ammonium + nitrate), and SOC, the responsive and non-responsive sites showed no significant differences. The soil nitrate-N test and SOC are widely adopted in N recommendation guides in the US and Brazil, respectively. This result is noteworthy because it demonstrates the inaccuracy of these commonly used tests, at least when used alone, as predictors of corn responsiveness to N. The chemical attributes Ca, K, P, and base saturation were also effective in differentiating responsive soils from non-responsive ones, probably reflecting an impact on the microbiota. We conclude that biological tests, especially enzymatic ones, are promising as predictors of N responsiveness of corn under tropical conditions, particularly when soil clay content is considered.





PO9_59 **DEVELOPMENT OF SLOW-RELEASE MOLYBDENUM FERTILIZERS USING SPARINGLY- SOLUBLE POWELLITE**

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Molybdenum (Mo) is an essential plant micronutrient, required only in small amounts. Nonetheless, Mo deficiencies in crop production are not uncommon, and to avoid yield loss, fertilizers enriched with soluble Mo compounds are often supplied. However, the application of soluble Mo compounds is linked to low Mo use efficiencies due to fast Mo fixation in acid-weathered soils and leaching in sandy soils.

This study explored the use of sparingly-soluble powellite (CaMoO_4) in Mo-enriched granular macronutrient fertilizers to achieve a slow Mo release and supply available Mo throughout a crop's growth period, thereby hypothesizing that the macronutrient carrier choice could be used to engineer the release pattern of powellite-derived Mo.

Powellite was prepared via a simple precipitation reaction. Macronutrient carriers, i.e. murate of potash, rock phosphate, and triple superphosphate, were co-compacted to pellets with either powellite or conventional soluble ammonium molybdate (amMo), and the Mo release properties of the different prepared granular fertilizers was assessed in a column dissolution experiment. In a pot trial, these various Mo fertilizers were applied to a sand growth substrate at $100 \mu\text{g-Mo kg}^{-1}$. First, the Mo leaching risk from these fertilizers was assessed with a simulated leaching treatment, and leachates were analyzed to determine cumulative Mo leaching losses. Subsequently, the Mo availability in these pots, as well as in replicated pots without a leaching treatment, was determined with the growth of chickpea (*Cicer arietinum*) for 80 days.

The column dissolution experiments showed that powellite-based fertilizers consistently released Mo more slowly than corresponding amMo -based fertilizers, with the slow release notably more pronounced for powellite embedded in carriers with high content and solubility of Ca. The pot trial demonstrated that powellite-based fertilizers can minimize Mo leaching in well-drained conditions in comparison with amMo -based fertilizers, with up to 23% fertilizer Mo lost with amMo -based fertilizers and no detectable Mo in leachates for powellite-based fertilizers. Interestingly, for the Mo uptake by chickpea, most powellite formulations still act as an adequate Mo source for crops.

These results demonstrate how a desired Mo release can be obtained by selecting a suitable powellite macronutrient carrier, highlighting the potential of powellite-based Mo fertilizers for more efficient Mo use in crop production.





PO9_60 A SPECIFIC EVALUATION OF FRASS IN THE REDUCTION OF MINERAL FERTILISERS IN PLANT NUTRITION

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Frass, often the largest by-product of insect farming — whether for food production or other industrial applications — has significant potential as a fertilizer and can contribute to more sustainable agriculture. Its valorization is essential, particularly through its integration with synthetic fertilizers, as it contributes to agricultural productivity while enhancing soil fertility and resilience. However, several factors influence frass effectiveness, including the insect species, the composition of the insect feed substrate, soil properties, climate conditions, and the specific crop it is applied to. These variables highlight the need for tailored application strategies. To evaluate whether frass from different insect species can reduce the need for synthetic fertilizers without compromising crop yield, we conducted a pot experiment using *Lolium multiflorum* L. grown in Haplic Fluvisol soil. Frass from *Hermetia illucens* (fed on either olive pomace or cereal), *Acheta domesticus* (feed source 50:50 chicken feed and vegetable mix), and *Tenebrio molitor* (fed on the wheat semolina) were applied in mixed fertilization at 20% and 40% proportions of frass. The results showed that mixed fertilization with frass, regardless of the proportion used, did not significantly affect plant fresh or dry matter production compared to mineral-only fertilization. Given the high mineral content of the clay soil used in the experiment, this outcome was expected, which naturally reduces the impact of organic fertilization. To assess the impact of frass in soils, we also measured soil enzymatic activities, which are important indicators of nutrient cycling and microbial activity. Results indicated that soil enzyme activity was similar or higher when applying frass in soils. Moreover, forage quality remained unchanged across all treatments, with no significant differences between mixed fertilization and mineral-only fertilization. These findings suggest that, under similar conditions, the tested frass formulations can partially replace synthetic fertilizers without compromising crop yield, forage quality, or soil health.

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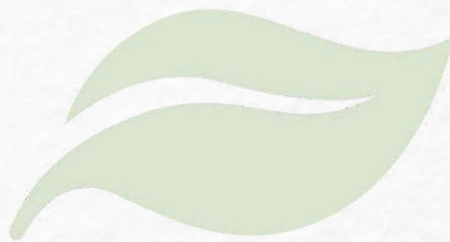


PO9_61 IMPACT OF LIVESTOCK BYPRODUCTS ON TOMATO YIELD AND QUALITY: ORGANIC VS. MINERAL FERTILISATION

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Livestock production generates substantial byproducts rich in plant nutrients, offering viable alternatives to mineral fertilisers and promoting circular agriculture by closing nutrient cycles. Reusing these byproducts can alleviate pressure on natural resources and reduce disposal costs. Tomatoes – a widely cultivated and important antioxidant source – are vital for food processing, agriculture, biotechnology, and pharmaceuticals and serve as key cash crops for smallholders and medium-scale commercial farmers. This study evaluated the effects of nutritional supplementation (additional 30 kg N ha⁻¹) using pig slurry (PS) and composted poultry manure (CPM) compared to sole mineral fertilisation on tomato crops. An experimental field trial was established in triplicate, with three treatments: (i) mineral fertilisation (control, CTRL), (ii) PS supplementation, and (iii) CPM supplementation. Fruits from each treatment were assessed for yield (tonnes/ha), biometric parameters (size and mass), CIELab colour, ripeness (SSC and AT), and bioactive composition [total phenolic compounds (TPC) and antioxidant activity (AOx) through DPPH and FRAP methods]. Results indicated that PS (ca. 119 tonnes/ha) reduced yield by ca. 17% compared to CTRL and CPM treatments (ca. 144 tonnes/ha), likely due to its high salt content, namely Na. In fact, significantly lower dry plant matter in the PS treatment suggested reduced water absorption, potentially caused by osmotic stress, which could have impacted productivity. No significant differences were observed in fruit quality parameters across the fertilisation methods; average fruit dimensions (ca. 50.9×39.7 mm; ca. 62.1 g) and CIELab colour parameters (L*=34.3, a*=20.3, b*=26.4), indicative of uniform red colouration, remained consistent. SSC (ca. 4.2°Brix) and TA (ca. 0.6%CA) confirmed appropriate ripeness levels for harvesting. The bioactive composition also remained unaffected by the fertilisation type (TPC ≈ 46.8 mg GAE/100g fw; AOx (DPPH) ≈ 2664.1 μmol TE/100g fw; AOx (FRAP) ≈ 4.0 mmol FeSO₄·7H₂O/100 g fw). Although PS supplementation may slightly reduce tomato yield, CPM is an effective alternative to mineral fertilisers that maintain fruit quality. These findings support the integration of livestock byproducts into crop fertilisation strategies to enhance agricultural sustainability.



PO9_62 **COULD MYCORRHIZAL FUNGI IMPROVE COTTON NUTRITION, YIELD, AND FIBER QUALITY UNDER ROTATION SYSTEMS?**

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¹ - São Paulo Western University (UNOESTE)

Mycorrhizal fungi (MF) can improve crop root growth, which may enhance nutrient uptake and yield. However, their effect on cotton remains poorly understood, particularly in long-term no-till systems where cotton follows cover crops. This study aimed to evaluate the effects of the mycorrhizal fungus *Rhizophagus irregularis* on cotton nutrition, yield, and fiber quality in sandy soil. The experiment was conducted in Presidente Bernardes, SP, Brazil, during the 2022/23 and 2023/24 seasons. A randomized complete block design was used in a split-plot arrangement with five replications. The main plots consisted of different cover crop treatments before cotton: (1) Fallow, (2) Single grass (SG), (3) Grass + Grass (G+G), (4) Grass + Legume (G+L), and (5) a mixture of cover crops (MIX) containing two grasses and a legume. In the subplots, *Rhizophagus irregularis* (200 g ha⁻¹) was either applied or not in the planting furrow. Rainfall totaled 1001 mm in the first season and 488.6 mm in the second. Leaf nutrient contents, yield components, and fiber quality were subjected to analysis of variance, and means were compared using Tukey's test ($p < 0.05$). The contents of N, B, Cu, and Fe in cotton leaves were not affected by crop rotations or MF inoculation. Phosphorus uptake was higher in the G+G (+6%) and MIX (+6%) treatments in the absence of MF during the 2022/23 season. The absence of MF also increased Mg leaf content in the fallow treatment (+18%) in 2022/23. K, Ca, S, and Zn leaf contents were affected only in the 2023/24 season. Leaf K content was higher in the fallow treatment compared to G+G (-24%) and G+L (-27%). MF inoculation increased Ca (+8%) and S (+4%) leaf levels but reduced Zn (-15%) leaf content. Cotton Mn leaf content was influenced only by crop rotation, being higher when cotton was grown after single grass (+26%) in 2022/23 and in the fallow treatment (+45%) in 2023/24. Fiber yield was not significantly affected by crop rotation or MF inoculation, although boll weight increased in G+L (+26%) without MF in 2022/23, and gin turnout increased in the MIX treatment (+5%) in 2023/24. Fiber quality parameters (micronaire, length, strength, uniformity, elongation, and short fiber index) were not significantly affected by crop rotation or MF inoculation. *Rhizophagus irregularis* increased Ca and S leaf contents while reducing Zn levels but did not significantly impact fiber yield or fiber quality traits.





PO9_63 PLANT GROWTH PROMOTION AND BIOFERTILIZER EFFECTS OF PSEUDOMONAS FLUORESCENS SECRETIONS IN ALKALINE IRON-DEFICIENT SOILS

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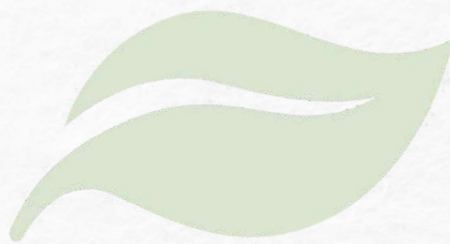
Biofertilizers have become decisive in addressing nutrient deficiencies in crops while reducing dependence on chemical fertilizers, which can compromise soil health and water quality. A promising alternative for overcoming iron deficiency in crops involves the application of biodegradable iron chelates, such as those based on naturally-produced siderophores. These small organic molecules, produced by bacteria, have a strong affinity for iron and are secreted into the environment to acquire this essential element for bacterial growth. In addition to siderophores, Plant Growth Promoting Rhizobacteria (PGPR) secrete biostimulant metabolites that can improve plant growth, enhance crop yield, and alleviate biotic and abiotic stress.

Microbial secretions of PGPR from *Pseudomonas* group, which contain pyoverdine – a yellow-green fluorescent siderophore synthesized under iron-limited conditions – along with other biostimulant metabolites, hold significant potential for addressing iron deficiency and promoting plant growth. This study assessed the biofertilizer and plant growth promotion effects of the *Pseudomonas fluorescens* RMC4 strain secretions applied to an iron-deficient and alkaline soil to grow lettuce plants (*Lactuca sativa*).

Various biochemical analyses were conducted on the plants, including evaluations of Nitrogen Balance Index (NBI), chlorophyll surface content, and epidermal flavonol and anthocyanin indexes using a Dualex leaf clip optical sensor. Reactive Oxygen Species (ROS) were quantified through 2',7'-dichlorofluorescein diacetate staining, amino acid contents were measured by derivatization and HPLC coupled with a fluorescence detector, and photosynthetic pigments were determined via colorimetry. Elemental analyses were also carried out using ICP-OES and AAS after soluble and available soil extracts and mineralization of the plant. A comprehensive soil characterization was performed after plant growth. Soil enzyme activity of β -glucosidase, urease, phosphatase, and arylsulphatase was determined following the ISO 20130:2018 standard, in addition to dehydrogenase activity.

Although no statistically significant differences were found in the soil characterization, except for an increase in soluble Na and Fe, positive effects have been observed on certain plant parameters such as nitrogen utilization efficiency and increased P content in leaves. However, a decrease was observed in the content of antioxidant compounds, such as flavonols, α -chlorophyll and β -chlorophyll, in the leaves. In conclusion, while photosynthetic capacity of the plants was negatively affected, *Pseudomonas fluorescens* RMC4 secretions contributed to Fe solubilization in the soil and may have facilitated P mobilization, leading to higher content in leaves. These findings provide valuable insights into the effects of bacterial secretions on both soil health and crop performance.





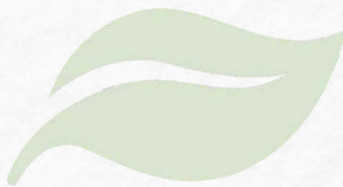
PO9_64 **READING MAIZE LEAVES: REVISITING CRITICAL NUTRIENT CONCENTRATIONS IN CANOPIES OF MODERN HYBRIDS**

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¹ - Purdue University

Nutrient sufficiency recommendations for leaf tissue samples in maize have not received scientific attention for decades. North American recommendations for critical nutrient concentrations are still based on whole-plant samples through the V6 stage and on ear-leaf sampling at the R1 stage. Modern hybrids have different leaf canopy structures and much higher yield potential than commercial hybrids of earlier eras. Modern hybrids are also grown at much higher plant density, and are capable of achieving higher leaf area index and prolonged stay green, especially during grain fill. Because of the joint interest in achieving high yields and better nutrient application efficiencies, individual leaves from various canopy positions were sampled in 4 modern maize hybrids grown at contrasting N rates and up to 5 plant densities. Leaf sampling occurred at V8, V12 and R1 growth stages. Leaf nutrient concentrations of N, P, K and S were compared to whole-plant nutrient concentrations at the same development stage, and to actual grain yields achieved in response to N rate. Leaf N concentrations at the ear-leaf position were higher at plant densities of 5 plants m⁻² than at densities of 8 plants m⁻² or 11 plants m⁻². The results confirmed that the best position to sample fully-expanded leaves for determination of whole-plant N and P status was generally below the ear leaf. When sampling occurred at R1, final grain yields were most highly correlated with leaf N concentrations from leaf 11 or 12 (i.e. 2-3 leaves below the ear leaf). Grain yields were also most highly correlated with P concentrations in leaf #8, and with S concentrations in the top leaf. Although much more research remains to be completed, these preliminary results confirm that the location of the leaf samples matters a great deal when sampling at growth stages between V6 and R1. Even at the R1 stage, leaf positions other than the ear leaf can be superior for characterizing nutrient sufficiency and evaluating whether nutrient deficiencies will limit the opportunity to achieve optimum yields. Future recommendations on critical nutrient concentrations in maize leaves should be based on calibrated studies conducted with multiple development stages at alternate leaf positions using modern hybrids and production practices.





PO9_65 **FROM SOILS TO FERTILIZERS: HARNESSING CLAYS FOR PRECISION NUTRIENT DELIVERY**

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Recycling phosphorus (P) addresses two critical challenges: environmental eutrophication and the limited availability of P for agriculture in tropical regions. Highly P-fixing soils demand suitable fertilizers, yet financial and logistical constraints make it difficult for smallholder farmers to access conventional P sources. Wastewater, a major contributor to environmental disruption, presents an opportunity for local P recovery. Transforming heavily weathered soil clay minerals into effective P carriers could offer a sustainable solution.

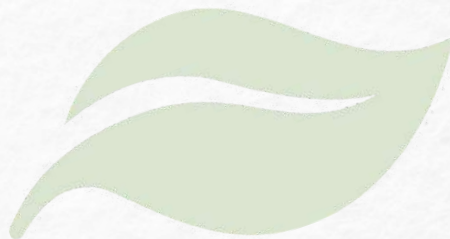
This study explores the development of a novel mineral-based P carrier for P recycling. In highly weathered tropical soils, naturally occurring minerals can serve as precursors for layered double hydroxides (LDHs)—nanostructured materials with both high P uptake and slow-release properties. Through a three-day hydrothermal reaction at 165°C, a MgAl₄-type LDH was synthesized from a Madagascar soil rich in Al(OH)₃ and a soluble magnesium source. Unlike traditional LDH synthesis, this method does not require extreme alkalinity and soluble metal salts.

The P uptake by the synthesized LDH was evaluated using synthetic P solutions and compared to actual wastewater samples. Additionally, in a pot trial with rice (*Oryza sativa* L.), the performance of P-loaded LDH as P fertilizer was compared to that of conventional triple superphosphate (TSP) in three P-deficient soils using a localized application technique—seedling P-dipping. The hypothesis was that the slow-release properties of LDH could prevent P from being rapidly sorbed by Fe- and Al-rich minerals in P-fixing soils.

