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Oral presentations

In order of the program

Presenting author in bold

Keynote 01

Plant biostimulants as a promising sustainable tool to improve nutrient use efficiency and crop quality

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Modern agriculture tackles the critical challenge of increasing food production while reducing reliance on synthetic chemical inputs and mitigating environmental impacts. In this context, plant biostimulants—comprising natural substances like humic acids, seaweed extracts, protein hydrolysate, and beneficial microorganisms—have emerged as key bio-based tools for sustainable crop management. This paper reviews the physiological and biochemical mechanisms by which plant biostimulants enhance Nutrient Use Efficiency (NUE) and improve crop quality[1]. Biostimulants stimulate root system architecture, upregulate nutrient transporter genes, and foster beneficial soil-microbe interactions, thereby facilitating the uptake, translocation, and assimilation of macro- and micronutrients[2,3]. Consequently, their integration into crop nutrition programs reduces fertilizer runoff and environmental pollution without compromising yield. Furthermore, biostimulant applications activate primary and secondary metabolic pathways, boosting photosynthetic efficiency and abiotic stress tolerance. This leads to marked improvements in crop quality attributes, including higher concentrations of antioxidant compounds, soluble solids, essential minerals, and extended shelf-life[4]. By optimizing nutrient utilization and elevating qualitative traits, plant biostimulants represent a viable biological strategy to bridge high agricultural productivity with ecological sustainability. Further research should focus on deciphering specific molecular modes of action and standardizing field protocols across diverse agroecosystems.

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Talk 01

Biostimulant efficacy for phosphorus acquisition in maize varies with recycled P fertilizer

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Phosphorus (P) recovered from secondary waste streams could reduce dependence on mined rock P, yet recycled P fertilizers often underperform when co-applied with non-microbial biostimulants. We tested whether the efficacy of three BS classes—humic substances, seaweed extract, and chitosan—is contingent on the paired recycled P source. Maize (*Zea mays* L. cv. Ronaldinio) was grown for 42 days in rhizoboxes on a P-deficient soil amended with one of four P treatments (control, monocalcium phosphate [Ca-P], struvite, or ASH-DEC sewage sludge ash [Na-SSA]), in a fully factorial BS design across four randomized complete blocks (n = 64). A parallel four-month plant-free incubation characterized P-availability dynamics without plant-mediated processes. BS efficacy was strongly source dependent. Under Ca-P and struvite, HSs and chitosan raised plant biomass by 21–34%, total P uptake by 23–36%, P partial factor productivity by 21–34%, and agronomic P-use efficiency by 63–77%; under Na-SSA, no BS produced detectable gains within the six-week window. The incubation, however, showed BSs progressively mobilized P from all fertilizers, including Na-SSA, with robust effects by days 90–120. This Na-SSA "paradox" reflects a kinetic mismatch between SSA-P mobilization and the crop establishment window, not inherent insensitivity. Mechanistically, HSs combined rhizosphere acidification (ΔpH −0.09 to −0.30) with 42–48% fine-root proliferation and a fivefold rise in shoot K/Mg, whereas chitosan stimulated rooting pH-independently while preserving ionome balance. Pairing struvite with HSs offers a practical strategy to improve maize P-use efficiency under circular fertilization, with Ca-P + HSs as a soluble benchmark and Na-SSA requiring extended windows.

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Talk 02

Evaluation of the zinc and boron fertilizer recommendations to maize tested at a field site in the Munich gravel plain

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Maize (*Zea mays* L.) grown in 2024 on a loamy soil at the TUM research station Roggenstein located in the Munich gravel plain showed severe interveinal chloroses of younger leaves. Soil analyses, including CAT soluble Zn according to VDLUFA suggested low plant available soil Zn contents to most probably be responsible for these symptoms. Moreover, soil analyses according to Albrecht/Kinsey were conducted, which additionally assessed B to be low in this soil and the resulting Zn and B fertilizer recommendations exceeded those based on the CAT soil analyses in Bavaria. To evaluate adequate Zn and B fertilizer rates to maize at this site, a field experiment was conducted in 2025 spanning a wide range of 0 to 22 kg Zn ha^{-1} and 0 to 6.6 kg B ha^{-1}.
At no stage maize plants developed any deficiencies symptoms. Grain yield was unaffected by Zn and B treatments. However, following the Bavarian recommendation for low Zn soils and adding 7 kg Zn ha^{-1} combined with a B application of 0.5 kg B ha^{-1} (maintenance rate) shifted the soil from Zn supply class "low" to "optimal" and leaf Zn supply status from "critical" to "adequate". Higher Zn rates increased both soil and leaf Zn. Leaf B status was "adequate" even without B application but also increased by higher B rates.
In conclusion, Bavarian recommendation of 7 kg Zn ha^{-1} met maize leaf Zn demand, reducing the risk of Zn deficiency, additional B application didn't offer any benefits. The experiment is continued in 2026.

Talk 03

Global integrators of light signalling and nutrient homeostasis safeguard symbiosis under light stress

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Their large, protein-rich seeds render many legume plants like beans, peas or soy attractive food or fodder crops. This is thanks to nitrogen-fixing root nodulation symbiosis (RNS) with rhizobial bacteria, a mutualistic association enabling legumes to not only form storage seeds but also thrive in nitrogen poor habitats. These benefits come at a cost: accommodating millions of bacteria that actively fix N_2 requires substantial nutrient and energy input. Evolutionarily successful hosts employ a multi-layered regulatory system balancing endogenous nutrient status and interorganismic nutrient exchange with symbiosis establishment and progression. Root infection as well as nodule organogenesis and -lifespan are tightly regulated, ensuring a mutualistic interaction. Under adverse conditions, established nodules can be deactivated by induction of nodule senescence in a process involving the transcription factor genes *NAM ATAF CUC* (*NAC*) *94* (Wang *et al*., 2023) and *FIXATION UNDER NITRATE* (*FUN*) (Lin *et al.*, 2024). The molecular basis and role of senescence induction in RNS regulation is still far from understood. We found that in *Lotus japonicus* (Lotus), the two photomorphogenesis genes *ELONGATED HYPOCOTYL5* (*HY5*) and the B-Box-containing zinc finger transcription factor gene *BBX21* are required and sufficient for maintaining nodule function under high light intensities (Sexauer *et al*., 2026). Loss of either *HY5* or *BBX21* results in a light-dependent increase of *NAC094* transcript levels, nodule necrosis and early senescence, and enhanced nodule proliferation. Moreover, expression of dominant negative *HY5* or *BBX21* is sufficient to induce nodule necrosis and hypernodulation. Our data establish *LjHY5* and *LjBBX21* as a novel gene pair safeguarding nodule function and nitrogen fixation by preventing light induced senescence.

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Keynote 02

Biochar use in soils and fertilizers to decrease nitrate leaching and nitrous oxide emissions

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Fertile soils worldwide, man-made or natural, often contain pyrogenic carbon produced either by wild fires or by human activities that employ pyrolysis. Biochar is the solid, persistent product of low- to high-tech pyrolysis techniques. It can be produced from a large variety of residual biomasses from wood chips, straw, to landscaping residues or many more. Due to the persistence of biochars, which can be well predicted from their chemical properties such as the H/C_{org} ratio, biochar is regarded as a "permanent" CDR (carbon dioxide removal) method (EU CRCF directive); "Biochar carbon removal" leads the voluntary CDR markets (see https://cdr.fyi). Biochar use in soils, animal husbandry or biogas production, or in building materials or asphalt, is included in the current IPCC methodology development for national accounting. Based on more than 35.000 published papers, some agronomic effects, benefits and drawbacks can be elucidated.

The talk will hence inform about the current state of knowledge regarding biochar production, certification, regulation and safe use in temperate and tropical soils. Particular emphasis will be placed on prominent and well-documented co-benefits of biochar use that relate to important plant nutritional effects, such as reduced nitrate leaching or nitrous oxide emissions [1-3], or pH-driven improvements in P nutrition in tropical soils. We will show own results across ~8 years plus meta-study and mechanistical evidence to discuss potential R&D routes that may deliver plant nutritional and soil fertility benefits together with the applied biochar-CDR via low-dose biochar-based fertilizers.

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Talk 04

Nitrogen in German Agriculture: Balancing Food Security with Environmental Sustainability

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Nitrogen is an essential element for agricultural productivity and has been a major driver for the remarkable increases in crop yields achieved over the past century. At the same time, reactive nitrogen losses from agriculture adversely affect human health, air quality, water resources, and climate. In this review, we trace the historical evolution of scientific understanding and public awareness of nitrogen-related environmental impacts and examine how these advances have shaped agricultural policy and management. Using Germany as a case study, we illustrate how scientific progress has challenged long-held assumptions about nitrogen cycling and informed increasingly targeted mitigation strategies. We discuss the transition from a primary focus on food production to a broader perspective that also considers ecosystem health, drinking water protection and climate change. Recent advancements in legislation on nitrogen management have led to a substantial increase in nitrogen use efficiency and a reduction in nitrogen surpluses. However, evidence suggests that under current management conditions, further reductions in fertilizer inputs are unlikely to significantly decrease environmental nitrogen losses and may compromise crop productivity and quality. Future progress therefore depends on optimizing nitrogen management rather than simply minimizing nitrogen inputs. We identify promising opportunities to further reduce nitrogen losses through improved agronomic practices, enhanced nutrient recycling, and site-specific management, while maintaining productive and resilient agricultural systems. Achieving this balance is essential to ensuring both food security and environmental sustainability.

Talk 05

Long-Term Field Evidence Linking Soil Organic Matter, Soil Health and Crop Resilience

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Soil organic matter is a key determinant of soil health and climate-resilient crop production [1]. It influences water retention, aggregate stability, nutrient cycling, microbial activity and the capacity of soils to buffer climatic stress and weather extremes. The long-term humus trial at the LUFA Speyer experimental station “Rinkenbergerhof” provides a rare opportunity to assess how soil organic matter management affects these functions under field conditions.

Since 1959, diverse organic amendments, including farmyard manure and straw incorporation, have been compared with exclusively mineral fertilization. In addition, irrigated and non-irrigated treatments allow long-term fertilization effects to be evaluated under contrasting water availability. The site is located in the Upper Rhine Valley near Speyer on a drought-prone sandy soil with low water-holding capacity. At trial establishment, soil organic matter was approximately 1.2%.

After more than six decades, the trial shows clear differences in physical, chemical and biological soil properties, including soil organic matter, soil functionality and crop performance. Recent results indicate that farmyard manure can support higher yields than mineral fertilization, particularly under drought stress. These findings suggest that, over the long term, organic amendments may support not only nutrient recycling, but also improved water availability, enhanced biological activity and a closer synchronization of nutrient release with crop demand.

Recent advances in soil physical, chemical and biological analytics now enable highly detailed assessments of soil–plant–microbial interactions. However, reproducible field evidence is essential for translating such multifaceted data into agronomically meaningful insights. The Rinkenbergerhof long-term field experiment therefore could represent a unique platform for linking mechanisms of soil-plant-microbial interactions with practical questions of soil health, nutrient management and climate-resilient crop production.

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Talk 06

Improving plant Si availability of diatomaceous earth materials through alkaline treatments

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Silicon (Si) is beneficial for plants; it is reported to reduce the impact of abiotic and biotic stresses [1]. To efficiently supply Si to plants, plant available Si supplements are needed. For this application, diatomaceous earth materials are often discussed [2]. They are used in technical applications (e.g. filters in the brewing industry) and could be recycled for use as a Si supplement. Unfortunately, their poor plant Si availability renders diatomaceous earth materials unsuitable candidates for delivering Si to plants [3]. To improve this property, their Si chemistry needs to be altered so that the fraction of plant available Si increases. Alkaline treatments have been shown to drastically change the chemical composition of Si rich waste materials, increasing their Si solubility strongly [4]. To check whether alkaline treatments can convert diatomaceous earth into a useable Si supplement, we treated brewery filter material and food grade diatomaceous earth either with different amounts of sodium hydroxide (NaOH) or potassium hydroxide (KOH) at high temperatures. The resulting products showed a drastic increase in their solubility in buffer solution (30 mM 3-(N-morpholino) propansulfonic acid, pH 7), regardless of the base used. While some extreme values might be triggered by base residues in the product, the median increase was 20-fold over all tested treatments compared to the precursor. Plant Si uptake responded with a median increase of +64.0% but the observations are inconsistent over the amount of base used. The process needs optimization for economic feasibility and product homogeneity but overall, the resulting products could be used as Si supplements in the future.

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Talk 07

Wearable Nanoporous Gold-Based Sensor for Potassium Monitoring in Plants

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Accurate and continuous tracking of potassium (K^+) dynamics is key to understanding plant nutrient status and enabling data-driven crop management, which is central to precision agriculture [1]. Microneedle-based sensing platforms have emerged as a promising approach for in-planta monitoring due to their minimally invasive nature and compatibility with miniaturized systems. When integrated with electrochemical sensing, they enable cost-effective devices with rapid response, high sensitivity, and selectivity. Sensors requiring no calibration are particularly valuable for continuous in-planta monitoring. To achieve this, a stable sensor potential is crucial [2], however, maintaining long-term potential stability remains a challenge. In this work, we present a microneedle-based electrochemical sensor that incorporates nanoporous gold as a solid-contact interface to address stability challenges. The nanoporous gold architecture provides a high surface area, resulting in enhanced double-layer capacitance, improved charge transfer, and reduced water layer formation at the electrode interface [3]. These properties enable the development of a highly stable ion-selective electrode suitable for long-term in-planta applications. The sensor demonstrates sensitive and selective K^+ detection under physiologically relevant conditions, along with improved potential stability. By enabling reliable, long-term monitoring with reduced calibration requirements, this nanoporous gold-based strategy contributes to the development of robust, low-cost sensing tools for agricultural applications, supporting improved nutrient management and more sustainable crop production.

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Talk 08

Physiological effects of foliar-applied magnesium salts on leaf apoplastic pH and stomatal regulation

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Nutrient absorption into the leaf occurs through the cuticle, but stomatal pores are also considered an important pathway for foliar nutrient uptake [1]. Magnesium (Mg) can be resupplied via the foliage as salts using different companion anions, such as chloride, sulfate, or nitrate. We hypothesized that stomata close in response to foliar sulfate application, as sulfate is involved in early drought stress-induced stomatal closure [2], thereby hampering foliar ion uptake. To test this hypothesis, stomatal aperture and apoplastic pH were monitored simultaneously by in planta fluorescence microscopy in Mg-deficient *Vicia faba* L., while non-destructive analysis of apoplastic washing fluid was used to assess short-term apoplastic ion dynamics. Photosynthetic recovery and stomatal conductance were determined to evaluate the physiological effectiveness of foliar-applied Mg. Here, we show that foliar Mg uptake and photosynthetic recovery were lower following Mg sulfate application compared with the other Mg salts. However, stomata did not close following foliar sulfate application. Interestingly, the apoplastic pH response differed in its alkalinization pattern but likewise did not induce stomatal closure. Analysis of apoplastic washing fluid indicated a strong but transient increase in recoverable ion concentrations, which declined sharply within 12 minutes. These findings suggest that transient delivery of sulfate to the leaf apoplast and apoplastic alkalinization alone may not be sufficient to trigger stomatal closure and that not only the amount, but also the duration of ion delivery may be critical for stomatal signalling. Stomatal closure induced by foliar sulfate application is therefore unlikely to explain the lower foliar Mg uptake.