Results showed that soil-derived LDH materials demonstrated rapid and preferential P uptake from wastewater, achieving 90% P removal efficiency from solutions containing 10 mg-P L⁻¹ at an LDH dose of 1 g L⁻¹. The material's maximum P uptake capacity was 6% by weight, making it suitable as a mineral fertilizer. In the pot trial, plant P uptake from the LDH material was 50% of that with TSP, highlighting a lower short-term P bioavailability with the soil-based LDH carrier. To enhance P uptake, selecting crops with specialized P acquisition strategies may be necessary.

Overall, this study provides proof-of-concept for a novel technology that enables the local recycling of P in tropical regions. By leveraging soil-based nutrient carriers, this approach could improve agricultural productivity while addressing the financial and logistical barriers that smallholder farmers face in accessing P fertilizers.





PO9_67 SEWAGE SLUDGE-BASED FERTILIZER IMPACTS ON LEAF MICRONUTRIENTS CONCENTRATION AND MAIZE YIELD UNDER TROPICAL CONDITIONS

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Composted sewage sludge (CSS) is an organic fertilizer rich in micronutrients and is an excellent sustainable alternative to synthetic fertilizers. However, research on CSS in the supply of micronutrients in tropical regions is scarce, so the consequences of long-term CSS application are still uncertain. Our objective in this study was to evaluate the effect of CSS application rates on maize nutrition and yield under no-till management in the Cerrado region of Brazil. A field experiment was conducted in a randomized complete block design with four replications, and five CSS rates (0.0; 5.0; 7.5; 10.0, and 12.5 Mg ha⁻¹), applied in three crop years, in addition to a treatment with conventional mineral fertilization (CMF). Foliar nutritional status (B, Cu, Fe, Mn, and Zn concentration) and grain yields were evaluated. Dunnett's test was applied ($P < 0.05$), in which the differences between CSS rates and the CMF treatment were verified. Regressions were performed to evaluate the effect of CSS application rates. The Mn and Zn concentrations in the maize leaf diagnosis showed quadratic adjustment to the CSS application rates, with an effect for Mn and Zn in second and in first CSS application, respectively. Leaf Mn concentrations at the highest CSS rates (10.0 and 12.5 Mg ha⁻¹) were similar to CMF throughout the three applications. As for grain yields, a linear adjustment to the CSS application rates was found, with the lowest productivity in the rates of 0.0 and 5.0 Mg ha⁻¹ differing from CMF only in the first application, with no differences between the highest doses and CMF throughout the three applications of the CSS. These results indicate that our productivity was higher than the national average in all treatments with CMF and CSS. We concluded that organic fertilizer derived from CSS can maintain micronutrient concentrations within the maize nutritional requirements (B: 7–17, Cu: 6–15, Fe: 70–200, Mn: 40–100, and Zn: 20–50 mg kg⁻¹), and increase yield, indicating its potential as a viable micronutrient source for crop production under tropical conditions. Recycling sewage sludge as organic fertilizer in agriculture, in addition to promoting a circular economy, contributes to a sustainable final disposal of this urban waste.





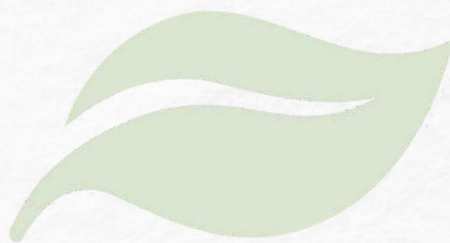
PO9_68 ROLES OF STRIGOLACTONES AND SIDEROPHORES IN SOIL PHOSPHORUS MOBILIZATION AND PLANT NUTRITION

Xiaomeng Chen (Italy)¹; Silvia Celletti (Italy)¹; Marcin Musialowski (Poland)²; Klaudia Debiec-Andrzejewska (Poland)²; Maria Martin (Italy)¹; Luisella Celi (Italy)¹; Michela Schiavon (Italy)¹

1 - Department of Agricultural, Forest and Food Sciences, University of Turin, Largo Paolo Braccini 2, 10095 Grugliasco, Italy; 2 - Department of Geomicrobiology Faculty of Biology, University of Warsaw, Miecznikowa 1, 02-096 Warsaw, Poland

Phosphorus (P) is an essential macronutrient for plant growth and yield, but its availability in soil is limited for plants due to retention and fixation processes. In acid soils, P is adsorbed on aluminium and iron (Fe) (hydr)oxides, while in alkaline soils, it precipitates with calcium. Additionally, P can form insoluble complexes with Fe cations, further reducing its accessibility. To cope with P deficiency, plants have developed various strategies, including the enhanced synthesis of strigolactones (SLs), phytohormones that regulate several P deficiency responses. Moreover, certain bacteria release both organic acids and enzymes that dissolve insoluble phosphates, as well as siderophores that chelate Fe³⁺ released during mineral dissolution. This study explores the role of siderophores in improving soil P mobilization and their influence on P nutrition in tomato (*Solanum lycopersicum* L.) plants differing in SL production. Two genotypes, an SL-deficient mutant (SL-) and wild type (WT), were grown for 28 days in four low-P content soils with varying pH conditions (acid, neutral, and alkaline with either high or low Fe). Plant growth parameters, root morphology, total P concentration, and leaf acid phosphatase (APase) activity were analyzed. The two genotypes showed a similar growth pattern across soil types, with reduced shoot height and biomass in acid soils. However, both genotypes exhibited enhanced root development, suggesting an increased root-to-shoot ratio as a response to P deficiency. Nonetheless, the SL- mutants exhibited reduced shoot and root biometric parameters compared to the WT, emphasizing the role of SLs in regulating plant growth and morphological adaptation to P deficiency. Total P concentration and leaf APase activity were highest in plants grown in alkaline soil with high Fe. This finding could indicate a stress response and/or reflect the plant's need to remobilize P from mature leaves. In a subsequent experiment, purified siderophores and siderophore-accompanying metabolites (SAMs) produced by *Pseudomonas* sp. ANT_H12B, an Antarctic strain, were applied to the four soils to evaluate their role in P mobilization. Before application, FT-IR spectroscopy and CHNS elemental analysis revealed that the siderophores were structurally similar to pyoverdine, a greenish-yellow siderophore, but with the addition of extra carboxylic groups and sulfur. After 48-hour application, different P pools in the soils were quantified using four extraction methods (i.e., CaCl₂, NaHCO₃, citric acid/citrate, and EDTA+NaOH). Both siderophores and SAMs enhanced the mobilization of soil-available and weakly adsorbed P, particularly in alkaline soils with high Fe, highlighting their potential to improve plant P nutrition.





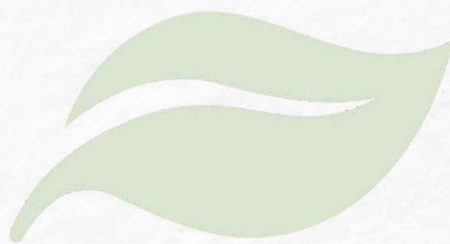
PO9_69 EFFECT OF FOLIAR FERTILIZATION ON THE DEVELOPMENT, PRODUCTIVITY, AND QUALITY OF GRAPE TOMATOES

Marilia Cecilia De Souza Bittencourt (Brazil)¹; Rodrigo Lima da Motta Junior (Brazil)¹; Fabiane Carvalho Ballotin (Brazil)¹; Reinaldo Bertola Cantarutti (Brazil)¹

¹ - Federal University of Viçosa

Foliar fertilizers can complement soil fertilization by supplementing plant mineral nutrition. Foliar fertilizers are useful for correcting or preventing micronutrient deficiencies during critical periods for plants, ensuring they receive the necessary nutrients for healthy growth. This study aimed to verify whether the foliar application of a fertilizer obtained from NH₃ recovered from poultry litter composting influenced the development and production of grape tomatoes. For this purpose, tomato plants received applications of a concentrated foliar fertilizer at solution doses of 0, 0.5, 1.0, 2.5, and 5%, containing 10% nitrogen (N), 12.4% phosphorus (P), 6.24% sulfur (S), 4% magnesium (Mg), 2% zinc (Zn), and 1% boron (B). The plants were grown in a greenhouse, and the foliar fertilizer was applied every 15 days, starting 20 days after transplanting (DAT). Thus, the experiment was conducted in a 5 × 2 factorial scheme (five foliar fertilizer doses × two soil fertility levels) under a randomized block design with three replications. Each experimental unit consisted of two pots, with one plant per pot, totaling two plants per experimental unit. Variables related to vegetative development (plant height, stem diameter, and number of leaves), productivity (number of fruits per plant, total fruit weight per plant, and average fruit weight), and fruit quality (soluble solids content, titratable acidity, SS/AT ratio, and pH) were analyzed. In addition, leaf nutrient analysis was performed to evaluate the plants' nutritional status, and photosynthetic parameters were measured using MultispeQ, including photosystem II quantum yield (Φ_{II}) and non-photochemical exciton quenching (NPQ). This study will allow the assessment of foliar fertilization effectiveness as a complement to soil fertilization in tomato cultivation, providing insights into its impact on plant development, productivity, and fruit quality. The results obtained will contribute to a better understanding of the role of foliar nutrition in supplementing soil fertilization, aiding in the development of more efficient nutritional management strategies.





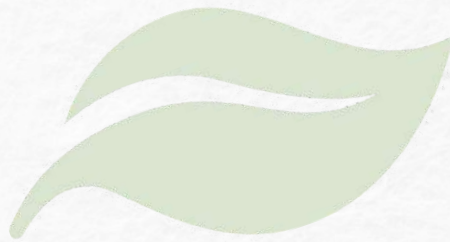
PO9_70 ENHANCING STABILITY OF HIGH-CONCENTRATION FLUID FERTILIZERS USING CELLULOSE CARBOXYMETHYL AND CARBON NANOPARTICLES

Rodrigo Lima da Motta Júnior (Brazil)¹; Marilia Cecilia de Souza Bittencourt (Brazil)¹; Fabiane Carvalho Ballotin (Brazil)¹; Reinaldo Bertola Cantarutti (Brazil)¹

¹ - Federal University of Viçosa

Fluid fertilizers are gaining prominence in modern agriculture as an innovative approach to plant nutrition. By providing nutrients in a soluble and readily available form, they enhance nutrient uptake efficiency, support plant growth, and improve crop yields. These fertilizers are widely used as nutritional supplements, stress mitigators, and productivity boosters, demonstrating significant benefits in crops such as maize, tomato, and sugarcane. However, producing and applying fluid fertilizers requires advanced technological processes to ensure stability, homogeneity, and nutrient availability. A key challenge is formulating a high-concentration, multi-nutrient fertilizer that remains stable in solution without precipitating or aggregating. One promising strategy to address this issue is the incorporation of stabilizing agents, such as dispersants and nanoparticles, to enhance suspension stability and prevent sedimentation. This study aimed to develop a highly concentrated fluid fertilizer containing nitrogen (N), phosphorus (P), sulfur (S), magnesium (Mg), zinc (Zn), and boron (B). The nutrient sources included $\text{H}_2\text{NH}_4\text{PO}_4$, $(\text{NH}_4)_2\text{SO}_4$, MgSO_4 , ZnSO_4 , and H_3BO_3 . Due to the high salt concentration, the formulation resulted in a concentrated suspension. To enhance stability and prevent sedimentation, cellulose carboxymethyl (CMC), carbon nanoparticles (CNPs), and their combination were evaluated as stabilizing agents at increasing concentrations of 0.5%, 1%, 2.5%, and 5%. The suspension underwent sonication to ensure proper dispersion, and aliquots were collected at 1, 5, 15, 30, 60, and 300 minutes. Turbidity measurements were conducted using a spectrophotometer to assess the degree of dispersion and sedimentation over time. By analyzing the relationship between dispersed particles and turbidity, this study provided insights into the effectiveness of different stabilizers in maintaining suspension stability. The findings contributed to the development of more efficient and stable fluid fertilizers, enhancing their applicability in precision agriculture.





PO9_71 **BALANCING NITROGEN USE EFFICIENCY, YIELD, AND QUALITY IN FLEMISH WINTER WHEAT PRODUCTION SYSTEMS**

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1 - Soil Service of Belgium; 2 - KU Leuven, Department of Earth and Environmental Sciences, Soil and Water Management

More than 80% of nitrogen (N) fertiliser recommendations for winter wheat (*Triticum aestivum* L.) in Flanders, Belgium, exceed governmental standards. This study aims to optimise an existing inorganic N fertilisation recommendation system to enhance N use efficiency while maintaining grain yield and quality standards.

Over two cropping seasons (2023–2024), six field trials were conducted on commercial farms across Flanders, each implementing fifteen treatments of calcium ammonium nitrate. These treatments varied in (i) total N, ranging from 0 to 250 kg N ha⁻¹, and (ii) split application strategies. In-season crop growth and soil mineral N content (0–90 cm depth) were monitored, while grain yield, grain quality parameters, and residual soil NO₃-N (0–90 cm depth) were assessed at harvest. Differences between treatments were considered significant at $p < 0.05$.

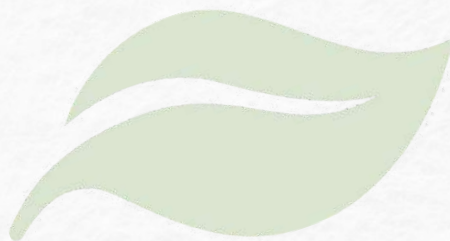
Results showed that agronomic N use efficiency (N-AE), defined as the increase in dry matter yield relative to an unfertilised control per kg of N applied, declined linearly with increasing N application. Location-specific N-AE ranged from 38 to 22 kg kg⁻¹ N at an application of 50 kg N ha⁻¹ and from 24 to 10 kg kg⁻¹ N at an application of 250 kg N ha⁻¹. Split applications delivering equal total N had no effect on N-AE at most locations.

Net N mineralisation, estimated as the balance between system N output and input while assuming negligible losses, decreased with increasing N application at all locations. At three locations, splitting N into three rather than two fractions resulted in higher N mineralisation.

Grain yield (at 15% moisture content) increased with N application up to 150 kg N ha⁻¹ at five locations and up to 180 kg N ha⁻¹ at one location. Further increasing N application to 250 kg N ha⁻¹ had no significant yield effect at any location. Split applications had limited impact on yield but increased grain protein content, particularly when a third fraction of up to 60 kg N ha⁻¹ was applied at ear emergence. Grain protein content increased with higher N application at all locations, ranging from 7.4 to 13.4% for fodder varieties and 7.9 to 15.7% for baking varieties at 50–250 kg N ha⁻¹.

In conclusion, the decline in N-AE with increasing N application is likely driven by diminishing yield responses and reduced soil organic N mineralisation.





PO9_73 EFFECTS OF SLOW-RELEASE NITROGEN FERTILIZER ON NUTRIENT USE AND ROOT GROWTH OF RICE

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1 - College of Resources and Environment, Huazhong Agricultural University, Wuhan 430070, China; 2 - Institute of Soil Science, Chinese Academy of Sciences, Nanjing 211135, China

【 Background 】 Rice, a staple food crop globally, is critical for food security. Fertilizer management and planting density are key determinants of rice population structure and yield. While conventional urea can rapidly stimulate growth, there are prone to uneven nutrient release, diminished late-stage utilization, and environmental pollution.

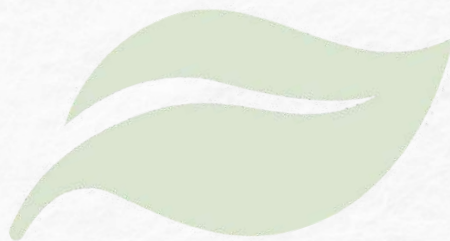
【 Objective 】 Evaluation of the reduced application of slow-release urea on nutrient utilization, population structure formation, and yield formation of rice.

【 Methods 】 In this study, two varieties (Huasheng You Yue Nong Si Miao and Yongyou 7850) were selected, and three treatments of no fertilization, conventional urea and 25 % reduced slow-release urea were set up, combined with different row spacing, and field experiments were carried out.

【 Results 】 Slow-release urea effectively recruits rice roots and forms a wrapped structure, which enhances the root's access to fertilizer. The application of slow-release urea, in comparison to conventional urea, significantly improves the mechanical strength and lodging resistance of the second internode. Furthermore, it promotes rice growth and yield formation by increasing SPAD value and tillering number, and enhancing photosynthetic capacity.

【 Conclusions 】 In conclusion, a 25 % reduction in slow release urea application effectively sustains rice growth and maintains comparable yield formation to conventional urea applied at the standard dosage.





PO9_74 MICRONUTRIENT SEED COATINGS OF LAYERED DOUBLE HYDROXIDES OVERCOME SEEDLING TOXICITY AND IMPROVE MICRONUTRIENT UPTAKE IN COMPARISON WITH SOLUBLE MICRONUTRIENT SEED COATINGS

Tim Meyvisch (Belgium)¹; Elden Willems (Belgium)¹; Maarten Everaert (Belgium)¹;

¹ - KU Leuven

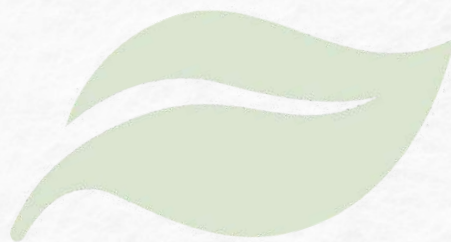
Zinc (Zn), boron (B), and molybdenum (Mo) are micronutrients, essential to crops, which can be efficiently applied to crops via seed coatings. However, fast micronutrient release from soluble seed coatings brings seedling toxicity risks due to high local micronutrient concentrations. Hence, this study aimed to develop novel Zn-B-Mo slow-release seed coating compounds, i.e. nanostructured Zn₂Al or Zn₃Al layered double hydroxides (LDHs) loaded with (poly)borate and molybdate, to prevent toxic conditions and enhance micronutrient supply to crops.