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Talk 09

Uptake and Translocation of Foliar-Applied Iron in Broccoli

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As a novel approach to improving iron (Fe) intake from plant-based foods, an ongoing research project is investigating the biofortification of vegetables. Broccoli is of particular interest because its high vitamin C content may enhance iron bioavailability [1, 2]. Therefore, a field trial was conducted to investigate Fe uptake and translocation in broccoli plants after foliar fertilization. Iron was applied two weeks before harvest at a rate of 0.3 kg Fe ha^{-1} using five different Fe fertilizers. To assess translocation from the leaves to the inflorescence, the heads of a subset of plants were covered with plastic bags during application. Plant material was analyzed after washing to remove externally adhering Fe.
No notable differences were observed among the tested Fe fertilizers. Fe content in petioles and stems were not affected by foliar fertilization. Covering the heads during treatment resulted in Fe content in the florets that were nearly identical to those of the control. In contrast, direct exposure of the inflorescences to the Fe-containing fertilizer solutions increased Fe content in the florets from 0.49 to 0.62 mg $(100\ g\ FW)^{-1}$ on average. In the leaf blades, Fe content increased from 1.7 mg $(100\ g\ FW)^{-1}$ in the control to 3.0 mg $(100\ g\ FW)^{-1}$ in Fe-treated plants. These results show that broccoli can take up Fe via leaves and florets, but only small amounts are translocated from the leaves to the inflorescence. Consequently, the potential for Fe biofortification of broccoli by foliar fertilization appears limited.

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Talk 10

Not accounting for biomass dilution by SiO_2 leads to the misinterpretation of the plant nutritional status in silicon trials

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Plant uptake and subsequent deposition of silicon (Si) can lead to concentrations of up to 10% of total biomass production. In the plant, Si is deposited in the apoplast as silica (SiO_2). So far, changes in biomass and element concentrations in Si trials have mainly been attributed to direct effects of Si on photosynthesis and nutrient uptake. This interpretation fails to recognize the significant biomass dilution effect of SiO_2, which also affects nutrient concentrations and thereby the interpretation of the plant nutritional status. This study aimed at quantifying the biomass dilution by SiO_2 and its implications for the interpretation of element concentration data.
Five independent hydroponic experiments with rice, wheat, and rapeseed were conducted at different Si supply levels (0-2000 µmol L^{-1}). Biomass and element concentrations were determined (measured data) and mathematically corrected for the SiO_2 content (corrected data).
With increasing Si supply, measured carbon concentrations were significantly reduced by up to 6%. This effect disappeared after mathematical correction of SiO_2 dilution. Similar results were found for elements with predominantly transporter-mediated uptake. For sodium, an element largely taken up via bypass flow, relative concentration changes attributable to mere biomass dilution were strongly outweighed by other effects, indicating that SiO_2 deposition mechanistically alters the uptake processes of this element.
We propose that meaningful analysis of changes in nutrient uptake patterns in Si trials can only be done after accounting for SiO_2 dilution. Not correcting the concentration of elements by SiO_2 dilution can lead to a misinterpretation of the nutritional status of plants.

Keynote 03

Cracking the vacuolar malate and fumarate transport in Arabidopsis, from structure to physiology.

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Malate and fumarate are organic acids having multiple functions in different plant tissues. In the leaves, they form a significant transient carbon stock synthesized during daytime and consumed at night. In photosynthetic tissues, these organic acids are diurnally stored and remobilised from the vacuole, and have key roles in metabolic regulations. In *Arabidopsis thaliana*, vacuolar anion channels of the Aluminium-Activated Malate Transporter (ALMT) family are involved in mediating the transport of these organic acids across the tonoplast. In recent years, we used a combination of approaches, from genetics to structural biology, to investigate the molecular properties of these ion transport systems and their impact of plant growth. Our data shed light on the specific molecular properties of the ALMT channels and on the importance of malate and fumarate transport in a C3 plants.

Talk 11

Vicia faba guard cells display selective nitrate uptake during stomatal opening

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Guard cells control stomatal movements through changes in their osmotic potential, which are mainly due to uptake and release of potassium ions and anions. In the literature, accumulation of K^+ in guard cells has primarily been associated with Cl^- uptake. However, nitrate transporters that function as NO_3^-/H^+ symporters, can also support stomatal opening [1]. We used the Scanning Ion-Selective Electrode (SISE) technique to uncover the anion uptake capacity and specificity of *Vicia faba* guard cells [2]. For plants grown in gardening substrate containing (16mg/100g) chloride and (19.8mg/100g) nitrate soil, we found that *V. faba* guard cells have a preference for NO_3^- uptake. However, if plant were grown at soil with low Cl^- (1.25 mg/100g) / high NO_3^- (30 mg/100g) availability their cells activated a Cl^- uptake system, while NO_3^- uptake was repressed. Our study thus revealed that guard cells of *V. faba,* normally prefer the uptake of nitrate, but switch to Cl^- at low chloride availability. We will discuss the impact that the preference for NO_3^-, or Cl^- uptake will have for stomatal movements in bean plants.

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Talk 12

OsDODA1 modulates development and iron deficiency responses in rice

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Rice is one of the three most important crops in the world[1]. Iron (Fe) is a transition metal that is essential for almost all living organisms. However, Fe is typically found in soil as low solubility ferric oxides, which limits its bioavailability for plant uptake, making plants susceptible to Fe deficiency (-Fe). The primary symptom of -Fe in plants is chlorosis[2]. *OsDODA1* is an uncharacterized gene in rice, identified within the convergence region of two QTLs associated with Fe toxicity[3]. We hypothesize that *OsDODA1*, as a LigB-type dioxygenase homolog, modulates the metabolism of aromatic compounds in rice roots, potentially including L-DOPA, thereby influencing the root-borne signal that regulates the shoot -Fe response. To investigate its function, we generated edited and overexpression lines and evaluated them under -Fe. Both gene-edited and overexpressing lines exhibited impaired development relative to the wild type (WT), with significantly reduced shoot and root lengths and dry weight. After 8 days of -Fe, chlorosis was visible in all genotypes; however, gene-edited lines - carrying either a truncated or a shortened version of the protein - displayed higher SPAD values than WT, while overexpression lines did not differ from the WT. Furthermore, gene-edited lines also showed better photosynthetic performance under -Fe compared to the WT. The iron concentration of plants grown under control and -Fe conditions was determined across different tissues. Under -Fe, the Fe concentration in developing leaves was significantly higher in the edited lines compared to the WT. These preliminary results suggest that *OsDODA1* plays a potential role in the regulation of Fe homeostasis in rice.

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Talk 13

Early stomatal avoidance mitigates iron toxicity by protecting photosynthetic machinery and pigment composition in rice

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Iron (Fe) toxicity is a severe nutritional disorder in lowland rice. Excess foliar Fe accumulation catalyzes the Fenton reaction, generating highly toxic hydroxyl radicals. This oxidative firestorm drives the lipid peroxidation of thylakoid membranes, actively degrading chlorophyll and carotenoid pigments, and impairing Photosystem II (PSII) efficiency. To elucidate the impact of excess Fe on photosynthesis and leaf pigment composition, we evaluated a set of contrasting genotypes. Two-week-old seedlings were grown in hydroponics for four weeks and then exposed to 500 mg/L Fe^{2+} for two weeks. We tracked daily stomatal conductance (*gsw*) and PSII quantum efficiency (ΦPSII), alongside spectral reflectance and SPAD. Gas exchange was measured 4 and 6 days after treatment (DAT). Fresh tissues and biomass were harvested at 7 and 14 DAT, coupled with *in situ* H_2O_2 visualization.

High-resolution tracking revealed that tolerant genotypes executed a rapid "stomatal shock" within 5 hours, drastically reducing *gsw* after being exposed to excess Fe. This early limitation physically blocked transpiration-driven Fe mass flow. Consequently, tolerant genotypes prevented H_2O_2 accumulation, preserved ΦPSII, and retained significantly higher biomass. Conversely, sensitive lines failed to regulate *gsw*, allowing an Fe influx that catalyzed massive H_2O_2 bursts. Spectral reflectance accurately captured this tissue degradation: sensitive lines exhibited a catastrophic collapse in the Photochemical Reflectance Index and extreme spikes in the Anthocyanin Reflectance Index to combat stress, culminating in a ~35% biomass penalty. We conclude that early stomatal avoidance dictates Fe tolerance, protecting internal pigment stability and photosynthetic capacity.

Talk 14

A Mixed Blessing: Clean Air Act to Improve Forest Health have Reduced the Sulfur Availability in Beech Trees

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In the early 1980s European forests were threatened by air pollution and sulfur (S) inputs with acid rain, causing massive forest dieback. Efficient measures to reduce air pollution were able to reduce S inputs in European forests by more than 70% since the beginning of last century [1]. Nowadays we have to face forest dieback again due to drought and increasing disease pressure.
For agricultural crops the involvement of S-containing compounds to combat pests and diseases was shown after observing S deficiency in the early nineties [2]. The project "***SIRT"*** funded by the FNR (grant 2223NR016B) has the target to investigate if S application has the potential to improve forest resilience and to identify site-related factors determining the site-specific S availability.
A variety of different stressed beech forest sites were identified in Lower Saxony together with local forest ranger and studied for their S status. Additionally, pot trials were conducted with young beech trees under controlled nutritional conditions and with drought stress application to investigate the effect of S application on stress resilience.
Results indicate that a leaf S content in beech trees <1,3 mg/kg DM indicate to S deficiency and was connected with stress indicators in natural forests like low natural regeneration, high fungal disease occurrence, drought stress symptoms or a high amount of deadwood. Pot trials revealed that S application has the potential to preserve biomass development under drought stress conditions and the vitality of trees, therefore could be a measure to support forest protection under climate change.

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Talk 15

The role of sulfur in regulating water use efficiency and metabolic acclimation to drought

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Improving intrinsic water use efficiency (iWUE) may be a promising way to enhance crop drought resilience. This study identifies a mechanism linking sulfur assimilation and nitrogen metabolism to the control of stomatal movement in grapevine. We show that sulfur deficiency strongly reduces iWUE through increased transpiration and reduced assimilation. We hypothesise that sulfur deficiency lowers abscisic acid biosynthesis, thereby increasing stomatal conductance, while simultaneously diminishing assimilation capacity via reduced chlorophyll and RuBisCO content. Conversely, increased sulfur supply enhanced iWUE, primarily by lowering transpiration with lower penalty to assimilation. Given the well-documented interaction of sulfur and nitrogen metabolism in other crops, we further investigated this interaction in grapevine. Sulfur deficiency triggered an accumulation of nitrogen-rich amino acids. We demonstrated that nitrogen status defines the metabolic response to sulfur deficiency by modulating the nitrogen overflow. By combining contrasting sulfur availability treatments with drought stress, we show that an optimised sulfur nutritional status, balanced with adequate nitrogen availability, enhances metabolic acclimation under drought. These findings show that ensuring an adequate supply of sulfur can be one way of optimising water use efficiency and plant resilience. To reduce fertiliser input, breeding programmes should target not only high nitrogen use efficiency but also high sulfur use efficiency for improved drought resilience.

Talk 16

ZIP transporters modulation by selenium facilitates divalent metal translocation in maize under sulfate salinity

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Selenium (Se) and sulfur (S) are recognized for their physical and chemical similarities, which is why Se competes with S for uptake, assimilation, and translocation. In our previous report, we found that in maize plants grown under sulfate salinity, moderate Se application effectively increased the accumulation of metal co-factors, including Zn, Mn, Fe, and Cu, thereby enhancing antioxidant enzyme activity (e.g., APX, CAT, GR, SOD, and GPX) [1]. Moreover, among the metal co-factors, a great change in Zn concentration in response to Se application was observed, highlighting their strong association in supporting the antioxidant defense system under stress. Thus, the current study was conceived to investigate a significant gap in the mechanistic pathway of Se-influenced metal transporters, specifically ZIP and heavy-metal ATPases, which are involved in the uptake of Zn and other micronutrients (Fe, Mn, Cu) under sulfate-salinity conditions. Thus, it was designed to test the hypothesis that Se application enhances the expression of ZIP family transporters in maize plants grown under sulfate-salinity conditions, thereby increasing micronutrient translocation and accumulation compared to Se-untreated maize plants [2]. The findings demonstrated that Se upregulated the expression of ZIP transporters and heavy-metal ATPases involved in metal uptake and translocation of Zn, Mn, Fe, and Cu under sulfate salinity conditions. However, in Se-untreated plants, no significant differences were observed in ZIP transporter expression levels. These results make a significant contribution to the field of environmental stress physiology by being the first to report the key genetic mechanism and to shed light on the role of Se in upregulating metal transporters, thereby increasing metal levels in salinity-affected maize plants.

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Talk 17

Comprehensive investigation of nutrient deficiency and elemental toxicity reveals extensive nutrient interactions and identifies unique and co-regulated genes in barley

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Plants require 14 mineral nutrients for growth and development, and nutrient imbalances, including deficiencies and toxicities, are major constraints on agricultural productivity [1-3]. Most studies focus on single nutrients, resulting in a limited understanding of transcriptional and metabolic responses across diverse nutrient perturbations. Conventional diagnostic approaches often fail to identify the primary limiting element, particularly in soils where multiple imbalances co-occur [3-5], highlighting the importance of more precise and element-specific tools.
Here, we established a comprehensive nutrient perturbation platform in barley by inducing mild deficiencies of all macro- and micronutrients together with aluminum (Al^{3+}) and manganese (Mn^{2+}) toxicities under controlled conditions. Combining ionomic analyses with RNA sequencing, we identified extensive nutrient interactions as well as both element-specific and co-regulated transcriptional responses. The dataset revealed candidate marker genes for individual nutrient imbalances alongside shared regulatory networks that respond to multiple nutrient stresses.
These results provide a comprehensive resource for understanding plant nutrient signaling and homeostasis and contribute to the development of improved molecular tools for diagnosing nutrient limitations under complex environmental conditions.

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Talk 18

Impact of the Golgi apparatus on cellular calcium-mediated stress responses

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In plant cells, characteristic transient free calcium (Ca^{2+}) elevations in the cytosol are a response to various environmental stresses. The *ER-type calcium-transporting* P_{2A}*-type ATPase 3* (*ECA3*) is expressed in diverse tissues of *Arabidopsis thaliana*, *e.g.,* vasculature and meristematic cells [1,2]. ECA3 pumps Ca^{2+} and manganese (Mn^{2+}); it localizes to the Golgi apparatus and the pre-vacuolar compartment in roots and shoots [1,2]. Here, we demonstrate that *eca3* knockout mutants show a severe hypersensitivity to salinity (sodium chloride) stress. The expression of *ECA3* in the vasculature suggests that the salt sensitivity of *eca3* mutants may be a result of altered systemic responses to high salt conditions. Indeed, our experiments indicate that *eca3* mutants display a delayed and reduced translocation of sodium to the shoot. Intriguingly, this is accompanied by a marked alteration of $[Ca^{2+}]_{cyt}$ responses to salt treatment on local level in the root tip and on systemic level in the shoot. Our data further suggest an altered Ca^{2+} signal in the Golgi of *eca3* mutants upon salt treatment. ECA3 pumps Ca^{2+} ions into the Golgi and thereby seems to reconstitute the basal Ca^{2+} status and stimulus-induced Ca^{2+} signatures in the cytosol, which may govern Ca^{2+}-dependent reactions in the secretory pathway. Collectively, our data point to a crucial role of the Golgi apparatus in the plant´s salt stress response.