In chemical incubation experiments, two micronutrient release mechanisms were examined for the synthesized Zn₂Al-B-Mo and Zn₃Al-B-Mo LDH, i.e. anion exchange and LDH dissolution. Next, in a seedling establishment trial, chickpea seeds coated with the Zn-B-Mo LDH coating were assessed for toxicity and compared with corresponding soluble seed coatings.

Assessment of the micronutrient release properties showed that both LDH compounds, i.e. the Zn₂Al-B-Mo and Zn₃Al-B-Mo LDH, gradually dissolved at a pH of ~4.5, releasing Zn, B, and Mo, while Zn₃Al-B-Mo released Mo more slowly than Zn₂Al-B-Mo through anion exchange (pH ~7). Therefore, the Zn₃Al-B-Mo LDH was selected for further testing in seed coatings as slow micronutrient release is preferred.

In the seedling establishment trial, unlike the soluble seed coatings, the LDH coatings prevented toxic effects on seed emergence and seedling growth at elevated micronutrient doses. This was due to the slow release of Zn, as indicated by the lower Zn contents obtained with the LDH coatings. The B and Mo content was similar or higher with the LDH coatings than with the soluble coatings. However, it remains possible that high B and Mo exposure was avoided during germination and early growth of the seedlings. Taken together, slow-release LDH seed coatings have great potential for controlling micronutrient supply to crops.





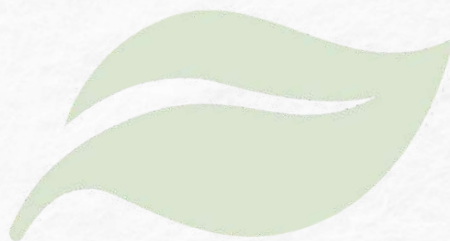
PO9_75 EFFECTS AND MECHANISMS OF VALUE-ADDED AMMONIUM PHOSPHATE FERTILIZER ON THE IMPROVEMENT OF SEED YIELD IN RAPESEED

Yajie Wang (China)¹; Lei Shi (China)¹

¹ - National Key Laboratory of Crop Genetic Improvement, Huazhong Agricultural University, Wuhan 430070, China

Secondary and micronutrients are often removed as by-products in the production of ammonium phosphate fertilizers, which not only increases the cost, but also wastes the mineral resources. In this study, the value-added ammonium phosphate fertilizers were developed, which can keep most of the above nutrients in them. Field experiments were conducted to study the effects of ammonium phosphate (GA), zinc-enriched ammonium phosphate (XGA), and iron-enriched ammonium phosphate (TGA) fertilizers on the seedling growth and yield of rapeseed cultivar "Huayouza 50" (*Brassica napus* L.) with application rates of 90 kg phosphorus (P) /ha (farmers' fertilizer practice) and 45 kg P/ha (50% reduction), respectively. The results showed that both XGA and TGA significantly increased the seed yield of rapeseed under both P application rates. At the application rates of 90 kg P/ha, the rapeseed yield under XGA and TGA treatments increased by 16.7% and 13.7%, respectively, compared to GA treatment. At 45 kg P/ha, the seed yield of them increased by 48.3% and 28.8%, respectively. Additionally, 45 kg P/ha XGA and TGA both significantly enhanced shoot P uptake and use efficiency, while reducing soil P surplus at harvest stage. Among of them, XGA treatment achieved the highest yield and maximum net income. The root secreted stigmaterol and other sterol metabolites of rapeseed could selectively recruit some bacterial groups such as Acidobacteria, Actinobacteria, and Chloroflexi, which contributed to an increase of active and moderately active soil P pools. Our results indicate that application of value-added ammonium phosphate fertilizers can reduce 50% P while maintaining the seed yield at the experimental site, and the root-associated metabolite-microbiome interactions could modulate soil P pools, ultimately improving Pi absorption and utilization efficiency.





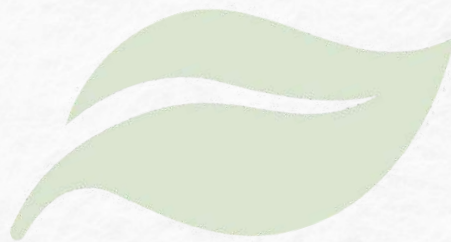
PO9_76 EFFECT OF CULTIVARS AND NATURE-BASED SOLUTIONS FOR THE REDUCTION OF PHOSPHATE FERTILIZER USAGE ON OILSEED RAPE

Lei Shi (China)¹; Bingbing Zhang (China)¹; Yajie Wang (China)¹; Guangda Ding (China)¹; Sheliang Wang (China)¹; Hongmei Cai (China)¹; Chuang Wang (China)¹; Fangsen Xu (China)¹; John P. Hammond (UK)²; Philip J. White (UK)³

1 - National Key Laboratory of Crop Genetic Improvement, Huazhong Agricultural University, Wuhan 430070, PR China; 2 - School of Agriculture, Policy and Development, University of Reading, Reading RG6 6AR, UK; 3 - Ecological Science, The James Hutton Institute, Invergowrie, Dundee DD2 5DA, UK

Oilseed rape (*Brassica napus* L.) is the most important temperate oil crop globally. Maintenance of soil phosphate (Pi) availability, through the application of Pi fertilizers and manures, is needed to maintain seed yield of oilseed rape. Over-application of the Pi fertilizers results in Pi accumulation in agricultural soils and adjacent ecosystems, where it can drive eutrophication in freshwater and coastal systems. In this study, field experiments were conducted to explore the optimal Pi fertilizer application rate for four oilseed rape cultivars and the potential of nature-based solutions including Pi solubilizing bacteria (PSB) and rooting agent (RA) to reduce Pi fertilizer application rates for oilseed rape. The seed yields of cultivars Shengguang 168 (SG168) and Huayouza 9 (HYZ9) were significantly higher than those of cultivars Zhongyouza 19 (ZYZ19) and Zhongshuang 11 (ZS11) across all Pi application rates. In comparison with Farmers' fertilizer practice (P26.2, 26.2 kg P ha⁻¹), Pi fertilizers could be reduced by more than 25% for the four cultivars, and be reduced by as much as 50% for SG168. The shoot dry weight and seed yield of ZS11 with the addition of RA at P21.0 (21.0 kg P ha⁻¹) in Expt. 2-1 and P15.7 (15.7 kg P ha⁻¹) in Expt. 2-2 showed no significant difference to that of P26.2 at the ripening stage, but were significantly higher than that of P21.0 and that of P15.7, respectively. At P0 (0 kg P ha⁻¹), addition of PSB significantly increased the shoot dry weight and seed yield of ZS11 at the ripening stage. However, at P21.0 in Expt. 2-1 or at P15.7 in Expt. 2-2, addition of PSB had no effect on shoot dry weight and seed yield of ZS11. These results highlighted the feasibility and potential to reduce the application rate and improve the use efficiency of Pi fertilizers in oilseed rape using nature-based solutions.





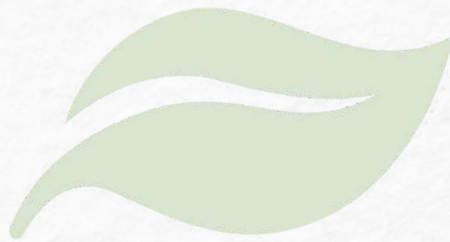
PO9_78 GRAIN YIELD AND NUTRIENT ACCUMULATION IN TWO CHICKPEA (CICER ARIETINUM L.) CULTIVARS VARIED WITH FERTILIZER TREATMENT

JB Ochanda Ogola (South Africa)¹; Vhulenda Madzivhandila (South Africa)¹; Sipho Maseko (South Africa)²

1 - Department of Plant and Soil Sciences, University of Venda; 2 - Department of Crop Sciences, Tshwane University of Technology

Grain yield and accumulation of mineral nutrients in aboveground plant parts are affected by crop cultivar, soil type, and management practices, amongst other factors. Earlier, we demonstrated that fertilizer treatments affected the accumulation of nutrients in the rhizosphere of 2 chickpea cultivars. However, higher levels of rhizosphere nutrients may not necessarily translate into higher uptake and accumulation of nutrients by the plants. Therefore, we assessed the effects of phosphorus fertilizer (P), rhizobium inoculation (R), and R+P on grain yield and the concentration of nutrients in the grain of 2 chickpea genotypes (ACC#1 & ACC#5) at two sites, Thohoyandou (clay soil, warmer) and Syferkuil (loamy sand soil, cooler), characterized by contrasting soil types and temperature regimes, in NE South Africa in 2018. Grain yield, and nutrient (nitrogen, phosphorus, potassium, calcium, magnesium, and zinc) content in the grain were determined at harvest maturity. Grain yield was consistently greater in ACC#5 (3965 vs 2480 & 2405 vs 2084 kg ha⁻¹) compared to ACC#1 at both sites. A similar trend was observed with the nutrient concentration in the grain. Except for magnesium, fertilizer treatment increased the concentration of the nutrients in the grain at both sites, but a combination of P and rhizobium inoculation exhibited greater increases. The higher nutrient concentration in ACC#5 as well as in plants subjected to a combination of P and rhizobium inoculation could be associated with greater accumulation of rhizosphere nutrients that was observed previously in those treatments. Clearly, chickpea productivity in this region may be enhanced by a combined application of fertilizer P and rhizobium inoculation irrespective of soil type but further studies, incorporating more chickpea genotypes, are recommended before definite conclusions can be drawn





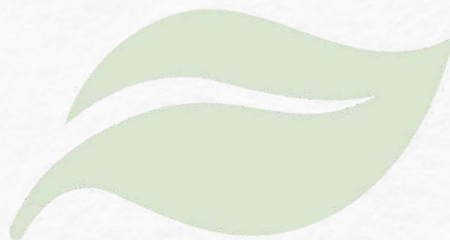
PO9_79 DYNAMICS OF IODINE UPTAKE FROM NUTRIENT SOLUTIONS TO LEAVES AND FRUITS, FOR IMPROVEMENT OF YIELD AND QUALITY IN SUBSTRATE GROWN FRUITING VEGETABLES UNDER FERTIGATION WITH RECIRCULATED DRAIN

Katja Hora (Belgium)¹

¹ - SQM Europe NV

Iodine (I) is available for farmers in fruiting vegetable production in European greenhouses since 2022. Here, fertigation combines irrigation and fertilization, delivering water and nutrients in precise and regularly analysed amounts. Recirculation of the nutrient solution further improves water- and nutrient-use efficiency on top of the sophisticated nutrient management and climate control in modern greenhouses. To understand the behavior of I in recirculated hydroponic systems, I concentrations were measured in the nutrient solution, substrate, drain solution, leaves and fruits, in several trials involving tomato and sweet pepper with recirculated drain in greenhouses in the Netherlands and Belgium. For comparison, similar measurements were done in an open-drain greenhouse in Spain. Data was collected from crops receiving both the naturally occurring I from the irrigation water and exogenous I – in the form of potassium iodate - added to the nutrient solution in varying dosages between 2-50 micromole L⁻¹. Additionally, the concentrations of other plant nutrients and parameters like pH and EC in the nutrient solutions were measured to evaluate interactions between these and I. The results show that the I absorbed by the roots, is translocated to the leaves. A high correlation coefficient ($R^2=0.9$) of I concentration in the substrate and the youngest fully developed leaf was found in a large-scale greenhouse (3 ha), but a lower correlation coefficient ($R^2=0.6$) was found for a small greenhouse compartment (184 m²) at a research station. A hypothesis to explain this observation was tested by a review of I concentration in leaves of control plants of RCB trials and I concentration in leaves of control plants in isolation. Volatilization of iodine by transpiration from plants receiving exogenous iodine, and uptake of iodine from the air by plants in the iodine-deficient plants when grown together in confined spaces is identified as a confounder in trials with I. At the tested concentrations, I in the tomato fruits in all cases remained below 22.5 µg I 100 g⁻¹ of fresh fruit, the minimal level that would enable to label these fruits as a source of iodine for human nutrition. No consistent interactions between iodine and other macro- or micronutrients in the nutrient solutions were observed. The outcome of the analyses were used in combination with other research to determine the final amount of iodine to be added to potassium nitrate as a reliable and easy source to enable efficient application of this beneficial nutrient in farmer's practice.





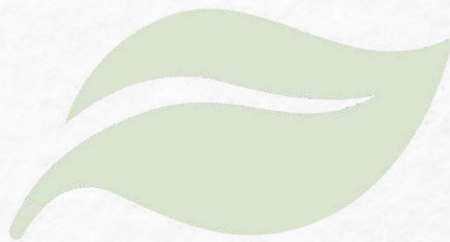
PO9_80 THREE VOLATILE ORGANIC COMPOUNDS PRODUCED AFTER EXPOSURE OF TOMATOES TO THE SOIL YEAST SOLICOCCOZYMA TERREA MODULATE ROOT NITRATE TRANSPORTERS UNDER NITROGEN DEFICIENCY

Mariajose Carvajal (Chile)¹; Francisco Albornoz (Chile)²; Marlene Gebauer (Chile)²; Daniela Catrileo (Chile)¹; Liliana Godoy (Chile)¹

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Beneficial microorganisms modify root architecture through different mechanisms mostly related to plant hormones synthesis. Less information is available regarding the emission of microbial volatile organic compounds (VOCs) and their effects on root architecture. Numerous studies describe the release of VOCs by bacteria and filamentous fungi, but little information is available regarding soil yeasts. The VOCs profiles released by the soil yeast *Solicoccozyma terrea* were evaluated in an experiment with tomato seedlings. Four treatments (tomato seedlings, T; *S. terrea* inoculum without tomato seedlings, St; tomato seedlings exposed to the volatiles of *S. terrea* inoculum, TSt; and, a control without tomato seedlings or yeast inoculum, C) were assessed in terms of root morphology. VOCs were analyzed by GC-MS, and in a second experiment, the response of tomato seedlings and root nitrate uptake transporters to specific compounds identified in the first experiment was evaluated under low and high N supply. A mixture with 57 VOCs was identified which promoted lateral roots formation in tomato plants. Three compounds (isopropyl alcohol, 2-pentylfuran and trans-1,3-pentadiene) were exclusively present in the TSt treatment. All three compounds stimulate lateral roots formation and increase root volume. These compounds show a stimulatory effect on the expression of NRT1.2, NRT2.1 and NRT2.3 nitrate transporters under N deficiency conditions. This study provides, for the first time, information on a soil yeast capable of promoting lateral roots formation in tomato through VOCs and that isopropyl alcohol, 2- pentylfuran and trans-1,3-pentadiene modulate root nitrate transporters expression under N deficiency conditions.





PO9_81 RNA-SEQ ANALYSIS REVEALS MOLECULAR MECHANISMS OF BIOSTIMULANT-MEDIATED DROUGHT TOLERANCE IN BARLEY

Seyed Hosseini (France)¹; Otto Kock (France)¹; Clement Le Verge (France)²; Cian Rynne (UK)³; Keith Lindsey (UK)⁴; Anton Besly (France)⁵

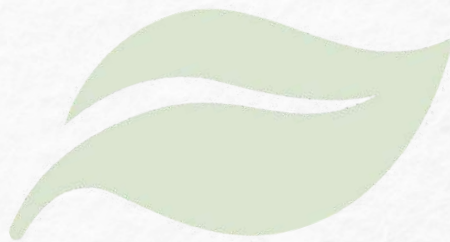
1 - Olmix Group, Research & Development, Plant Care Discovery department; 2 - Olmix Group, Research & Development, Product Design Department; 3 - Department of Biosciences, Durham University; 4 - Department of Biosciences, Durham University; 5 - Olmix Group, Research & Development, Plant Care Discovery Department

Drought stress is a major abiotic factor limiting crop productivity worldwide. Biostimulants, particularly algae-based products, have shown a great potential to ameliorate the negative effects of drought and improve plant stress tolerance. However, the underlying molecular mechanisms by which biostimulants confer drought tolerance remain largely unknown (Jagtap and Meena, 2021; Kapoore et al., 2021). Transcriptomic analysis using RNA-Seq can provide valuable insights into the global gene expression changes and regulatory networks involved in biostimulant-mediated drought stress response. In the present study, RNA-Seq analysis was performed on drought-stressed barley plants supplied with an algae-based biostimulant. The results revealed that the application of biostimulant had a much larger effect on the barley transcriptome under drought condition compared to well-watered control plants. Furthermore, functional enrichment analysis of the DEGs identified several key biological pathways that were modulated by the biostimulant application under drought stress. Particularly, the pathways associated with enhanced growth included those involved in ion transport, membrane function, cell wall remodeling, and auxin signaling cascades.

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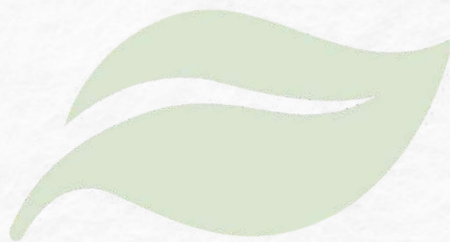
PO9_82 **STARTER FERTILIZER TOXICITY MITIGATION MECHANISMS BY OPTIMIZING THE PLACEMENT RATES IN CEREAL CROPS.**

William Makaza (Zimbabwe)¹; Lotfi Khiari (Canada)¹; 2; Mounir El Achaby (Morocco)³

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Efficient management of starter fertilizers co-placed and subsurface with barley and maize seeds is crucial for economic and environmental sustainability, aiming to reduce the risks of fertilizer salt damage and NH_3 toxicity while promoting early plant vigor during critical growth stages, which can potentially lead to enhanced growth, vigor, and yield. This research investigated the effects of nitrogen and potassium starter fertilizers on barley and maize across three calcareous soil types characterized by fine (G1), medium (G2), and coarse (G3) textures and established safe-starter fertilizer recommendation models. For barley pop-ups, starter fertilizer rates ranged from 0 to 60 kg N ha⁻¹, and 0 to 74 kg K ha⁻¹ were applied, while for the maize seed-fertilizer co-placement, the rates applied were 0 to 20 kg N ha⁻¹ and 0 to 16 kg K ha⁻¹. In subsurface application, these fertilizers were applied only for maize at 0 to 75 kg N ha⁻¹, and 0 to 120 kg K ha⁻¹. Maximum safe starter ammoniacal-N-fertilizer rates for co-placed and subsurface crops are as follows: barley; urea = 35 kg N ha⁻¹ in G2 soils; DAP=52 kg N ha⁻¹ for G1 whilst 12 and 37 kg N ha⁻¹ for G2 and G3; MAP≥60 kg N ha⁻¹ for G1 – G3 soils; MOP and SOP= ≥74 kg K ha⁻¹. Maize co-placed rates were DAP=3 kg N ha⁻¹ (G1), MAP=5-7 kg N ha⁻¹ across all textures; MOP=14 kg K ha⁻¹ for G1, G2, and G3, respectively, while SOP ≥16 kg K ha⁻¹. All N sources had maximum sub-surface rates of 75 kg N ha⁻¹ for G1 soils, DAP and Urea=25 kg N ha⁻¹, while MAP=75 kg N ha⁻¹ for G2 soils. Maintaining 25 and 75 kg N ha⁻¹ of DAP and MAP individually in G3. Visual appearances including delayed seed emergence, leaf chlorosis, and stubby coleoptiles were observed at varying seed-placed, and subsurface N and K rates. Intricate significant interrelationships among various emergence parameters, root architecture, aboveground and root biomass, and chlorophyll content were recorded. Data indicates that the cubic model could be used for predicting seed-safe rates for multiple fertilizer types.





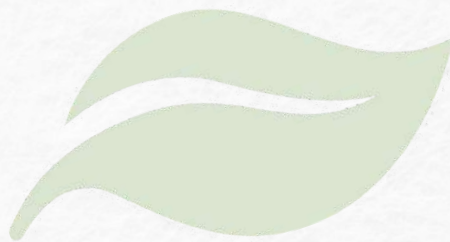
PO9_84 AMMONIA VOLATILIZATION AFTER NITROGEN DOSE APPLICATION ON MARANDU GRASS

Alana Nascimento Vasco (Brazil)¹; Suzana Pereira de Melo (Brazil)¹; Milton Ferreira de Moraes (Brazil)¹; João Vitor Leonel dos Santos (Brazil)²; Bruna Silva Nobre (Brazil)¹

1 - UFMT; 2 - USP

Ammonia volatilization (N-NH_3) is the main responsible for the reduction in the efficiency of nitrogen fertilizer application in tropical pastures. The objective of this study was to quantify the losses of N-NH_3 after the application of nitrogen (N) doses in *Brachiaria brizantha* cv. Marandu, in the second year of cultivation. The experiment was carried out in the experimental unit located at the Federal University of Mato Grosso, in the municipality of Barra do Garças, with annual rainfall of 1503 mm and average annual temperatures between 22°C and 35°C. The experimental design was randomized blocks, with five N rates (0, 60, 120, 180 and 240 kg ha⁻¹ of N), using urea (46% of N) as a source, with four replications, totaling twenty experimental units, with 30 m² each. The doses were divided into four applications of 60 kg ha⁻¹ of N, applied on the dates of 12/02/2022, 01/14/2023, 02/16/2023 and 03/14/2023, respectively. Volatilized ammonia was collected using SALE's chambers inserted in PVC cylinders with an area of 0.008 m², on days 1, 2, 5, 9, 14 and 20 after application of each fertilizer dose and quantified by distillation and titration. The data obtained were submitted to analysis of variance and when they were significant at 5% probability, the regression test was performed. The volatilized ammonia accumulated after the four urea applications adjusted in a linear regression, with losses of 3.83, 7.39, 15.42, 24.40 and 38.55 kg ha⁻¹ of N-NH_3 , at the doses of 0, 60, 120, 180 and 240 kg ha⁻¹ of N, respectively. Comparing the dose of 240 kg ha⁻¹ of N with the doses of 0, 60, 120 and 180 kg ha⁻¹ of N, it is observed superiority of 906%, 421%, 150% and 57% in the losses of ammonia volatilization, respectively. The doses applied influenced the volatilization of ammonia and with the increase in the doses there was an increase in the losses of N-NH_3 in the use of the urea source.





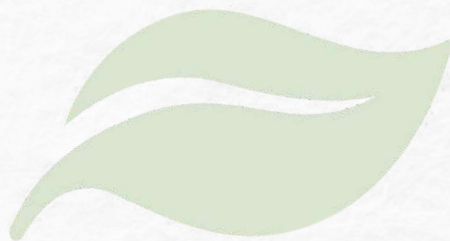
PO9_85 NANO DAP AUGMENTS PRODUCTIVITY, PHOSPHORUS USE EFFICIENCY, AND PROFITABILITY OF SPRING WHEAT IN INDIA

Dr Binaya Kumar Parida (India)¹; Yashbir Singh Shivay (India)²

1 - Coromandel International Ltd; 2 - Indian Institute of Agricultural Research, Pusa, New Delhi

Agriculture is undergoing a transformation through innovations like nano fertilizers, which offer the potential to enhance productivity and sustainability. This study aimed to evaluate the effectiveness of nano DAP to improve growth, yield attributes, nutrient uptake, and economic viability in wheat (*Triticum aestivum* L.) cultivation. A two-year field experiment during the rabi seasons of (2022–2024) was conducted at the ICAR-Indian Agricultural Research Institute, New Delhi, India, using a randomized complete block design with ten treatments. These included a control (zero P), 50%, 75%, and 100% of the recommended dose of phosphorus (RDP), with or without nano DAP sprays (2.5 ml and 5 ml L⁻¹), replicated three times. Results demonstrated that the application of 100% RDP combined with two foliar sprays of nano DAP significantly increased grain yield by 34.8% and 14.7% in the 2022–2023 and 2023–2024 seasons, respectively, compared to the control. However, in 2023, P50 + nano2.5 ml L⁻¹ resulted in a 13.7% reduction in yields, while P50 + nano5 ml L⁻¹ showed a 7.8% decrease compared to P100. In 2024, both treatments achieved yields comparable to P100. Similarly, P75 + nano recorded yields on par with P100. Additionally, grain phosphorus (P) and nitrogen (N) uptake, showed substantial increases of 69.9% and 42.2% for P, and 54.2% and 26.7% for N across the two seasons, compared to control. Economic analysis revealed higher net returns of US \$ 1,022.30 and US \$ 1,248.90 ha⁻¹ year⁻¹ in 2022–2023 and 2023–2024, respectively. Reducing the P application to 75% RDP with two foliar sprays of nano DAP (5 ml L⁻¹) resulted in wheat yields of 4.25 t ha⁻¹ and 6.04 t ha⁻¹ in 2022–2023 and 2023–2024, respectively, which were statistically comparable to the yields achieved with 100% RDP. This treatment also significantly improved N uptake (84.2, 125.0 kg ha⁻¹), P uptake (20.4, 24.2 kg ha⁻¹), and net returns (US \$ 958.60, US \$ 1,197.10 ha⁻¹ year⁻¹) during 2022–23 and 2023–24, respectively. P50 + nano5 ml L⁻¹ and nano2.5 ml L⁻¹ reduced net returns by 7.8% and 1.5% in the first year, and by 10.6% and 6.0% in the second year, respectively, compared to P100. Thus, demonstrating its potential as an economically viable and environmentally sustainable alternative to conventional P application.





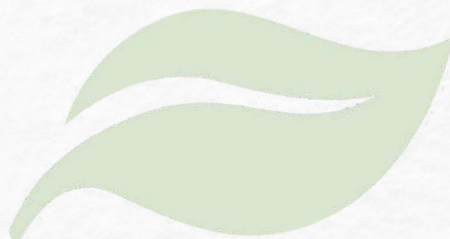
PO9_86 THE SOIL APPLICATION OF A PLANT-DERIVED PROTEIN HYDROLYSATE SPEEDS UP SELECTIVELY THE RIPENING-SPECIFIC PROCESSES IN TABLE GRAPE

Peli Marika (Italy)¹; Ambrosini Stefano (Italy)¹; Sorio Daniela (Italy)²; Pasquarelli Fabrizia (Italy)³; Zamboni Anita (Italy)¹; Varanini Zeno (Italy)¹

1 - Biotechnology Department, University of Verona; 2 - Centro Piattaforme Tecnologiche, University of Verona; 3 - SPAA s.r.l

Grapevine is one of the most extensively cultivated fruit crops, playing a crucial role in the economies of many grape-growing regions around the world. However, grape production currently faces significant challenges due to climatic adversities and the pressing need to adopt sustainable production models. The use of plant biostimulants offers a promising and viable alternative to traditional practices, sustainably enhancing grape production and quality even under adverse conditions. In this context, we tested a maize gluten-derived protein hydrolysate (GDPH) on the Black Magic early table grapevine variety. The product, obtained from the enzymatic hydrolysis of the wet-milling process by-products, was applied to the soil by drenching to evaluate its effects on yield, grape ripening, and fruit quality. The GDPH, administered at veraison, positively affected many parameters as early as 14 days post-application. It increased anthocyanin and sugar concentrations and berry diameter while maintaining optimal levels of berry firmness. Through transcriptomic analysis of the berries, we found that the GDPH accelerated the berry ripening process by up-regulating the expression of genes involved in anthocyanin biosynthesis and enhancing the modulation of key developmental regulators in berries. Furthermore, the selective modulation of genes related to cell wall metabolism explained the observed preservation of berry firmness. Our findings suggest that GDPH treatments may boost grapevines' resilience by increasing the tolerance to both abiotic and biotic stresses, as evidenced by the impact on several genes related to such responses. Taken together, our results highlight the efficacy of this plant-derived biostimulant in enhancing berry colouration with minimal impact on fruit texture, which is particularly important for table grape production. The demonstrated positive effects on berry pigmentation and the ability to enhance quality parameters emphasise the need for further research to elucidate its mechanisms of action. Ultimately, optimising its application in agricultural practice will help unlock its full potential as a plant biostimulant.





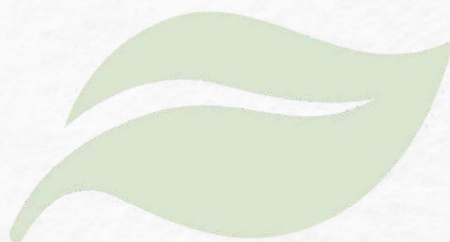
PO10_1 EFFECT OF POTASSIUM ON NUTRIENT UPTAKE IN MAIZE COMPARING ORGANIC VINASSE FERTILIZER WITH MINERAL FERTILIZERS KCl AND K₂SO₄

Tiago Tezotto (Brazil)¹; Nicole Santibañez (Brazil)¹

¹ - Universidade de São Paulo

Brazil is the second largest consumer of potassium which demand for fertilizers has been achieved mainly by imports. Vinasse is a waste rich in organic matter and K and when applied to the soil it becomes a potential K fertilizer. The present study aims to evaluate the concentrated vinasse on the availability of K for the development of maize compared to the mineral sources KCl and K₂SO₄. Greenhouse experiment was conducted at Soil Science Department, Universidade de São Paulo, Piracicaba - SP. The treatments included three potassium sources (organic K, KCl and K₂SO₄) in five doses (0, 25, 50, 75 and 100 mg/dm³). The plant material was collected and dried, weighed and taken for analysis. Chemical analysis of the soil was performed at the end of the experiment. Analysis of nutritional status was performed by quantifying the nutrient levels of the aerial part of the plant and the roots. Only the K content changed in the soil. For the KCl source, an increase was observed due to the increase in the dose, while for the K₂SO₄ and Korg sources there was a reduction in the content in the soil due to the increase in the applied content. Total dry mass reduction was observed for the Korg source, which at the highest dose (100 mg/dm³) presented 28.64 grams, while for the KCl and K₂SO₄ sources the values observed were 44.48 and 38.86 grams, respectively. The pH 9.9 characterized in the Korg source did not significantly alter the soil pH due to the addition of 25, 50, 75 and 100 mg/dm³ of K. For the KCl source, an increase in the content was observed due to the increase in the dose, while for the K₂SO₄ and Korg sources there was a reduction in the soil content due to the increase in the applied content. For the Korg source, less root development was observed. This could indicate some negative effect on root development by the Korg source due to the presence of other substances that could act as contaminants and impair root growth. For the aerial part, neither the K content nor the accumulated K did not differ between the KCl, K₂SO₄ and Korg sources. The greatest increases in content and accumulation were observed at the highest dose (100 mg/dm³) of the KCl source. K₂SO₄ and Korg presented similar contents and accumulation at the doses evaluated (25, 50, 75 and 100 mg/dm³).





PO10_3 DIAGNOSTIC ACCURACY OF SOIL AND TISSUE K AND P ANALYSES FOR PREDICTING ALFALFA PERFORMANCE.

Jeffrey J Volenec (United States)¹; Sylvie Brouder (United States)¹

¹ - Purdue University

Soil testing remains the primary tool used to inform fertilizer management in North America, but when and how deep to sample soils is currently debated particularly in perennial and no-till systems where nutrient stratification occurs. In addition, the impact of co-limiting nutrients on identification of critical values is anticipated, but poorly characterized. Our objective was to determine the effectiveness of soil test P (STP) and K (STK), and herbage P and K as predictors of alfalfa performance. We also evaluated specificity and sensitivity of these predictors using receiver operating characteristics (ROC) analysis. Plots were fertilized with a factorial combination of four P and five K rates. Soil samples in 5-cm increments were obtained after each forage harvest from May 2000 to Sept. 2004 and analyzed for STP and STK. Tissue P and K were also analyzed. Linear-plateau (LP) regression was used to determine critical STK and STP values as influenced by soil depth, month and year, and critical tissue P and K concentrations. The confounding effect of P limitations on critical STK levels, and K limitations on critical STP levels was also assessed. High forage yields were obtained when at least 200 kg K and 25 kg P were applied per ha. Including progressively deeper soil increments in the LP regressions altered the slopes and join points ("critical values") as expected, but did not impact plateaus or R²-values. Critical values of the LP regressions were generally similar for analyses conducted by month (averaged over years) and years (averaged over months). Excluding P-limited plots from the K LP regression and K-limited plots from the P LP regression improved model performance. This improvement was confirmed with ROC analysis where diagnostic accuracy improved from "sufficient" to "good" classes. ROC analysis also indicated that herbage K was a much better predictor of alfalfa performance than STK in P-limited plots. It also indicated that herbage P could not predict alfalfa yield if data from K-limited plots were included, but both STP and herbage P were "sufficient" to "good" predictors of alfalfa yield if low-K plot data were removed. The combination of L-P regression (provides critical values) and sensitivity/specificity (ROC) analysis was important for understanding the utility of soil and herbage K and P in a fertilizer recommendation framework for alfalfa.





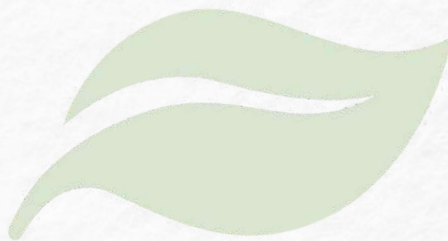
PO10_4 UNDERSTANDING THE TEMPORAL DISSOLUTION OF POLYHALITE FERTILISER IN SOILS

Rodrigo C. da Silva (Australia)¹; Euan Smith (Australia)¹; Casey L. Doolette (Australia)¹; Binoy Sarkar (Australia)¹; Jianyin Huang (Australia)²; Brigid A. McKenna (Australia)²; Kathryn Bartlett (UK)³; Peter M. Kopittke (Australia)²; Enzo Lombi (Australia)¹

1 - University of South Australia, Future Industries Institute, Mawson Lakes 5095 SA, Australia; 2 - University of Queensland, School of Agriculture and Food Sustainability, St Lucia 4072 QLD, Australia; 3 - Anglo American Crop Nutrients, Woodsmith Mine Site, Whitby, YO22 5BF, United Kingdom

High rates of K fertiliser are applied to croplands worldwide, but their current usage is highly inefficient – for example, the current K use efficiency in cereal production is only 19%. Although farmers have primarily relied on conventional K fertilisers (e.g. KCl), alternative forms of K fertilisers are now making their way into the market, such as polyhalite ($K_2SO_4MgSO_4CaSO_4 \cdot 2H_2O$). Nonetheless, the behaviour of this multi-nutrient fertiliser in soils remains unknown. To bridge this knowledge gap, we investigated the interactions between polyhalite and soils, aiming to optimise nutrient availability for crop growth. The solubilisation of polyhalite fertiliser was evaluated over 56 days in contrasting soils: Aridisol, Oxisol, Alfisol, and Vertisol. Sulphate of potash (SOP) was also used as a reference, fully soluble fertiliser, and a weak electrolyte treatment (10 mM NaCl) was included in the experiment to assess whether the environmental matrix impacted the fertiliser dissolution. Approximately 100 g of each soil was added to a vial containing polyhalite or SOP granules (8.7 mg K per vial; ~150 kg K/ha). The granules were enclosed in a woven nylon mesh (45 μ m) attached to a 3D-printed support in the centre of the soil volume. The assembled treatments were incubated in the soils at 80% water holding capacity from 3 to 56 days. Then, the fertiliser granules were removed from the vials, dried, weighed, imaged (by micro-computed tomography μ CT, and scanning electron microscope), and analysed for their mineralogical and elemental compositions. Regardless of the fertiliser type, maximum dissolution occurred within four weeks, with SOP fully dissolving in the soil and solution matrices. In contrast, polyhalite dissolution reached 68% (proportion of the total added) in a 10 mM NaCl solution and <45% in soils. Three-dimensional μ CT images demonstrated the high porosity of the polyhalite granules, confirming significant mass loss despite their post-incubation appearance. XRD analysis revealed that the composition of the residual granules changed during the incubation from 100% polyhalite to 100% gypsum ($CaSO_4 \cdot 2H_2O$). This was explained by the incongruent dissolution of polyhalite whereby K and Mg were completely released while >50% of Ca and S remained in the granule, forming gypsum. In conclusion, polyhalite dissolution depends on the matrix (soil and 10 mM NaCl). The complete release of K and Mg from the polyhalite meets short-term crop demands, while the slow solubilisation of the residual granules, consisting of gypsum, may provide long-term agronomic value, enhancing crop growth, particularly in Ca- and S-deficient soils.