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Talk 19

Natural variation in reproductive heat tolerance of quinoa revealed by deep learning-based phenotyping and genome-wide association mapping

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Quinoa (*Chenopodium quinoa* Willd.) is gaining importance as a climate-resilient crop due to its exceptional nutritional quality and tolerance to multiple abiotic stresses. However, increasing temperatures during the reproductive stage severely threaten yield stability, highlighting the need to identify naturally heat-tolerant germplasm for future breeding. Here, we screened a diversity panel of 150 quinoa genotypes for reproductive-stage heat tolerance. To capture heat-induced changes in inflorescence development, we developed a convolutional neural network (CNN)-based image analysis pipeline for automated phenotyping of quinoa panicles and flowers from high-resolution macro images. The extracted architectural and floral traits were integrated with agronomic and yield data to characterise variation in heat responses across the population. Substantial natural variation in reproductive heat tolerance was observed, with lowland quinoa accessions showing the highest levels of tolerance. Several panicle architectural traits clearly distinguished tolerant from susceptible genotypes and were strongly associated with yield maintenance under heat stress. Genome-wide association studies (GWAS) combining phenotypic and image-derived traits identified multiple candidate loci underlying heat tolerance. These findings demonstrate the power of combining automated deep learning-based phenotyping with genetic mapping to dissect complex stress-adaptive traits. Our results provide valuable candidate genes and phenotypic markers for breeding heat-resilient quinoa cultivars, contributing to the development of climate-adapted cropping systems under increasing global temperatures.

Talk 20

The Function of Thiols to Separate Cadmium from Zinc in Soil-Crop Systems

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Thiols are reduced sulfur groups present in organic molecules (R-SH) in soils and crops. A key property of thiolates (the deprotonated form of thiols) is that they have a higher affinity for soft metals such as cadmium (Cd) over less soft metals such as zinc (Zn). Hence, thiols could separate the ubiquitous pollutant Cd from the micronutrient Zn. This potential function is highly relevant, as these two metals have similar biogeochemical properties and take similar pathways in soil-crop systems. To date, it is well known that thiols such as phytochelatins can retain Cd in roots, thereby limiting its transfer to edible crop parts. However, little information exists on the function of thiols to separate Cd from Zn in soils and crops. Here, we present results from a series of experiments that illustrate how thiols can filter Cd over Zn in soils and crops. In a first step, we provide combined stable isotope (natural abundance) and synchrotron-based speciation data of Zn and Cd in crops. Opposing isotope fractionation and concentration patterns of Cd and Zn as well as predominant binding of Cd to thiolates suggest that they separate these metals in crops. In a second step, we present very recent data from soil incubation experiments and synchrotron-based speciation data suggesting that thiols in soils strongly determine the Zn:Cd ratios in (operationally defined) phytoavailable soil pools. Finally, we discuss how these findings can be used to develop agricultural strategies that optimize the essential trace metal concentrations in crops and thereby their quality.

Talk 21

Zeolite Amendment to Biogas Digestate and Cattle Slurry Reduces Gaseous Nitrogen Losses and Stabilizes Nitrogen Supply to Silage Maize

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Recycling of nutrients contained in cattle manure slurry (MS) and biogas digestate (BD) is central to circular agriculture. However, gaseous losses of ammonia (NH3) and nitrous oxide (N_2O) pose additional environmental threats. We conducted a two-year field study to evaluate the effects of incorporating 1% (w/v) natural zeolite into MS (amended one day before application) and BD (co-fermented during anaerobic digestion). In the field, fertilizers were surface band applied at 170 kg N ha^{-1} and subsequently incorporated into a high-buffering loamy soil. Gaseous emissions, soil N_{min} dynamics, water-filled pore space (WFPS), and crop nitrogen recovery efficiency (NRE) and partitioning harvest index (HI) and nitrogen harvest index (NHI) were monitored.
Based on a three-factorial linear mixed-effects model evaluation, results showed that zeolite amendment significantly reduced cumulative NH_3 emissions ($P < 0.01$) across years and organic fertilizer types. With respect to N_2O emissions, zeolite addition led to a non-significant trend of 22-38% reduction. Agronomic parameters like maize dry matter yield, HI (~0.58), or NHI (~0.65) showed no differences. However, under the dry conditions in 2025 where soil WFPS fell to 30%, a critical point where nutrient diffusion was restricted, we observed agronomic deficits in pure organic fertilizer treatments. Under these stress conditions, zeolite-amended digestate (BDZ) tended to increase agronomic efficiency (AE) by >60% compared to unamended digestate (n.s.), while zeolite-amended manure (MSZ) tended to improved NRE by >80% over pure manure (n.s.). Hence zeolite application – apart from effects on gaseous N losses – may provide an agronomic buffering effect under dry field conditions.

Keynote 04

Plant mineral nutrition from mechanisms to the rhizosphere: what changes when soil and microorganisms enter the picture?

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Meeting the challenges of productive, resilient and resource-efficient agriculture requires moving beyond nutrient supply towards understanding how plants acquire and use nutrients within their growing environment. Iron (Fe) provides a paradigmatic example: despite its abundance in soils, its availability to plants is frequently limited.

Studies under controlled conditions have been fundamental in dissecting the physiological and molecular machinery of Fe acquisition. They revealed a highly regulated and plastic response integrating local and systemic signals, plant nutritional status, nutrient interactions and Fe chemical form. Thus, even under controlled conditions, Fe acquisition emerges as an integrated plant process, with regulation extending far beyond a simple on/off response.

When soil is introduced, however, the meaning of nutrient availability changes. Fe availability is dynamically determined by mobilisation–immobilisation processes, spatial heterogeneity and reciprocal root–soil interactions. In the rhizosphere, microorganisms add further complexity by competing for, mobilising and transforming Fe while interacting with plants, also affecting their molecular responses to nutrients unbalances.

Drawing on our research from controlled systems to soil–plant–microorganism interactions, we argue that these approaches provide complementary levels of understanding. Mechanistic studies remain essential to establish causality, whereas translating this knowledge into more sustainable crop nutrition requires understanding how these mechanisms operate within the rhizosphere. The Fe–Cu interaction in vineyard soils illustrates how the agronomic consequences of an adaptive physiological response to Fe limitation may change when the mechanism operates within the rhizosphere context. To address agricultural challenges, plant nutrition should retain its mechanistic focus on the plant while extending its experimental boundaries to the system where nutrient acquisition actually occurs: the rhizosphere.

Talk 22

Long-term biochar effects on soil organic carbon and microbial nutrient-cycling indicators in temperate arable and grassland soils

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Biochar is increasingly used as a soil amendment with co-benefits for nutrient retention and crop nutrition, yet its long-term effects on soil organic carbon (SOC) and on the biological functions governing nutrient cycling remain poorly resolved under temperate conditions. A decade after application we asked how durably biochar stores carbon, how much measured SOC derives from the char itself, and whether soil microbial communities are altered. We revisited three temperate field experiments — two arable soils (15–30 t ha^{-1} woodchip biochar) and one grassland (9 t ha^{-1} miscanthus-straw biochar, plus hydrochar and raw-feedstock comparisons). SOC stocks were determined to 1 m on an equivalent-soil-mass basis; microbial structure and function were screened by qPCR (bacteria:archaea, fungi:bacteria) and substrate-induced respiration (MicroResp).
In the two arable soils, biochar treatments held significantly higher SOC stocks than controls (0–30 cm: +29% and, dose-dependently, up to +46% at 30 t ha^{-1}; $p<0.001$), largely reflecting the co-measured pyrogenic carbon. At one site the whole-profile gain (+39 Mg ha^{-1}) exceeded the applied biochar carbon, hinting at additional native-carbon accrual, though heterogeneously distributed char is under-recovered by percussion cores [1]. In the grassland, no significant difference was found. qPCR and a preliminary MicroResp screening showed no clear treatment effects, possibly indicating little disturbance of the microbial functions underpinning nutrient mineralisation and plant supply.
Fractionation into mineral-associated (MAOM), particulate (POM) and pyrogenic carbon is underway; together with a biochar-spiking calibration and added grassland sampling, it will resolve how much carbon biochar truly adds to the nutrient-supplying organic-matter pools.

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Talk 23

Proteomic Insights into Plant and Bacterial Metabolism during the Common Bean-*Rhizobium* Symbiosis under External Nitrogen Availability

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Legume nodules are specialized symbiotic organs in which rhizobial bacteroids fix atmospheric nitrogen in exchange for plant-derived carbon and energy. External mineral nitrogen regulates nodulation and symbiotic nitrogen fixation in a nitrogen-form- and concentration-dependent manner. Nitrate is typically associated with strong inhibition of nodule formation and nitrogenase activity, whereas ammonium responses are less well understood and may exert weaker suppression of nitrogen fixation[1,2].

We investigated how external nitrogen influences the common bean - Rhizobium symbiosis across plant performance, nutritional status, and plant and bacterial proteomes. Plants were grown without external nitrogen, with nitrate, or with ammonium. Using a proteomic workflow that simultaneously extracted plant and bacterial proteins from nodules and surrounding plant tissue, we captured integrated host and bacteroid responses to mineral nitrogen availabilty. This dual-proteome approach revealed how nitrogen form reshapes metabolic interactions between the legume host and its symbiotic bacteria.

Our results indicate that external nitrogen reduces plant investment in nodule metabolism and promotes reliance on mineral nitrogen. However, nitrate and ammonium induced distinct proteomic responses. Under nitrate supply, bacteroids maintained key metabolic functions, reflected by increased abundance of nitrogenase and associated Nif proteins, electron transport and redox-related proteins, and tricarboxylic acid cycle enzymes. These changes suggest that nitrate supports sustained bacteroid metabolic activity despite reduced plant energy allocation to nodules. In contrast, ammonium was associated with a strong reduction in symbiotic bacterial metabolism. Together, these findings suggest that nitrate may preserve bacteroid metabolic capacity and maintain the potential for reactivation if external nitrogen becomes limiting.

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Talk 24

Inositol Pyrophosphate Signalling Links Phosphate Sensing and Arbuscular Mycorrhizal Symbiosis in *Lotus japonicus*

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Phosphorus availability is a major factor limiting crop productivity. Plants respond to phosphate (Pi) deficiency through phosphate-starvation responses (PSRs) and by establishing arbuscular mycorrhizal (AM) symbioses that enhance nutrient acquisition. However, the molecular mechanisms linking Pi sensing with AM development remain incompletely understood.

Recent work has identified inositol pyrophosphates (PP-InsPs), particularly $InsP_7$ and $InsP_8$, as central regulators of Pi sensing through the SPX–PHR signalling module [1,2]. Here, we investigated the role of the PP-InsP synthase VIH2 in the model legume *Lotus japonicus*. Biochemical analyses demonstrated that LjVIH2 functions as an $InsP_8$ synthase. Loss of VIH2 strongly reduced $InsP_8$ accumulation, caused constitutive activation of phosphate-starvation responses, and enhanced phosphate accumulation in shoots. Remarkably, *vih2* mutants displayed substantially increased arbuscular mycorrhizal colonization across a broad range of external phosphate concentrations. Enhanced fungal colonization was accompanied by increased arbuscule abundance and maintenance, elevated expression of mycorrhiza-associated marker genes, and improved accumulation of several mineral nutrients, including phosphorus, nitrogen, magnesium and sulfur [3].

Grafting experiments further revealed that VIH2 regulates AM colonization through both local and systemic signalling mechanisms. Together, these findings identify VIH2-dependent inositol pyrophosphate signalling as an important regulatory link between phosphate sensing, nutrient acquisition and root endosymbiosis. The results provide new insights into how plants balance nutrient status with beneficial microbial interactions and may contribute to future strategies for improving nutrient-use efficiency in crops.

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Talk 25

Chloride: From Plant Micronutrient to Beneficial Macronutrient

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Whereas chloride (Cl^-) is universally recognized as an essential macronutrient in animals, it is classified as a micronutrient in higher plants. From an agronomic perspective, Cl^- has long been considered of limited relevance because its natural availability is generally assumed to satisfy plant requirements. Moreover, its reputation has been largely negative owing to its presumed antagonism with nitrate nutrition and its potential toxicity under high, or even moderately elevated, concentrations [1, 2].

However, higher plants actively accumulate Cl^- to contents that are characteristic of a macronutrient, implying a substantial investment of metabolic energy that is unlikely to be justified without important physiological benefits. Our research has demonstrated that Cl^- fulfills specific biological functions that extend far beyond its traditional role as a micronutrient or nonspecific anionic solute. In particular, Cl^- acts as a beneficial macronutrient that enhances the efficiency with which plants use water, nitrogen, and carbon/energy, the three fundamental resources underpinning plant growth and productivity [3,4]. These functions include improved cellular and whole-plant water relations, enhanced nitrate assimilation and increased tolerance to water and nitrogen deficiency.

This presentation will highlight recent evidence that Cl^-, when supplied at macronutrient levels, plays a central role in regulating photosynthetic performance. I will discuss how Cl^- enhances PSII photochemical efficiency during early vegetative development [5] and promotes regulated non-photochemical quenching (NPQ) in mature plants, highlighting the implications of these findings for crop productivity and agricultural sustainability.

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Oral presentations

Differences in the format are due to the different formatting by the authors.

Presenting author in bold

Poster presentation 1

Intercropping to increase recycled fertilizer use efficiency.

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Strategically using natural processes to increase P availability through intercropping may serve as a sustainable strategy to optimize P use of recycled fertilizers. However, competition for resources may counteract the facilitation of P access, and intercropping systems need to be specifically designed for this purpose.
In a meta-study, we investigated whether intercropping systems can increase nutrient use efficiency by analyzing field trials in temperate regions. In this study, we emphasized the suitability of maize intercropping systems in making use of complementarity effects and increasing nutrient use efficiency especially in maize and legume intercropping systems.
Based on these results, we wanted to clarify how to design intercropping systems to optimize the usage of recycled P fertilizers by linking the influence on soil processes to recycled P fertilizer use in pot trials. We found that legumes did not have the same effect on the P processes in the soil as non-mycorrhiza plants, however, in tendency maize growth and P uptake were stimulated when intercropped with common bean, pea, and blue lupin. In contrast, non-mycorrhiza plants stimulated phosphatase activity in the soil the most and altered significantly the microbial community by recruiting beneficial bacteria, however, did not increase maize biomass due to strong aboveground competition. In combination with recycled fertilizer, Buckwheat could use any recycled P source efficiently, with no impact on intercropped maize, while alfalfa in tendency could stimulate maize growth when fertilized with meat and bone meal.
These findings provide valuable insights into the future design of circular cropping systems.

Poster presentation 2

Influence of Vinasse and Biochar on zucchini growth in an urban outdoors environment

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With city populations growing [1] and urbanization progressing, the interest in urban agriculture and urban gardening is increasing [2]. In both urban gardening and commercial agriculture, zucchinis (Cucurbita pepo) present an important and popular crop [3; 4]. Sustainability in urban gardening is a matter of concern.

Biochar is a porous, carbon-rich material produced by pyrolysis of organic feedstock [5; 6; 7]. Its large surface area enables nutrient retention and gradual nutrient release [8]. Vinasse is a by-product of alcohol production [9] and can be used to enrich untreated biochar with nutrients. Previous studies have demonstrated positives effects of biochar on plant growth and yield [10; 11; 12; 13], but research base regarding vinasse and biochar application in urban gardening remains limited.

To test the effect of Vinasse and Biochar treatment in urban hobby garden conditions, we performed an outdoors experiment in two consecutive years with zucchini. Since this crop is nitrogen-demanding [3], we expected effects by the Vinasse and Biochar treatments.

Plant performances were monitored by manual phenotypic measurements, including determination of leaf numbers, leaf lengths and widths, leaf SPAD values and fruit yields.

Vinasse showed the best improvement compared with untreated controls, while vinasse-activated Biochar performed nearly equally well. In contrast, Biochar alone performed similarly poorly as the untreated control.

Hence, vinasse treatment is a recommended fertilizer in hobby gardens for zucchini cultivation. Future work will address the responses of roots and the underlying physiological and molecular mechanisms upon vinasse and biochar treatments.