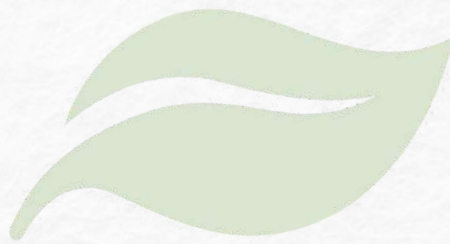
PO10_6 SURFACE LIMING AND FERTILIZATION WITH GRANULATED POLYHALITE FOR CROP GRAIN PRODUCTION UNDER A NO-TILL CROPPING SYSTEM

Eduardo Fávero Caires (Brazil)¹; Murilo de Oliveira Delgobo (Brazil)¹; Vanderson Modolon Duarte (Brazil)¹; Elaine Margarete Guimarães (Brazil)¹; Carlos Eduardo Serber (Brazil)¹; Lino Ricardo Rios Furia (Brazil)²

1 - State University of Ponta Grossa; 2 - Research and Development, Anglo American

No-till systems have gathered momentum in world agriculture in the face of a new paradigm of "sustainable production intensification". Soil acidity limits crop yields across large areas of the globe. The addition of base cations to acidic soils can increase microbial growth, thus aiding with carbon sequestration in these soils. Polyhalite has emerged as an alternative source of K that also contains Ca and Mg as sulfates in its composition. A field experiment was performed in Parana State, Brazil, on an acid Oxisol under no-till, to evaluate the effects of surface liming and fertilization with granulated polyhalite on crop grain yields, biological activity, and soil chemical properties. The cropping sequence consisted of two cycles of a black oat–maize–wheat–soybean succession. Black oat was grown as a cover plant. A randomized complete block design was used, with four replications in a 4 × 2 factorial arrangement. The treatments consisted of a control and K applications as muriate of potash (MOP), MOP + elemental S, and polyhalite on plots without and with surface application of dolomitic lime. Total grain yield and biomass-C input from crop residues were higher with both the surface liming and the application of polyhalite. Applying polyhalite on unlimed plots increased total grain yield and total biomass-C from crop residues by 12% and 11% compared to applications of MOP, with or without elemental S, and by 44% and 42% compared to the no-K control, respectively. On limed plots, applications of polyhalite and MOP, with or without elemental S, provided similar increases in total grain yield and total biomass-C input from crop residues compared to the no-K control treatment. Surface liming provided greater enzyme activities of β -glucosidase and arylsulfatase. Enzyme activity of β -glucosidase was not changed by applying K fertilizers. Enzyme activity of arylsulfatase was in the following order according to the application of fertilizers: MOP > polyhalite > MOP + elemental S. While the soil organic carbon pools stocks as well as the enzyme activities of β -glucosidase and arylsulfatase were more related to surface liming, the total grain yield and the biomass-C input from crop residues were more related to the applications of polyhalite on unlimed plots and MOP + elemental S on limed plots. The results of suggest that applications of lime, MOP, and elemental S could be replaced by using polyhalite in a single application, resulting in economic gain in the correctives and fertilizers management.





PO10_7 RESOLVING THE POTASSIUM PUZZLE IN CANADA USING PLANT ROOT SIMULATOR (PRS®) TECHNOLOGY

Ken Greer (Canada)¹; Eric Bremer (Canada)¹

¹ - Western AG Group of Companies

Potassium (K), first discovered as an element over 200 years ago, remains a puzzle when considering sufficiency for plant productivity and crop response to fertilizer K. Many special symposiums have addressed the Frontiers in K Research. In 2015, the outcomes of one such symposium hosted by the International Plant Nutrition Institute clearly stated that the “Overall goal of soil K assessment (is) to characterize the soil supply (flux). Once we know the soil supply, we can begin to estimate how much K we need to apply”.

Although measuring the flux of bioavailable K from soil pools can be easily done using resin methods such as the Plant Root Simulator (PRS®) probes, the question of sufficiency level and plant response to fertilizer K still remains.

Our poster will show that this nexus between soil supply, plant demand/uptake and year to year responsiveness to added K fertilizer can be solved using PRS® flux measurements and an integrated modeling approach. Based on the foundational work of Barber (1995), the K flux to a modeled root system can be integrated, thus predicting season-long K uptake. Our PRS® CropCaster® method uses a “dynamic K response” to account for the interaction of evapotranspiration stress, plant K sufficiency and K fertilizer response.





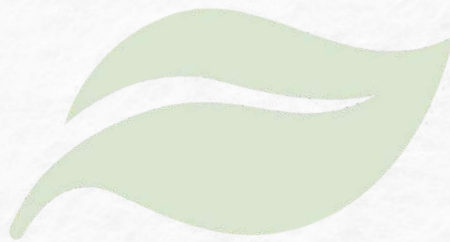
PO11_1 SULFUR-DRIVEN RESTRUCTURING OF THE FUNGAL MICROBIOME IN SUGAR BEET REVEALED THROUGH ITS METABARCODING

MARIA CRISTINA DELLA LUCIA (Italy)¹; Saptarathi Deb (Italy)¹; claudia chiodi (Italy)¹; matteo borella (Italy)¹; silvia celletti (Italy)²; andrea squartini (Italy)¹; Giuseppe concheri (Italy)¹; Piergiorgio stevanato (Italy)¹

¹ - Università degli Studi di Padova; ² - Università di Torino

Sulfur (S) is an essential macronutrient involved in key metabolic processes and its availability can influence plant-associated microbial communities. However, its role in shaping the fungal microbiome of sugar beet (*Beta vulgaris* L.) remains poorly understood. This study examined the effect of S availability on fungal communities associated with the roots and leaves of sugar beet seedlings. Seedlings were grown in a climate-controlled chamber using two growing systems: hydroponics and pots containing a soil-sand mixture. In the hydroponic system, seedlings were grown for eight days in nutrient solutions either lacking sulfate (S-deprived) or supplemented with 100 μM MgSO_4 (S-supplied). In the pot-based system, seedlings were grown for four weeks under three distinct S treatments: 0 μM MgSO_4 , 50 μM MgSO_4 , and 500 μM MgSO_4 . Roots and leaves were sampled separately. For pot-grown seedlings, roots were harvested together with the adhering soil representing the root-associated rhizosphere compartment. DNA was extracted and the fungal ITS1 region was amplified using primers ITS1-1F-F/R. Sequencing data were processed using QIIME2 and taxonomy was assigned with the UNITE v10 database. Beta diversity analysis (Bray-Curtis dissimilarity, NMDS ordination) revealed that growing conditions were the main driver of fungal community structure. In hydroponic samples, significant clustering based on S availability indicated sulfur-dependent shifts in fungal composition. No significant differences in beta diversity were detected among S treatments in pot-grown seedlings. Alpha diversity analysis showed that S significantly affected root-associated fungal diversity in hydroponics, but not in leaves. In pot-grown seedlings, alpha diversity metrics (Chao1, Shannon, Simpson) showed no significant differences across S treatments. Linear Discriminant Analysis Effect Size (LEfSe) identified distinct fungal genera enriched under different S regimes in the roots and rhizosphere of pot-grown seedlings. *Peziza*, a saprotrophic decomposer, was enriched under S deprivation. High S supply favored *Mortierella*, *Aspergillus*, and *Humicola*, while low S favored *Iodophanus* and *Plectosphaerella*, with the latter including potential plant pathogens. These findings suggest that S availability influences fungal diversity in sugar beet, especially under soil-free conditions. This highlights the context-dependent nature of plant-microbiome interactions and suggests a role for S in shaping fungal community structure. Future work will explore the functional roles of these fungal taxa identified and their correlation with plant health, aiming to better understand microbiome-mediated effects of S nutrition on crop performance.





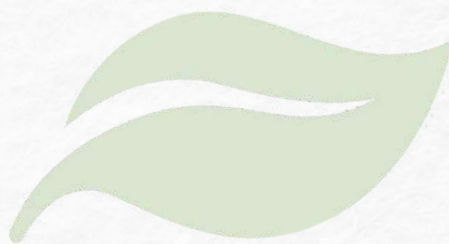
PO11_2 **STUDY OF COUMARINS TRAFFICKING IN ARABIDOPSIS THALIANA**

Rossile Alice (France)¹; Li Meijie (France)¹; Berger Nathalie (France)¹; Watanabe Shunsuke (Japan)²; Dubos Christian (France)¹

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Iron is an essential micronutrient for plant growth and development, as well as for crop productivity and the quality of their derived products. Despite its abundance in the Earth's crust, iron is often poorly available to plants, particularly at neutral to alkaline pH, which account for one-third of cultivated lands. To cope with this poor bioavailability, plants have evolved sophisticated mechanisms to mine iron from the soil. Recently, it has emerged that non-grass species secrete iron-mobilizing coumarins (specialized metabolites derived from the phenylpropanoid pathway) by the plant root system via the PDR9/ABCG37 transporter to improve Fe uptake. The next challenge is now to characterize the dynamic of coumarin transport by identifying and characterizing the molecular actors involved. For this purpose, candidate genes will be selected following two complementary strategies: (i) the analysis of large-scale expression data sets and (ii) the set-up of a genetic screen. Recent results and findings will be presented and discussed.





PO11_5 CHARACTERIZATION OF CUCUMBER RESPONSE TO IRON AND PHOSPHORUS DEFICIENCY

Michele Canciani (Italy)¹; Arianna Lodovici (Italy)¹; Fabio Marroni (Italy)¹; Roberto Pinton (Italy)¹; Luigi Lucini (Italy)²; Laura Zanin (Italy)¹; Nicola Tomasi (Italy)¹

¹ - University of Udine; ² - Università Cattolica del Sacro Cuore

In alkaline condition, both Iron (Fe) and Phosphorus (P) are scarcely available for plant acquisition leading to nutritional stresses in crops. In recent years, strong cross-connections between plant responses induced by Fe and/or P deficiency have been reported in the literature, suggesting a close interplay in the regulation and functionality of Fe- and P-acquisition mechanisms. Indeed, some genes induced in response to low-available P are also upregulated in low-Fe conditions and conversely, some components of the P acquisition are enhanced in Fe deficiency. This synergism between Fe- and P-deficiency responses might be taken advantage to improve the acquisition of these poorly bioavailable nutrients. To investigate the interplay between Fe- and P-nutritional pathway *Cucumis sativum* plants were hydroponically grown under Fe and/or P deficiency (+Fe+P, +Fe-P, -Fe+P, -Fe-P; for three weeks). In roots, the transcriptomic profiles indicated that when plants were exposed to -Fe-P, more than 5500 genes were differentially modulated compared to +Fe+P of which about 17% exclusively modulated by -Fe-P and not shared with -Fe+P or +Fe-P. Metabolomic analyses showed also an induction of secondary metabolites' and amino acids' and hormone synthesis. Using hyperspectral imaging analysis, we discriminate between Fe deficiency and P deficiency focusing on reflection intensity changes in specific wavelength bands. Key wavelength bands were selected using Competitive Adaptive Reweighted Sampling (CARS) algorithm. Using these wavelengths and two different classification algorithms, Support Vector Machine (SVM) and Linear Discriminant Analysis (LDA), it was possible to develop a classification model to discriminate between the two deficiencies with an accuracy of the model up to 100% of the test data. Next soluble form of either Fe or P were resupplied, first results indicated that -P and -Fe-P plants exhibited an enhanced accumulation of Fe, and the reciprocal is also enhanced (P in -Fe and -Fe-P). These findings confirm that there is a significant interplay between the responses of the plant to Fe and P deficiency. Furthermore, the transcriptomic data suggest that the double deficient plants have a specific response that it is not display by either single deficient plant. Fundings CEDRIC project is funded by Interreg Italia Austria, DM1062/2021-Tomasi, DM737/2021-Tomasi and Agritech National Research Center are funded by European Union Next-GenerationEU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR)–MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.4–D.D. 1032 17/06/2022, CN00000022) and the Departmental Strategic Plan (PSD) of the University of Udine - Interdepartmental Project on Artificial Intelligence (2020-25).





PO11_6 MG APPLICATION PROMOTES CROP YIELD AND QUALITY

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Magnesium (Mg) is an essential nutrient for a wide array of fundamental physiological and biochemical processes in plants. However, how Mg application affects crop production and the underlying mechanism are still largely unclear.

Taking advantage of meta-analysis, greenhouse pot experiments, and biochemical and molecular approaches, we find that Mg has become a limiting nutrient for optimum crop production as a multifaceted result of the introduction of high-yielding fertilizer-responsive cultivars, intensive cropping without replenishment of Mg, soil acidification, and exchangeable Mg leaching. In particular, 55% of arable lands in China are Mg-deficient (<120 mg kg⁻¹ soil Exchangeable Mg). Meta-analysis shows that the mean value of yield increases derived from Mg application is 8.5%, when combining all yield measurements together, regardless of the crop species and cultivar, soil condition, and other factors. The stimulatory effect increases to 11.3% when soil pH is lower than 6.5.

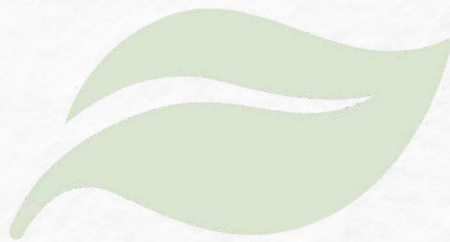
Mg also plays important roles in maintaining root growth and promoting crop nutritional quality. Under Mg limitation, systemic down-tuning of gene expression in the auxin signaling pathway preconditions a smaller tomato root system. The reduced biosynthesis and accumulation of carbohydrates and carotenoids decrease fruit yield and quality.

Transcriptome profiling indicates that 119, 279, and 180 genes are differentially expressed under Mg limitation at the green mature, breaker, and red mature stages, respectively. The low accumulation of total free amino acids (30.5–62.3%) and soluble proteins (25.0 – 22.7%) in the fruit aligns with the differential expression of genes involved in amino acid transport/metabolism, while Mg application enhances lycopene accumulation in fruits by increasing the enzyme activity and expression level of lycopene biosynthesis-related enzyme genes.

Furthermore, the expression of transcription factor MYB6 is up-regulated when WRKY8 is down-regulated in fruits with Mg application. Functional disruption of MYB6 leads to lower levels of lycopene accumulation whereas loss of WRKY8 function mutant lines enhance lycopene accumulation. The WRKY8 is directly activated by MYB6, and WRKY8 binds the promoter of MYB6 to repress its expression. Thus, the MYB6 and WRKY8 negative feedback loop may fine-tune lycopene accumulation during fruit ripening under Mg application.

Our findings pave the way towards a better understanding of Mg physiological functions and its potential in promoting quality crop production towards sustainable agriculture development via Mg-efficient breeding and responsible nutrient management programs.





PO11_7 TRANSCRIPTION FACTOR ATNAC002 POSITIVELY REGULATES CU TOXICITY TOLERANCE IN ARABIDOPSIS THALIANA

Wen Zhang (China)¹; Venuste Munyaneza (China)¹; Surya Kant (China)¹; Hongmei Cai (China)¹; Chuang Wang (China)¹; Lei Shi (China)¹; Sheliang Wang (China)¹; Fangsen Xu (China)¹; Guangda Ding (China)¹

¹ - College of Resources and Environment/Microelement Research Center/Key Laboratory of Arable Land Conservation (Middle and Lower Reaches of Yangtze River), Ministry of Agriculture and Rural Affairs, Huazhong Agricultural University, 430070, Wuhan, China

Copper (Cu) is an essential micronutrient for plant growth and development, but environmental Cu pollution has become increasingly severe, adversely affecting both ecosystems and crop productivity. In this study, we identified the AtNAC002 gene as a positive regulator of Cu toxicity in *Arabidopsis thaliana*. We found that AtNAC002 expression was induced by Cu excess, and the *atnac002* mutant was Cu-sensitive, accumulating more Cu than the wild-type. Additionally, *atnac002* mutants exhibit reduced activities of antioxidant enzymes (SOD, POD, and CAT), leading to increased levels of reactive oxygen species and malondialdehyde, which decrease Cu resistance. AtNAC002 might play a role in vacuolar and mitochondrial Cu compartmentalization by regulating genes involved in Cu detoxification, specifically COX11 and HCC1. Furthermore, AtNAC002 was implicated in flavone and flavanol biosynthesis, with the *atnac002* mutant showing reduced flavonoid content. Our findings suggest that AtNAC002 is integral to the regulation of Cu toxicity tolerance in *Arabidopsis*. This knowledge is critical for advancing our understanding and offers potential molecular breeding targets to enhance plant performance under Cu excess, which is significant for improving global food security and forest restoration.





PO11_8 PHOSPHORUS NUTRITIONAL STATUS GENE EXPRESSION SIGNATURE IDENTIFIED THROUGH CONTROLLED-RELEASE FERTILIZERS PLANT RESPONSES.

Claudia-Anahí Pérez-Torres (Mexico)¹; Eva García-Ilizaliturri (Mexico)³; Carlos Espinoza-González (Mexico)⁴; Emanuel Villafán (Mexico)³; Mizraim Olivares-Miranda (Mexico)³; Antonio Cárdenas-Flores (Mexico)⁵; Enrique Ibarra-Laclette (Mexico)³

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Understanding plant nutrition is essential for developing new strategies that sustainably enhance agricultural productivity while safeguarding natural ecosystems. Phosphorus is a vital macronutrient for crop growth and development. Although plentiful in the lithosphere, the form that plants utilize, inorganic orthophosphate (Pi), is insoluble and diffuses slowly through soils. Consequently, these low concentrations of available soil phosphorus require constant applications of phosphate fertilizers. However, due to their high reactivity, plants poorly uptake these fertilizers, leading to significant environmental issues such as soil degradation and water eutrophication. In the last few years, it has been demonstrated that slow or controlled-release fertilizers can enhance efficiency while reducing ecological impacts. Initially, synthetic polymers were proposed as encapsulating matrices for developing these fertilizers; however, their long-term use has led to microplastic accumulation in the soil, the effects of which are still poorly understood.

In contrast, using natural polymers produces biodegradable, biocompatible fertilizers that are either non-toxic or minimally toxic. Recently, by spray drying process, we have developed innovative and promising controlled-release fertilizers using natural polymers such as chitosan, waxes, starch, cellulose, or some of their derivatives. The release rate from these microcapsules depends on various factors, including the physicochemical properties of the polymer coating^{1,2}. In some cases, plants recognize these natural polymers and trigger metabolic responses, enhancing growth¹. Consequently, using transcriptomic approaches and *Arabidopsis thaliana* as model organism, we have analyzed physiological and molecular responses to conventional and some of our innovative controlled-release fertilizers. This allows us to explain why some fertilizers promote plant growth and development through the synergistic effect of the fertilizer and its coating. Additionally, we have identified specific responsive genes and propose could be used as a gene signature to diagnose and prognosticate plant nutritional status and even determine the exact dose of fertilizer required for particular crops.

Acknowledgments

This study was supported by the Secretaría de Ciencia, Humanidades, Tecnología e Innovación (SECIHTI) [grant number CF-2023-G-947].

References

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PO11_9 EXCESSIVE TILLERING IN MAIZE: EFFECTS OF DIFFERENT FERTILISATION TREATMENTS IN THE BERLIN-DAHLEM LONG-TERM FIELD EXPERIMENTS DIII AND IOSDV

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¹ - Albrecht Daniel Thaer-Institute of Agricultural and Horticultural Sciences, Faculty of Life Sciences, Humboldt-Universität zu Berlin, Invalidenstraße 42, 10115 Berlin, Germany

Introduction

Tillering can increase intraplant competition and cause uneven maturation in maize (*Zea mays* L.). Domesticated genotypes are generally unbranching and the study of regulatory networks of maize shoot architecture is an active field of research. In 2024, unprecedented tillering was observed in two long-term experiments (LTEs) designed to test the effects of nitrogen, phosphorous, lime and organic fertilisation.

Purposes and Aims

We tested the effects of fertilisation and genotype on tillering of maize under the conditions of an exceptionally warm spring with sufficient soil moisture. The following main hypotheses were tested: H1: Omitting mineral nitrogen or phosphorous fertilisers causes reduced tillering, but the effects depend on the organic fertilisation treatment. H2: Excessive tillering cannot be attributed to a single genotype.

Methods

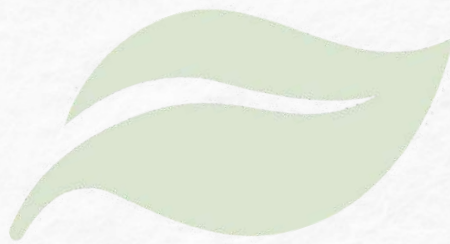
Observations from the weather-station in Berlin-Dahlem (Germany) were obtained and compared with average values for the reference period 1991-2020. Numbers of tillers in the two LTEs, DIII and IOSDV, were determined. Linear mixed models were used to evaluate the effects of mineral and organic fertilisation treatments on the numbers of tillers. The cultivar grown in both LTEs was included in a variety trial with 39 genotypes at the Thyrow field station outside Berlin and numbers of tillers were determined.

Results and Discussion

A maximum of five tillers per plant was observed, which could not be attributed to pests. Omitting mineral fertilisers was significantly ($p < 0.05$) associated with reduced lateral branching in both LTEs. The effects of mineral fertilisation did depend on organic fertilisation treatments, with differences between the two LTEs. Potential reasons and implications will be discussed. The cultivar that was grown in the LTEs showed an average tendency to form lateral shoots in the variety trial, indicating that the observations from the LTEs are not unique to this genotype. Thus, both hypotheses could be confirmed. The abnormal tillering was attributed to the unusual weather conditions after sowing because it could not be explained by changes in the LTEs or by a particular genotype. Whether the tillering had negative impacts on maturation or yield formation has yet to be tested.

Conclusions

Warmer temperatures early in the vegetation period are likely to re-occur as a consequence of climate change. Thus, the effects of abnormal tillering on yield formation should be evaluated and a stronger emphasis on phenotyping for tillering in maize candidates might be appropriate.



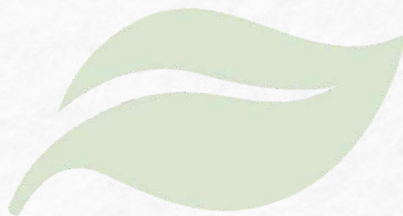
PO11_10 **SPX1-RHD6/RSL1 MODULE NEGATIVELY REGULATES ROOT HAIR ELONGATION UNDER LOW PHOSPHORUS CONDITIONS IN ARABIDOPSIS THALIANA**

Xinyu Yang (China)¹; Yi Ding (China)³; Tao Wu (China)¹; 2; Pan Yuan (China)¹; 2; Sheliang Wang (China)¹; 2; Chuang Wang (China)²; Fangsen Xu (China)¹; 2; Lei Shi (China)¹; 2

1 - National Key Laboratory of Crop Genetic Improvement, Huazhong Agricultural University, Wuhan 430070, China; 2 - Microelement Research Center, Key Laboratory of Arable Land Conservation (Middle and Lower Reaches of Yangtze River), Ministry of Agriculture and Rural Affairs, Huazhong Agricultural University, Wuhan 430070, China; 3 - College of Resources and Environment, Huazhong Agricultural University, Wuhan 430070, China

Phosphate (Pi) limitation severely restricts plant growth. Although root hair elongation is a recognized adaptive response to Pi starvation, the direct molecular link between Pi signaling and the root hair developmental process under Pi deficiency remains unclear. In this study, we used Arabidopsis mutants, protein interaction assays (Y2H, LCI, pull-down and Co-IP), and transcriptional activity analyses (qRT-PCR, dual-luciferase reporter system and EMSA) to elucidate how SPX1 modulates the activity of RHD6 and RSL1, which are key transcription factors driving root hair development in response to Pi availability. SPX1 loss-of-function mutants exhibited elongated root hairs, which was very similar to Pi starvation responses. *spx1rhd6rsl1* triple mutant resembled the defective root hair phenotype of *rhd6rsl1*, indicating that SPX1 acted in the upstream of RHD6/RSL1 to regulate root hair development. Under Pi sufficient conditions, SPX1 physically interacts with RHD6/RSL1 in an inositol polyphosphate (InsP6)-dependent manner, repressing the ability of them to activate downstream genes. Pi deficiency disrupts this interaction by depleting InsP6, thereby releasing RHD6/RSL1 to promote root hair elongation. Our work identifies SPX1 as a Pi-dependent molecular switch that directly links Pi signaling to root hair development, providing new insights into the molecular and physiological basis of root plasticity.





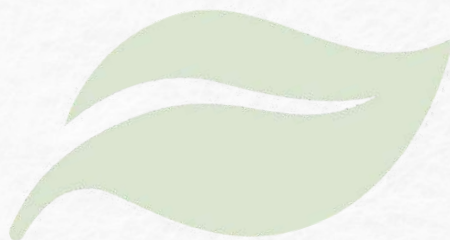
PO11_11 GENOME-WIDE ASSOCIATION STUDY IDENTIFIES SIGNIFICANT GENETIC LOCI FOR YIELD-RELATED TRAITS IN RESPONSE TO LOW PHOSPHORUS STRESS IN BRASSICA NAPUS

Lei Shi (China)¹; Haijiang Liu (China)¹; Chuang Wang (China)¹; Guangda Ding (China)¹; Hongmei Cai (China)¹; Sheliang Wang (China)¹; Fangsen Xu (China)¹; John P. Hammond (UK)²; Philip J. White (UK)³

1 - National Key Laboratory of Crop Genetic Improvement, Huazhong Agricultural University, Wuhan, 430070, China; 2 - School of Agriculture, Policy and Development, University of Reading, Reading RG6 6AR, UK; 3 - Ecological Science, The James Hutton Institute, Invergowrie, Dundee DD2 5DA, UK

Phosphorus (P) is an essential macronutrient for plant growth and development. However, phosphate in the soil is easily fixed by the metal cations to form insoluble compounds, which are difficult to be directly absorbed and used by plants. P deficiency reduced the plant growth, plant height, branch number, and finally decreased the seed yield of *B. napus*. Therefore, revealing the genetic mechanism of *B. napus* tolerant to suboptimal P conditions, identify P - efficient candidate genes, and to breed P -efficient varieties are important ways to sort out the "phosphorus crisis". In this study, 403 varieties among an association panel of *B. napus* collected from all over the world were used conducted the field experiments to investigate the seed yield (SY), plant height (PH), branch number (BN) and seed weight (SW) at low (LP) and sufficient (SP) P conditions. Based on the SNPs developed by whole-genome resequencing, GWAS was performed for the above traits. A total of 1773, 686, 770 and 667 SNPs significantly associated with SY, PH, BN and SW were identified at SP, respectively. A total of 476, 131, 34 and 420 SNPs significantly associated with SY, PH, BN and SW were identified at LP, respectively. Among significant SNPs associated with seed yield and yield-related traits at LP, chrC07_39807169 and chrC09_14194798 were identified simultaneously for SY_LP in two trials, and two candidate genes (*BnaC07.ARF9* and *BnaC09.PHT1;2*) significantly induced by P deficiency were identified by combined GWAS with qRT-PCR. There were significant differences in the gene expression level of *BnaC07.ARF9* and *BnaC09.PHT1;2* between P -efficient and -inefficient varieties at LP. SY_LP had a significant positive correlation with the gene expression level of both *BnaC07.ARF9* and *BnaC09.PHT1;2*. *BnaC07.ARF9* and *BnaA01.PHR1* could directly bind the promoters of *BnaA01.PHR1* and *BnaC09.PHT1;2*, respectively. In addition, there was significant positive correlation in the relative expression level between *BnaC07.ARF9* and *BnaA01.PHR1* at LP in P - efficient and -inefficient varieties. There was a significant positive correlation in the relative expression level between *BnaA01.PHR1* and *BnaC09.PHT1;2* in P -efficient and -inefficient varieties at LP. The above results indicate that the function of *BnaC07.ARF9* in P efficiency could be attributed to regulating *BnaC09.PHT1;2* by regulating *BnaA01.PHR1*.





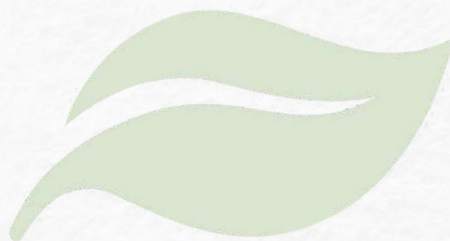
PO11_12 GENOME-WIDE ASSOCIATION STUDY IDENTIFIED BNAPAPI7 GENES INVOLVED IN EXOGENOUS ATP UTILIZATION AND REGULATING PHOSPHOROUS CONTENT IN BRASSICA NAPUS

Lei Shi (China)¹; Hao Li (China)¹; Chuang Wang (China)¹; Guangda Ding (China)¹; Hongmei Cai (China)¹; Sheliang Wang (China)¹; Fangsen Xu (China)¹; Ying Zhang (China)²; John P. Hammond (UK)³

1 - National Key Laboratory of Crop Genetic Improvement, Huazhong Agricultural University, Wuhan, 430070, China; 2 - Hunan Institute of Agricultural Environment and Ecology, Hunan Academy of Agricultural Sciences, Changsha 410125, Hunan, China; 3 - School of Agriculture, Policy and Development, University of Reading, Reading RG6 6AR, UK

Deficiency of available phosphorus (P) in soil has become an important limiting factor for yield and quality in oilseed rape (*Brassica napus*). In many soils, organic P (Po) is the main component of the soil P pool. Po must be hydrolyzed to inorganic P (Pi) through acid Phosphatase (APases), and then taken up by plants. However, root-secreted APases (SAP) activity, as a quantitative trait, plays an important role in soil Po utilization; those genetic loci are not clear in *B. napus*. In this study, we performed a genome-wide association study for SAP activity under Pi-deficiency using a panel of 350 accessions of *B. napus* and more than 4.5 million polymorphic single nucleotide polymorphisms (SNPs). Thirty-five significant SNPs associated with SAP activity were identified. BnaA01.PAP17 (BnaA01g27810D) was a candidate gene underlying lead SNP (ChrA01_19576615). We experimentally verified that both BnaA01.PAP17 and its three homologous genes had similar expression pattern in response to Pi-deficiency. The dynamic changes in BnaPAP17s expression level were opposite to those of Pi concentration in both roots and leaves, suggesting their potential utility as Pi marker genes in *B. napus*. Transient expression of BnaPAP17s in tobacco leaves proved that BnaPAP17s were located in the apoplast as secreted APases. The overexpression of BnaPAP17s enhanced SAP activity in response to Pi-deficiency and resulting in increased P content in plants when ATP was supplied as the sole P resource. Taken together, these results suggest that BnaPAP17s contributed to SAP activity, thus having a function in extracellular Po utilization in *B. napus*.





PO11_13 THE BNAMIR827–BNAA09.NLA1–BNAPHT1 MODULE REGULATES PHOSPHATE HOMEOSTASIS, POLLEN VIABILITY, AND SEED YIELD IN BRASSICA NAPUS

Lei Shi (China)¹; Chuang Wang (China)¹; Sheliang Wang (China)¹; Hongmei Cai (China)¹; Zhu Liu (China)¹; Guangda Ding (China)¹; Fangsen Xu (China)¹; John P. Hammond (UK)²; Surya Kant (Australia)³

1 - National Key Laboratory of Crop Genetic Improvement, Huazhong Agricultural University, Wuhan 430070, China; 2 - School of Agriculture, Policy and Development, University of Reading, Reading RG6 6AR, UK; 3 - School of Agriculture, Biomedicine & Environment, La Trobe University, AgriBio, Ring Rd, Bundoora, Vic 3083, Australia

Phosphorus (P) is an essential macronutrient for the growth and yield of crops. However, there is limited understanding of the regulatory mechanisms of phosphate (Pi) homeostasis, and its impact on growth, development, and yield-related traits in *Brassica napus*. Here, we identified four NITROGEN LIMITATION ADAPTATION1 (BnaNLA1) genes in *B. napus*; their expression was predominant in roots and suppressed by Pi starvation-induced Bnamir827. All the BnaNLA1 proteins have similar sequences, subcellular localizations, and abilities to rescue the growth defects of the *atnla1* mutant. One of the genes, BnaA09.NLA1, is expressed abundantly in roots, and also in old leaves, anthers, and pollen. Knocking out of BnaNLA1 genes or overexpressing Bnamir827 resulted in increased concentrations of Pi in leaves and stamens and reduced pollen viability, thereby negatively impacting seed yield. Bimolecular fluorescence complementation (BiFC) and split-ubiquitin yeast two-hybrid (Y2H) analyses demonstrated that BnaA09.NLA1 interacted with seven Pi transporters highly expressed in roots and/or anthers (i.e. BnaPT8/10/11/27/35/37/42) to regulate Pi uptake and Pi allocation in anthers. Taken together, this study demonstrates that the Bnamir827–BnaA09.NLA1–BnaPHT1 module is involved in regulating Pi uptake and Pi allocation in floral organs, which is vital for the growth, pollen viability, and seed yield of *B. napus*.