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Poster presentation 3

Reduction of Soil N_2O Emissions by Applying a Nitrification Inhibitor to Broccoli Crop Residues

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After incorporating nitrogen-rich crop residues into the soil, increased N_2O emissions can occur in open-field vegetable production, with emission levels influenced by site-specific and weather conditions. Previous laboratory experiments showed that the application of a nitrification inhibitor has an emission-reducing effect in this context. Against this background, the study investigated whether this effect can also be observed under field conditions. To this end, different application rates of the nitrification inhibitor 3,4-dimethylpyrazolyl phosphate (DMPP) were applied to fresh, chopped broccoli leaves, which were then incorporated into the soil at a nitrogen rate of 170 kg N ha^{-1} at two field sites in the Oldenburg region. The study examined variants without crop residues, with crop residues without the inhibitor, and with DMPP at half, single, and double application rates. The standard dosage was 2,70 L ha^{-1} (30% w/w); the water application rate was 600 L ha^{-1} in all variants. N_2O emissions were measured from November 4, 2025, to March 10, 2026, using a laser-based infrared gas analyzer (MIRA).
At both sites, three distinct emission phases occurred, coinciding with freeze-thaw cycles. Incorporating crop residues increased cumulative N_2O emissions from an average of 8,7 to 80,1 g N ha^{-1} compared to the control treatment without crop residues. On average, only minor differences in emission levels were observed, while DMPP demonstrated a comparable reduction effect at both sites. DMPP reduced cumulative N_2O emissions by 43 – 53% from an overall average of 80,1 g N ha^{-1}. Increasing the dose beyond the standard application rate did not result in any further reduction in emissions under the conditions studied. Thus, the experiment demonstrates that the application of DMPP following the incorporation of nitrogen-rich broccoli crop residues can contribute to reducing climate-relevant N_2O emissions in open-field vegetable production.

Poster presentation 4

Combining ionomics, molecular physiology and spatial distribution mapping to dissect iron and zinc uptake resilience to water limitation in maize (*Zea mays* L.)

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Over 1.2 billion people suffer from iron (Fe) and zinc (Zn) deficiencies, many of whom rely on maize (*Zea mays* L.) as a major dietary staple. Meanwhile, climate change is increasing the frequency of drought events, threatening crop productivity and quality. While processes contributing to plant Fe and Zn homeostasis are relatively well characterized, mechanisms that confer their uptake resilience under water limitation remain elusive.

To identify variation in nutrient uptake tolerance to drought, we subjected eight maize breeding lines to phenotypic analysis under water limitation. Field-grown plants had between 41 and 77% reduced leaf Fe concentrations under water limitation, and between 29 and 61% reduced leaf Zn concentrations compared to well-watered plants. Grain Fe and Zn responses to water limitation ranged from a 23% increase to a 36% decrease in Fe and a 20% to 42% decrease in Zn. A drought tolerant genotype also exhibited enhanced Fe uptake resilience, indicating dual resilience exists in the maize breeding pool.

Current experiments aim to pinpoint root anatomical and molecular variation associated with Fe and Zn uptake resilience. At the mechanistic level, we are investigating how root apoplastic barrier plasticity regulates element uptake and selectivity under drought. By mapping the spatial distribution of Fe and Zn in root tissues via nanoSIMS and microPIXE, we aim to determine the effects of root barrier variation on highly localized uptake dynamics. Our approach will reveal key mechanisms at the interface between micronutrient accumulation and drought resilience in maize, providing crucial information future breeding programmes.

Poster presentation 5

Targeted application of glucosinolate-rich nasturtium plant material modulates root knot nematode suppressive potato rhizosphere soil microbiome

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Biofumigation where glucosinolate-containing brassica plant materials are incorporated into soil is a common practice used to suppress soil-borne pathogens. While this practice has been used to manage plant parasitic nematodes in agriculture, the effects in the field are often inconsistent. It is also unclear whether nematode suppression is entirely caused by the released biocidal isothiocyanates into the soil or by a modulation of the soil microbiome.
We conducted greenhouse and field plot trials to test whether soil incorporation of benzyl glucosinolate-containing nasturtium (*Tropaeolum majus* L.) plant material modulate potato rhizosphere soil microbiome to suppress root knot nematodes.
Addition of the pelleted nasturtium plant material to soil significantly reduced the number of *Meloidogyne chitwoodi* invading potato roots by up to 60% compared to the soil without the pellets. Sterilisation of the soil significantly reduced the suppressive effect of the incorporated nasturtium pellets compared to natural soil. Potato rhizosphere microbiome from field plots and greenhouse pots treated with the pellets significantly reduced nematode root invasion by up to 35% on new potato plants in sterile sand compared to the control without the microbiome from the pellet-treated pots.
These results suggest that soil incorporation of glucosinolate-containing nasturtium plant material modulate plant-associated rhizosphere soil microbiomes to enhance root knot nematode suppression. Using amplicon sequencing, we will analyse the microbial community to pinpoint nematode antagonists selectively enriched in potato rhizosphere following nasturtium pellets treatment. This study underscores the potential use of nasturtium plant materials to modulate nematode suppressive soil microbiomes as a tool for sustainable management of root knot nematodes in organic and conventional potato farming.

Poster presentation 6

Rhizosphere acidification links ammonium nutrition to Fusarium proliferation in soils with high pathogen pressure

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Using maize and *Fusarium* as a model system, we investigated whether nitrate and ammonium nutrition alter the interaction between plants, the soil microbiome and fungal pathogen populations depending on initial soil pH and natural pathogen pressure.
Maize was grown in soils with low or high *Fusarium* pressure, as well as pH, and supplied with no nitrogen, nitrate or ammonium. Then, plant rhizosphere metabolites and microbial community composition were assessed (16S and ITS). In high pathogen pressure soil, ammonium fertilization reduced fungal richness and strongly increased the abundance of maize-associated pathogenic fungi, mainly *Fusarium*. In contrast, maize-associated beneficial fungi were most abundant under no nitrogen fertilization. Raising soil pH reduced both the ammonium-associated increase in pathogenic fungi and the no-nitrogen-associated enrichment of beneficial fungi to comparable levels. Rhizosphere glutamine concentrations were highest in nitrate-fertilized low pathogen pressure soil and ammonium-fertilized high pathogen pressure soil, with a slight reduction after pH adjustment.
A follow-up experiment tested whether ammonium-driven *Fusarium* proliferation results from general bulk soil acidification or plant-mediated rhizosphere effects. High-pH, high pathogen pressure soils were fertilized with ammonium in planted and unplanted pots. Microbiome analyses of different soil compartments, combined with ONT sequencing of *Fusarium* TEF1 amplicons, showed that ammonium fertilization did not generally promote *Fusarium* in bulk soil. Instead, Fusarium proliferation and microbiome reshaping depended primarily on rhizosphere effects.
These findings suggest that ammonium nutrition can promote *Fusarium* proliferation in high pathogen pressure soils through rhizosphere-mediated processes linked to acidification, implicating targeted nitrogen fertilization as a disease management strategy.