PO11_14 IMPROVING THE UTILIZATION OF P IN ANIMAL MANURED SOILS USING TRANSGENIC PLANTS THAT EXPRESS A MICROBIAL PHYTASE

Timothy George (UK)¹; Lawrie Brown (UK)¹; Molly Brown (UK)¹; Peter Gregory (UK)²; Alan Richardson (Australia)³; Paul Hadobas (Australia)³

1 - The James Hutton Institute;; 2 - The University of Reading; 3 - CSIRO Agriculture, Canberra, Australia

Introduction

Sustainability of P is a major global issue with the combined effects of variability in costs for mineral fertilisers and their profligate use leading to both limitations and excess of P across different agricultural systems. Systems where animal manures are used for fertilisation often accumulate P to a point beyond where excess P contributes to eutrophication. Increasing the availability of organic forms of P, such as inositol phosphates that can be a significant component of the organic P present in manure and soil, should be an important research target.

Purpose

We investigated whether *Nicotiana tabacum* plants that express phytase either constitutively or under an inducible promoter show increased capacity to acquire P from soils that have received long-term applications of manure from either monogastric or ruminant sources. This allows us to speculate whether there is potential to promote the production of phytase in the rhizosphere to improve the efficiency and environmental impact of agricultural enterprises which rely on animal manures for fertilisation.

Methods

We tested whether transgenic *N. tabacum* plants which express a fungal phytase gene (*phyA* from *Aspergillus niger*), either constitutively or under control of a root-hair P-inducible promoter, were able to acquire more P from soils with long-term supplementation with manures.

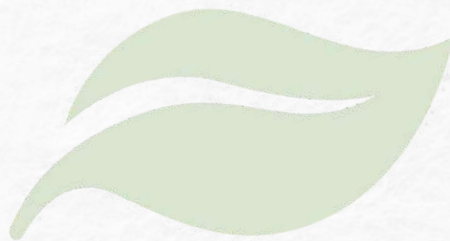
Results

Plants that constitutively expressed phytase had enhanced root phytase activity and ability to accumulate up to 4.2-fold more P than control plants when grown in soils supplemented with monogastric animal manures. In contrast, the same plants did not accumulate more P in soils supplemented with ruminant manure.

Conclusions

These results suggest that P-use efficiency could be improved in systems fertilised with monogastric animal manure by increased phytase activity in the rhizosphere enhancing the use of legacy P and reducing the need for continued addition of inorganic fertilisers.





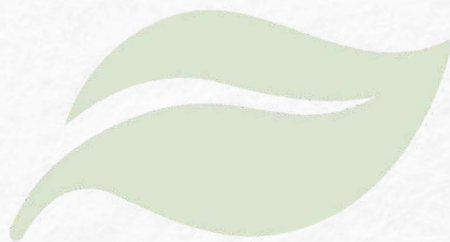
PO12_2 BIOACCUMULATION OF MOLYBDENUM IN IMPERATA CYLINDRICA PLANTS FROM MINING TAILINGS WATER

Catalina Vidal Perez (Chile)¹; Felipe González (Chile)²; Christian Snatander (Chile)¹; Rodrigo Pérez (Chile)¹; Antonieta Ruiz (Chile)¹; Yasna Tapia (Chile)³; Pablo Cornejo (Chile)¹

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Tailings water constitutes the aqueous component of the waste generated during the copper (Cu) extraction process. A high concentration of potentially toxic elements (PTEs) in these waters can cause significant environmental damage, including contamination of water resources, loss of vegetation cover, and soil erosion in areas where these residues are deposited. The effective treatment of tailings components and the reuse of their water are matters of both environmental and economic interest, particularly considering the vast volumes of tailings produced in mining activities—approximately 30 tons of tailings per ton of extracted ore. In this context, the use of plant species that accumulate PTEs in their tissues represents a promising alternative to explore their potential as filters for these contaminants. Such plants could contribute to the purification of mining waters, making them suitable for agricultural and forestry applications. In this study, we hypothesize that *Imperata cylindrica* could function as a biofilter for PTEs present in mining waters. The water used in this experiment was collected from the Ovejería tailings pond, located in the Metropolitan Region of Chile. The experimental design included a treatment in which *I. cylindrica* was cultivated in a hydroponic system with tailings water for 30 days, alongside a control group where the plants were grown under identical conditions but with a nutrient solution instead of tailings water. The chemical characterization of the mining waters revealed that the only PTE exceeding the Chilean rule (NCh 1333) for irrigation water was molybdenum (Mo), with a concentration of 0.701 mg/L. The treatment with tailings water did not decrease biomass production in *I. cylindrica*, nor did it have a negative impact on cellular lipid peroxidation. Mo accumulation showed significant differences only at the root level, with values of 67 mg Mo kg⁻¹ in the treatment exposed to PTEs and 12.4 mg Mo kg⁻¹ in the control treatment. These results suggest that *I. cylindrica* has potential as a bioremediation agent for PTEs such as Mo, particularly by utilizing its root tissue as an accumulator of these elements.





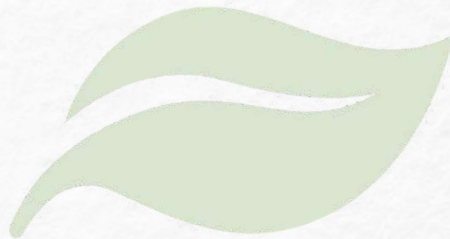
PO12_3 DIMENSIONALITY REDUCTION FOR ESTIMATING NUTRIENT CONTENTS IN SOYBEAN LEAVES USING NIR SPECTROSCOPY

Alaine Margarete Guimarães (Brazil)¹; Pablo Henrique Ferreira (Brazil)¹; Eduardo Fávero Caires (Brazil)¹

¹ - State University of Ponta Grossa

Near-infrared (NIR) spectroscopy may be a viable alternative for estimating leaf nutrient contents. This study aimed to estimate nutrient contents in soybean leaves using dimensionality reduction techniques in databases obtained by NIR spectroscopy. The database consisted of 231 soybean leaf samples collected from six experimental areas in the Campos Gerais region, Paraná, Brazil. Nutrient contents were obtained by sulfuric digestion and determination by the Kjeldahl method for N, nitric-perchloric digestion and determination by colorimetry for P, flame photometry for K, barium sulfate turbidimetry for S, atomic absorption spectroscopy for Ca, Mg, Cu, Fe, Zn and Mn, and incineration and colorimetric determination by the azomethine H method for B. A FOSS NIR spectrophotometer, model DA 1650, was used, comprising wavelengths from 1,100 nm to 1,650 nm with a reading interval of 2 nm, totaling 286 attributes per sample. Artificial intelligence methods of feature selection were applied from the SynthesisFS tool, which uses a set of algorithms involving several selection techniques and generates an attribute ranking based on the synthesis of the results obtained from the different techniques. Once ranked, the attributes were selected based on the one that obtained the highest value up to a limit of 10% and 20% of the first attribute selected. The database containing all attributes was also used. Three algorithms were used to generate estimative models: M5Rules, SMOReg and LinearRegression. Correlation coefficient (r) with a threshold of 0.70 was used to evaluate the generated models. Without the use of dimensionality reduction, correlations above 0.70 were obtained for N, P, K, Mg, S, Cu and Mn, always with the SMOReg algorithm, with emphasis on K ($r = 0.78$). M5Rules algorithm achieved correlations above the threshold for P, K, S and Mn, with $r = 0.79$ for P. When applying dimensionality reduction to up to 10%, the best result was for K, using the LinearRegression algorithm, obtaining $r = 0.84$. With dimensionality reduction at 20%, six nutrients (N, P, K, S, Fe and Zn) among the 11 analyzed had generated models considered satisfactory, regardless of the algorithm used. Using the LinearRegression algorithm, the highest correlations were obtained, with $r = 0.88$ for S and $r = 0.92$ for both P and K. Therefore, nine nutrients (N, P, K, Mg, S, Cu, Mn, Fe, Zn) could be satisfactorily estimated considering the criterion adopted. The feature selection method at 20% presented the best estimates, especially for S, P and K.





PO12_4 NUTRIENT EFFECTS OF GLACIAL ROCK FLOUR IN TEMPERATE AGRICULTURE: INSIGHTS FROM A DANISH FIELD TRIAL

Charlotte Vermeiren (Denmark)¹; Saulo Augusto Quassi de Castro (United States)²; 1; Lars Stoumann Jensen (Denmark)¹

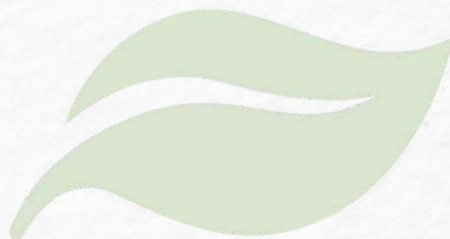
1 - University of Copenhagen, Department of Plant and Environmental Sciences; 2 - Louisiana State University, LSU AgCenter, Dean Lee Research and Extension Center

Rock flour is recognised as a promising soil amendment in agriculture that can promote crop yields and contribute to climate change mitigation. Enhanced weathering (EW) of these materials can stimulate CO₂ drawdown by capturing it in bicarbonate alkalinity, while the released nutrients can improve the fertility of the soil. In Greenland, rock flour is produced in vast quantities by glacial movement of the kilometer-thick Inland Ice sheet, yielding ultrafine particles by natural grinding and sorting of minerals. Glacial rock flour (GRF) has a large specific surface area, and is enriched in readily weatherable minerals such as biotite (containing in particular K, Mg), making it an interesting candidate for EW in agriculture.

We tested GRF effects on plant nutrition and soil fertility in a maize field trial in temperate climate. Soil pH (<5.5) and content of available K and Mg was low. Nine treatments were included: five doses of GRF (10-50 ton ha⁻¹), a positive and a negative control ($\pm$ mineral fertilizer P and K reference, no GRF, "BAU") and two combination treatments (BAU + 10 or 30 ton GRF ha⁻¹); all received the same mineral N fertilizer rate. Plant and soil samples were collected at different stages throughout the growing season, and analysed for uptake and availability of essential and beneficial elements (K, Mg, Na, Ca, P, Si).

Soils receiving GRF doses were increasingly better buffered against changes in soil pH throughout the growing-season. This is particularly interesting for more sandy, acidic soils, such as are prevalent in Northern Europe, as well as soils with latent aluminium toxicity. Final maize dry matter yield was not improved significantly by any of the treatments compared to the negative control, suggesting that K and Mg were not the most limiting resource, despite low soil availability and significant differences between the negative and positive control and some of the GRF treatments at the vegetative stage. However, plant K concentrations increased significantly with increasing GRF dose, reaching the same level as BAU fertilisation from 30 ton GRF ha⁻¹. Nutrient offtake and exchangeable base concentrations in soil indicated that 3-5% of the K and Mg contained in GRF was released within this first growing-season. Extraction tests on pure GRF suggested this release of K and Mg was partly by initial rapid dissolution, but also by GRF weathering. These results highlight the potential of GRF as a soil amendment with nutrient effects beyond the first growing-season.





PO12_5 INTEGRATED RHIZOSPHERE MANAGEMENT FOR HIGH PRODUCTIVITY AND NUTRIENTS USE EFFICIENCY

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1 - Interdisciplinary Research Center for Agriculture Green Development in Yangtze River Basin, College of Resources and Environment, Southwest University, Chongqing 400715, China; 2 - State Key Laboratory of Nutrient Use and Management, China Agricultural University, Beijing, 100193, China

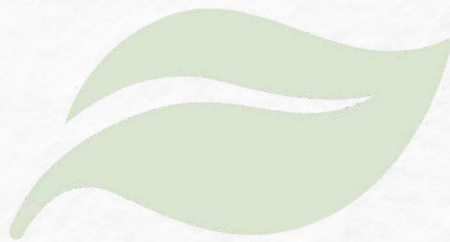
Localized fertilization techniques such as band and spot applications, which based on rhizosphere management principle, have been proven in previous studies and actual production to significantly enhance nutrient use efficiency. However, intensive agricultural production systems still face challenges in achieving both high yield and high resource efficiency, especially in low fertility soils. There is an urgent need for innovative rhizosphere management technologies which can ensure high crop productivity while improving nutrient use efficiency and minimizing environmental costs.

In high-yield maize systems, post-silking nutrient demands are particularly critical. However, conventional fertilization methods often fail to meet the increased nitrogen needs during the reproductive stages. Using big data and artificial intelligence, we have designed a nutrient management strategy that combines controlled-release urea with common nitrogen sources, and integrated balanced phosphorus and potassium supplementation. This one-time rhizosphere fertilization applied at sowing, achieved significant improvements in maize yield, nutrient use efficiency, and reductions in greenhouse gas emissions across field experiments, large-scale on-farm demonstration, and actual production throughout China's maize-producing regions.

To address the possible inhibition on root growth associated with one-time fertilization, we have developed organic-based granules fertilizer that not only create a favorable rhizosphere environment but also promote root growth. When combined it with inorganic fertilizers, this integrated system promotes root establishment during vegetative stages and prolongs root senescence during reproductive stages. Furthermore, we innovatively invented fully bio-based polymer-coated controlled-release urea to eliminate residual film contamination risks inherent in common coating materials.

Finally, through 20 network on-farm experiments conducted across major production regions over three consecutive years, the integrated organic-inorganic rhizosphere nutrient management strategy achieved multi-objective synergism - yield optimization, nutrient use efficiency maximization, and environmental cost mitigation.





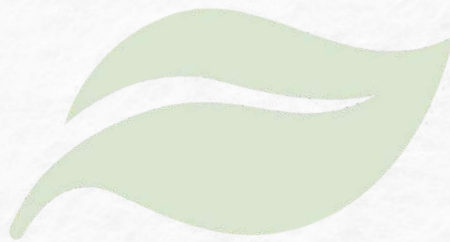
PO12_6 **OXYGEN-NANOBUBBLE-MODIFIED BIOCHAR MITIGATES METHANE EMISSIONS FROM PADDY SOILS**

zhimin sha (China)¹

¹ - Shanghai Jiaotong University

Biochar modified by oxygen nanobubbles (BOC) was developed under high pressure to enhance methane mitigation stability in rice paddies. The modified biochar exhibited a BET surface area of 20.31 m² g⁻¹ and an average pore size of 2.76 nm, providing an optimized structure for oxygen nanobubble retention (diameter <100 nm, height <30 nm). Oxygen-loading capacity reached 14 ± 0.06 mg g⁻¹, confirmed by microscopic characterization. In a soil column experiment with rice cultivation, BOC (1% application rate) reduced cumulative methane emissions by 68.5% compared to the control (CKN) and 58.7% versus conventional biochar (BC), attributed to prolonged soil redox elevation via slow oxygen release. Microbial analysis revealed suppressed mcrA (methanogenesis) and enhanced pmoA (methane oxidation) gene activity in BOC-treated soil. Rice roots in BOC displayed a 36% increase in maximum root length and 44% higher root porosity versus BC, suggesting amplified oxygen secretion capacity that further stimulated methane oxidation. Aboveground biomass remained unaffected ($p > 0.05$) across treatments, indicating no yield penalty. This study demonstrates that oxygen-nanobubble-modified biochar effectively halves methane emissions without compromising rice productivity, offering a viable strategy to support the Global Methane Pledge.





PO12_7 DEVELOPMENT OF ACID-RESISTANT SEED PELLETIZATION FORMULA AND ITS EFFECTS ON IMPROVING RAPESEED GROWTH IN ACIDIC SOIL

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Soil acidification impedes crop growth. Seed pelletization was used to improve crop resistance to various stress environments but not acidic soil. This study aimed to develop rapeseed seed pelletization and to assess the promotional effects of pelletization on rapeseed growth under acidic conditions. Two main acid-resistant functional agents (Ca(OH)_2 and biochar) and a basic formula including sodium carboxymethyl cellulose, H_3BO_3 , nano-silica, brassinolide, sodium naphthalene acetate, indoleacetic acid, and yeast metabolite were used to evaluate the effects on rapeseed growth by seed pelletization. Then, the mechanism of alleviating acidic stress by seed pelletization was investigated. A basic formula was developed by soil test. Three acid-resistant seed pelletization cases (① 0.5% Ca(OH)_2 + a basic formula; ② 10% biochar + a basic formula; ③ 0.25% Ca(OH)_2 + 5% biochar + a basic formula) were confirmed to have significant plant growth promotion. Compared to the unpelletized treatment, seed pelletization significantly increased root length and dry weight of rapeseed seedling by 67.32%-78.34% and 46.47%-74.12%, respectively. It also increased nutrient uptake and reduced the accumulation of toxic Al by 11.72%-16.23% in rapeseed roots. Moreover, seed pelletization modulated the local soil environment at the sowing site, increased soil pH by 0.88-1.11 in the microzone, thereby reducing the adverse effects of acidic stress. In conclusion, Seed pelletization in rapeseed can enhance its tolerance to acidic stress and promote plant growth. Additionally, our results provide new insights into the strategies to alleviate the inhibitory effects of acidic soil.





PO12_8 NEW UTILIZATION FOR LASER ABLATION ICP-MS. INTEGRATION OF 2-DIMENSIONAL SEMI-QUANTITATIVE IONIC MAPS IN A ROOT MICRO-HYDROLOGICAL MODEL.

Noémie Thiébaut (Denmark)¹; Lei Ding (Belgium)²; Marco D'Agostino (Belgium)²; Théo Degand (Belgium)²; Adrien Heymans (Sweden)³; Francesco Minutello (Denmark)¹; Thomas Dagbert (Belgium)²; Monica Rothwell (Belgium)²; Valentin Couvreur (Belgium)²; Daniel P. Persson (Denmark)¹

1 - Plant and Soil Science Section, Department of Plant and Environmental Sciences, Faculty of Science, University of Copenhagen, 1871, Denmark; 2 - Earth and Life Institute, Université catholique de Louvain, 1348, Louvain-la-Neuve, Belgium; 3 - Umeaa Plant Science Center, Dept of Forest Genetics and Plant Physiology, 90187, Umeaa, Sweden

With the ongoing climate change, finding potent breeding traits relative to drought tolerance in plants is urgent. Specifically, the Water Pump project focuses on fine roots from several species (maize, tomato, and a panel of perennial plants) to evaluate the impact of sub-cellular osmolytes distribution on shoot water supply. To achieve this estimation, we utilize a micro-hydrological model of water flow across cell walls, membranes and plasmodesmata (MECHA, Couvreur et al., 2018). The model requires data input on the localization of different solutes across cell layers, as well as between apoplast and symplast. Among those, ions, specifically some macronutrients, make up for an important contribution to the osmotic potentials in the roots.

In the context of this project, the need to precisely localize ions permits to push the limits of our laser ablation ICP-MS (LA ICP-MS) system. Several challenges with respect to ion localization in plant tissues have to be tackled, to precisely map the ions in root cross-sections. Only then, the model will correctly integrate the different osmotic potentials and consequently deduce water movements in plants. These technical challenges include (i) improving the quality of the cut roots after shipping, (ii) quantification and normalization of the ion concentrations, (iii) efficient data extraction from 2D images and (iv) data management in order to integrate them into a root micro-hydrological model.

Therefore, we conducted a range of optimization steps, including re-exploring the use of Laser Micro-Dissection (LMD) in combination with LA-ICP-MS (Chen et al., 2020), and investigating the possibility of using AI for image analysis.

Altogether, we created a new way of using LA ICP-MS to analyze ion content in different cell-layers, with the ambition of integrating the data in a root micro-hydrological model. This technical advances will also be highly useful in the field of plant nutrition.

Chen, A., et al. (2020). "Towards single-cell ionomics: A novel micro-scaled method for multi-element analysis of nanogram-sized biological samples." *Plant Methods*, 16(31).
Couvreur, V., et al. (2018). "Going with the Flow: Multiscale Insights into the Composite Nature of Water Transport in Roots." *Plant Physiology* 178(4): 1689-1703.





PO12_9 ELEMENT CONCENTRATIONS FROM INDUCTIVELY COUPLED PLASMA MASS SPECTROMETRY FOR ESTIMATION OF BEAM EXPOSURE CONDITIONS FOR IN-AIR MICRO- PARTICLE INDUCED X-RAY EMISSION ANALYSIS OF PLANTS

**Yusaku Noda (Japan)¹; Nobuo Suzui (Japan)¹; Yong-Gen Yin (Japan)¹; Yuta Miyoshi (Japan)¹;
Kazuyuki Enomoto (Japan)¹; Naoto Yamada (Japan)¹; Jun Furukawa (Japan)²; Naoki Kawachi
(Japan)¹**

1 - Takasaki Institute for Advanced Quantum Science, National Institutes for Quantum Science and Technology (QST); 2 - Faculty of Life and Environmental Sciences, University of Tsukuba

Observing the localization of elements in plants is an important step in building a picture of elemental transport. In-air micro-Particle Induced X-ray Emission analysis (micro-PIXE) is a technique for elemental mapping in living organisms. This analysis allows simultaneous multi-element analysis. In this method, an ion beam bombards the sample, causing trace elements to emit characteristic X-rays, which are then detected. Unlike existing analytical methods using an electron beam, the sample is measured in air, allowing observation in living cells and the mapping of elemental localization that reflects biological functions.

However, a bottleneck in plant localization analysis, including this method, has been determining how much elemental concentration is needed in the plant to be mapped. Therefore, an attempt was made to estimate the observation conditions for in-air micro-PIXE from the elemental concentrations in plant bodies obtained by inductively coupled plasma mass spectrometry (ICP-MS).

We selected iron (Fe) and zinc (Zn) as nutrient elements and sodium (Na) and cesium (Cs) as harmful elements. To infuse the selected elements into the plant samples, a mixed solution containing compounds at the following concentrations was prepared: 100 mM CsCl, 100 mM NaCl, 100 mM Fe-EDTA, and 100 mM ZnSO₄. The mixed solution was stepwise diluted from 100 mM to 0.01 mM. Next, the stems of *Lotus japonicus* were cultured in this mixed solution. After that, elemental concentrations were analyzed using ICP-MS, and elemental mapping was performed on the same samples using in-air micro-PIXE.

The results showed that four elements in the sample, except for Na, exhibited a stepwise concentration gradient, as did the treated solution. In-air micro-PIXE also successfully mapped the elements except for Na, providing a picture of the different localization patterns in the plant depending on the element. The measurement time increased as the concentration of the treated solution decreased.

The correlation between the number of detections of Fe, Zn, and Cs obtained by in-air micro-PIXE and the quantitative values obtained by ICP-MS was then verified, and the observation conditions of in-air micro-PIXE could be estimated. From the above, it was possible to predict in advance how much irradiation time is needed to observe the localization of Fe and Zn, which are essential trace elements in plants, or how much Cs must accumulate in the plant body to observe the toxic element Cs.





PO12_10 IMPROVING NITROGEN USE EFFICIENCY: EVALUATION OF A NOVEL ENHANCED EFFICIENCY UREA FERTILISER

**Tessa Faulks (Australia)¹; Terence Turney (Australia)²; 1; Owen McCarron (Australia)²;
Victoria Blair (Australia)¹; Antonio Patti (Australia)¹**

1 - Monash University; 2 - Sonic Essentials

With increasing world population and decreasing arable land available, emphasis has been drawn to more effective fertiliser use to reduce losses and improve crop outputs. When fertiliser is applied to the soil, it's not all stored and taken up by plants, but some is lost to the environment¹. Using urea as an example, it's estimated that between 40 – 70% of applied urea may be lost to the environment by leaching, immobilisation and volatilisation^{2,3}. Increasing nitrogen use efficiency (NUE) of urea fertiliser is key in the maintenance of soil and plant health while also meeting global food demands.

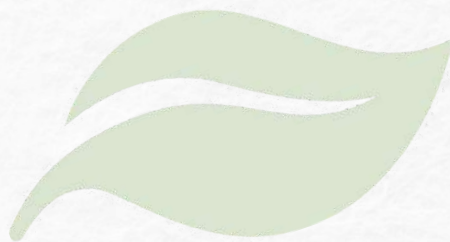
A common management technique to improve NUE is through use of enhanced efficiency fertilisers (EEFs). The goal of these fertilisers is to reduce the immediate availability of the nutrient and thus increase the amount available over time in the soil and for plant uptake⁴. However, current commercially available EEFs have drawbacks including the presence of toxic or non-biodegradable components, costly development and manufacturing procedures and they often show irregular and ineffective slowed nutrient release⁵.

In this study, we introduce a novel EEF for urea and compare its performance against uncoated urea and three commercially available urea-based EEFs through a series of water dissolution, column leaching, pot and field trials. The novel coating demonstrates significantly slower nutrient release (up to 500%) in water compared to uncoated urea and two commercially available coatings (carbon-coated and sulphur-coated urea), highlighting its potential to reduce nitrogen losses and improve nutrient cycling in soil.

Column leaching trials were conducted across four different soil types to further evaluate the performance of the novel fertiliser in soil environments. The detailed study measured nitrous oxide and ammonia emissions, as well as concentrations of urea, ammonium, and nitrate in the soil leachate. Additionally, immobilised and available nitrogen in the soil fraction post trial was analysed to provide a comprehensive nitrogen balance for the treatments. Preliminary findings indicate that the novel EEF outperforms commercial alternatives, showing a reduction in both nitrous oxide emissions and the leachate concentrations of ammonium and nitrate.

Supporting evidence from a silver beat pot trial and a summer corn field trial further demonstrates the potential benefits of the novel EEF in promoting plant growth. This research presents a detailed comparison of the novel fertiliser to existing commercial EEFs and will discuss a full nitrogen balance, shedding light on the enhanced efficiency and environmental benefits of the novel formulation.





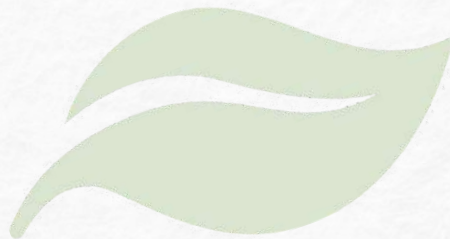
PO12_12 **POTENTIAL OF FLUID FERTILIZERS PRODUCTION FROM RECOVERED AMMONIA EMITTED DURING WASTE COMPOSTING**

Fabiane Carvalho Ballotin (Brazil)1; Rodrigo Lima da Motta Júnior (Brazil)2; Vinícius Bastos (Brazil)3; Gustavo Spagnol (Brazil)4; Rochel Montero Lago (Brazil)4; Deusanilde de Jesus Silva (Brazil)2; Reinaldo Bertola Cantarutti (Brazil)2

1 - Universidade Federal de Lavras, UFLA, Brasil, MG.; 2 - Universidade Federal de Viçosa, Viçosa, Minas Gerais, Brasil; 3 - Universidade Federal de Viçosa, UFV, Viçosa, Minas Gerais, Brasil; 4 - Universidade Federal de Minas Gerais, UFMG, Belo Horizonte, Brasil

During composting of poultry farming waste, a large amount of NH_3 is generated, however, around 50% of it is volatilized. This NH_3 could be used to produce nitrogenated fertilizers, especially fluid fertilizers, which plays an essential role in complementing soil fertilization. In this work, the main objective was to estimate NH_3 volatilization in the composting of waste from a poultry farm and the potential production of fluid fertilizer. The measurements were carried out in the composting mixture of excretions, coffee straw and wood sawdust, in a row of 0.70 x 6.00 x 60,00 m, continuously mechanically rotated. For the measurement trials, NH_3 chambers collection were used made by PVC tubes of 0.15 m high and 0.1 m diameter, containing at the upper end a nylon foam soaked in H_2SO_4 0.5 molL⁻¹ (NH_3 trap). Chambers were installed at the waste deposition point (point 0) and then at 15, 30, 45 and 60 m. NH_3 collection was carried out for 30 min, when the traps were removed, placed in a plastic bag and reserved until analysis. The foams were washed with deionized water and the N content was determined via Kjeldahl distillation. The average NH_3 emission calculated was 0.173 kg/day.m², being 5.17 Kg NH_3 /h across all the composting area. Simulating NH_3 capture by an acid solution H_3PO_4 4 molL⁻¹, a production of 30.000 L/month of fertilizers is estimated with 10 % of N and 12 % P, which will be the basic input for fluid fertilizers production.





PO12_13 INFLUENCE OF TRICHODERMA SPP. (HYPOCREALES – FUNGI) ON THE QUALITY OF COMMON BEAN SEEDS

Maria Márcia Pereira Sartori (Brazil)¹; Michelane Silva Santos Lima (Brazil)¹; Adriana Zanin Kronka (Brazil)¹

¹ - Universidade Estadual Paulista (UNESP), Faculdade de Ciências Agronômicas

The growing demand for more sustainable agriculture has driven the search for products that reduce the use of pesticides in crop management. A promising alternative is the use of biological agents, as microorganisms play a crucial role in antagonizing soil-borne phytopathogens, enabling the production of agrochemical-free products. Beans are a staple food consumed in most countries, and therefore, their quality is of utmost importance worldwide. In this context, the objective of this research was to evaluate the effect of treatment with five strains of *Trichoderma* sp. as a substitute for or in combination with fungicides on the quality of common bean seeds stored under controlled conditions.

To assess the quality of common bean seeds treated with chemical and biological agents during storage, vigor tests (germination, moisture content, accelerated aging, seedling growth, dry matter mass, and field emergence), biochemical tests (electrical conductivity), and seed health assessments were conducted. The common bean seeds were treated and stored at a constant temperature of 30°C and 75% relative humidity, following a completely randomized design comprising seven treatments: control (no application), fungicide treatment, and five different *Trichoderma* strains (without fungicide application).

For the variables seedling length (shoot and root, in cm), dry mass of shoot and root (g), electrical conductivity, viability, and first germination count, the behavior over time was evaluated using the area under the curve (AUC), processed in Origin software (2019). The data from the seven treatments were subjected to Principal Component Analysis (PCA) to reduce the dataset and explain correlations and variances. The variables with the highest variability were tested for normality (Kolmogorov-Smirnov test), followed by analysis of variance (ANOVA) and Tukey's test at a 5% probability level, using Minitab 16 statistical software.

Among the *Trichoderma* treatments, four strains demonstrated superiority in improving seed quality. A similar result was observed for seed health, as all *Trichoderma* strains showed potential for controlling *Aspergillus*, *Fusarium*, *Rhizopus*, and *Colletotrichum* fungi in common bean cultivation. However, further detailed studies are necessary to validate this potential. This research also highlights the importance of a careful and detailed selection of *Trichoderma* strains to be introduced in the target area.





PO12_14 THE USE OF STABLE ISOTOPES TECHNIQUES IN THE EVALUATION OF BIOINPUTS

Neraldo Cesar Gritti (Brazil)¹; Pedro Henrique Moreno Silva (Brazil)¹; Fernando Ferrari Putti (Brazil)²; Maria Márcia Pereira Sartori (Brazil)¹

1 - Universidade Estadual Paulista (UNESP), Faculdade de Ciências Agronômicas; 2 - Universidade Estadual Paulista (UNESP), Faculdade de Ciências e Engenharia

The application of chemical pesticides has raised concerns about pest resistance, human health risks, and environmental contamination. As a sustainable alternative, biological control agents, such as the fungus *Trichoderma*, have been widely studied for their effectiveness against phytopathogenic fungi, oomycetes, and insect pests. This research aimed to evaluate the influence of *Trichoderma* treatment on the physiological quality and longevity of bean seeds, using Isotope Ratio Mass Spectrometry (IRMS) to analyze stable isotopes of carbon ($\delta^{13}\text{C}$), oxygen ($\delta^{18}\text{O}$), hydrogen ($\delta^2\text{H}$) and nitrogen ($\delta^{15}\text{N}$). High-vigor bean seeds (germination above 80%) were inoculated with *Trichoderma* spores and stored under controlled conditions (10°C, 60% relative humidity) for up to 160 days. Samples were collected at regular intervals for germination tests, sanitary quality, and isotopic measurements.

The results demonstrated that seeds treated with *Trichoderma* exhibited greater longevity and higher germination rates compared to untreated controls. Isotopic analysis revealed a significant reduction in the concentrations of carbon, hydrogen, and nitrogen in treated seeds, indicating active consumption of these elements by the fungus. The p50 value (time for 50% of seeds to remain viable) was calculated to assess seed longevity, showing that *Trichoderma*-treated seeds maintained viability for a longer period than untreated seeds. Specifically, treatments with three different *Trichoderma* strains (SLV1, SLV1-IF209, and SLV10) resulted in germination rates above 50% for extended periods, while untreated seeds showed a faster decline in viability.

The study also highlighted the role of environmental conditions, such as temperature and humidity, in preserving seed quality. Seeds stored in cold chambers (10°C) retained their viability longer, emphasizing the importance of proper storage for treated seeds. The IRMS analysis provided insights into the metabolic activity of *Trichoderma* within the seeds, as evidenced by changes in isotopic ratios over time. These findings suggest that *Trichoderma* not only enhances seed longevity but also actively interacts with seed components, potentially improving their resistance to environmental stress.

In conclusion, the use of *Trichoderma* as a seed treatment offers a promising sustainable alternative to chemical pesticides, improving seed longevity and germination rates. The integration of stable isotope techniques, such as IRMS, provides a powerful tool for understanding the mechanisms behind these effects, paving the way for further research and application of bioinputs in agriculture.





PO12_15 **CHARACTERIZING POLYACRYLAMIDE HYDROGELS CONTAINING A ZROH BINDING PHASE FOR SAMPLING CARBOXYLATES EXUDED BY ROOTS GROWN IN SOIL**

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Root exudates are crucial for plants survival and thus agricultural production. However, the sampling and reliable quantification of root exudates from soil-grown plant root remains experimentally very challenging, as exudates are mineralized quickly by microorganisms and bind to the mineral soil phase. Moreover, obtaining samples without disturbing the root system is nearly impossible. Thus, most of the studies on root exudates are carried out under highly artificial hydroponic growth conditions. This study aims to develop a non-destructive method for the precise localization and quantification of various carboxylates (including aconitate, citrate, fumarate, lactate, malate, oxalate, and succinate) exuded from the roots of plants grown in soil. To achieve this, we apply polyacrylamide hydrogels that contain zirconium hydroxide (ZrOH) as a binding phase directly onto the root mat of rhizotron-grown plants, enabling effective capture of these carboxylates.

In the first experimental steps we characterized the ZrOH gels for their capability of efficient carboxylate uptake and elution. Gels were immersed in 10 mL solutions containing single carboxylates with total amounts between 11.3 and 34.5 µg. Carboxylate elution from the gel was performed with 1 mL 0.5 mol L⁻¹ NaOH for 24 hours. Carboxylates were measured with ion chromatography coupled to a quadrupole mass spectrometer. Complete (100%) uptake was observed after 5 hours of immersion for every carboxylate, and the elution efficiency ranged from 87.4 ± 3.8% to 120.0 ± 5.4%.

Our initial findings indicate that ZrOH gels are effective for capturing carboxylates and can be efficiently eluted, suggesting that these gels have the potential to be used as a non-destructive method for sampling carboxylates released by plant roots. Future research will focus on determining the capacity of these gels, conducting competition tests, and testing this method on plant roots grown in rhizotrons.

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THANK YOU
See you soon!