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Poster presentation 7

Polyacrylamide ZrOH Hydrogels for Spatially Resolved Sampling of Carboxylates Exuded from Roots Growing in Soil

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Reliable sampling and quantification of root exudates from intact, soil-grown roots remain a major challenge. We further developed a non-destructive method for the sampling, two-dimensional mapping, and quantification of seven root-derived carboxylates (aconitate, citrate, fumarate, lactate, malate, oxalate, and succinate) using polyacrylamide zirconium hydroxide (ZrOH) hydrogels. The hydrogels efficiently adsorbed all tested carboxylates and achieved elution efficiencies of 95–111%. Their high binding capacity (up to 1.82 µmol cm^{-2}, depending on pH and carboxylate species) exceeds concentrations typically found in the rhizosphere. In addition, if adsorbed on the hydrogels, carboxylates remained stable for several weeks at 4 °C.
Wheat plants were grown in soil-filled rhizoboxes, allowing hydrogel application to selected root regions with minimal disturbance. ZrOH hydrogels were placed in contact with rhizosphere for 24 h, retrieved, sectioned for spatial analysis, and eluted for carboxylate quantification by ion chromatography–mass spectrometry. This approach enables quantitative, millimetre-scale, two-dimensional maps of carboxylate exudation along the root axis and within the surrounding rhizosphere.
Compared with conventional soil–hydroponic hybrid methods, this technique preserves intact root systems, allows repeated sampling of the same plant over time, and captures temporal changes in exudation throughout plant development. The combination of non-destructive sampling, high recovery, storage stability, and high spatial resolution provides a robust platform for investigating rhizosphere processes under realistic soil conditions. This method offers new opportunities to study the dynamics of root exudation and plant–soil interactions while overcoming key limitations of destructive sampling approaches.

Poster presentation 8

A friend in need: Three-way interaction between *Asparagus officinalis*, arbuscular mycorrhizal fungi and soilborne *Fusarium* spp.

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Asparagus officinalis is one of the most important vegetable crops in Germany, with a cultivation area of around 20,000 hectares. It is a perennial crop that can be profitably grown for around eight years. Due to 'asparagus decline syndrome', which is mainly associated with elevated soil concentrations of pathogenic Fusarium species (e.g., *F. oxysporum* f.sp. *asparagi*, *F. proliferatum*), a gradual decline in productivity and growth can be observed over the lifespan of the crop. In the past, inoculating asparagus with arbuscular mycorrhizal fungi has proved successful, as it strengthens plant health and curbs the occurrence of pathogen infections [1]. Here, we investigated the response of the asparagus variety 'Backlim' to *F. oxysporum* and *F. proliferatum* in the presence of two mycorrhizal strains (*Rhizophagus irregularis*, *Funneliformis mosseae*). In one trial, simultaneous inoculation of mycorrhiza and *F. proliferatum* was investigated, as well as pre-inoculation with mycorrhiza four weeks prior to pathogen application. No effect of the timing of mycorrhiza application on shoot and root fresh weight of Fusarium-inoculated plants was found. In a second trial, mycorrhiza inoculation took place during the sowing of the asparagus, and the mycorrhizal plants were subsequently inoculated with the pathogen *F. oxysporum*. Species-dependent mycorrhization of asparagus roots was observed in both trails: *R. irregularis* colonised the roots more extensively (15-48%) than *F. mosseae* (3-4%). However, plants inoculated with *F. mosseae* had a higher shoot and root fresh weight as compared to plants inoculated with *R. irregularis*, when inoculated with *F. oxysporum*. The results provide a promising base for further studying mycorrhiza-based plant protection.

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Poster presentation 9

Citrate vs. malate: an assessment of plant cost-adjusted micronutrient solubilisation efficiency

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Root-derived carboxylates enhance plant acquisition of poorly available micronutrients by mobilising them in the rhizosphere. Citrate and malate are particularly important because they can complex Fe, Zn, Mn, and Cu. We quantified micronutrient solubilisation by citrate and malate and evaluated whether citrate, despite its higher metabolic cost, provides greater plant-cost-adjusted solubilisation efficiency (PACE) than malate.
Batch extractions were conducted on three contrasting soils using 500 µmol L^{-1} citrate, malate, or their combination in 10 mmol L^{-1} KNO_3 or NaN_3 (biocide). Controls contained only water or KNO_3/NaN_3. Carboxylates were quantified by HPLC-DAD, total soil elements by XRF, and solubilised micronutrients by ICP-OES. We furthermore developed a novel PACE framework linking micronutrient solubilisation to the metabolic costs of carboxylate production.
Both carboxylates solubilised only per-mille fractions of total soil Fe, Zn, Mn, and Cu, with soil organic matter strongly influencing the release. Citrate generally mobilised more micronutrients than malate because of its greater complexation capacity, particularly when microbial degradation was suppressed. After accounting for plant energetic and carbon costs, citrate remained the most efficient ligand for all four micronutrients. However, in one soil where citrate was rapidly degraded, its advantage disappeared, demonstrating that microbial turnover can counteract its higher intrinsic efficiency.
While it is well established that the effectiveness of root-derived carboxylates is shaped by soil properties and microbial activity, our study advances this understanding by introducing the newly developed PACE framework. This PACE framework provides the first quantitative approach for evaluating micronutrient solubilisation efficiency relative to plant metabolic investment, offering a new perspective on the ecological and physiological significance of rhizosphere carboxylate exudation.

Poster presentation 10

Belowground echoes of grazing: substrate-dependent soil and microbial responses with possible implications for pasture vegetation

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Alpine pastures are semi-natural grasslands in which plant nutrition depends on interactions among soil nutrient availability, organic matter turnover, and microbial processes. In this study, we investigated how grazing management may affect belowground conditions and, in turn, pasture vegetation, in two South Tyrolean alpine pastures: Vallelunga, on siliceous substrate, and Val di Funes, on dolomitic-calcareous substrate. Abandoned, intermediate and grazed pastures were compared by analysing soil physicochemical properties, bacterial 16S rRNA and fungal ITS metabarcoding.
The effects of grazing were strongly site-specific. In Val di Funes, grazed plots showed higher total organic carbon, total nitrogen and Olsen phosphorus, together with a lower C/N ratio. This suggests greater nutrient availability that could support plant growth and productivity under grazing. In contrast, at Vallelunga, grazing was associated with lower aggregate stability and reduced organic carbon, indicating a possible decline in soil structure and nutrient retention capacity, with potential negative effects on plant establishment and resource uptake.
Microbial community shifts were consistent with these contrasting soil responses. Rather than indicating a single grazing effect, changes in fungal and bacterial communities suggested shifts in the balance among microbial groups involved in root interactions, organic matter decomposition, and open-grassland functioning. These shifts may influence nutrient mineralisation, root–microbe interactions and the resilience of pasture vegetation.
Overall, grazing appears to affect plant nutrition indirectly, by reshaping soil fertility, physical structure and microbial processes. However, its consequences for pasture plants depend strongly on local edaphic conditions, indicating that grazing management should be adapted to site-specific soil constraints.

Poster presentation 11

Combining biological nitrification inhibition and phosphorus mobilization in undersowing mixtures to improve nutrient use efficiency in maize

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Nitrogen (N) and phosphorus (P) use efficiencies remain major constraints to sustainable maize production. Nitrification converts plant-available ammonium into highly mobile nitrate, increasing the risk of N losses through leaching and denitrification, while only a small fraction of total soil P is present in plant-available forms [1, 2]. Diversifying cropping systems through undersowing is an effective strategy to improve nutrient cycling [3, 4]. In this study, we evaluate undersowing mixtures for maize designed to simultaneously improve the N use efficiency by exploiting the biological nitrification inhibition (BNI) activity of a ribwort plantain (*Plantago lanceolata*) component and enhance the P availability through a P-mobilizing species component (*Phacelia*, *Lolium*, or *Festuca*) [5-7]. To account for natural variation, we screened diverse genotypes of *Plantago* for markers associated with high BNI capacity in a pot-based experiment. Furthermore, our hydroponics-based screening for P-mobilization traits identified *Phacelia* and *Festuca* among the better-performing species. Subsequently, undersown mixtures incorporating the best-performing cultivar of *Plantago* with either *Phacelia* or *Festuca* are being evaluated in a two-year field trial to assess their potential to improve nutrient use efficiency in spring-sown maize. Additionally, the trial investigates practical aspects of undersowing, including sowing time and successful establishment under herbicide-free management. Initial field observations indicate that establishing the undersown crop while minimizing weed competition remains a key challenge. By integrating complementary root processes, this study advances the development of multifunctional undersowing mixtures for improved nutrient cycling in maize cropping systems.

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Poster presentation 12

Nitrate leaching mitigation in German Agriculture: Progress, Policy and Agricultural Practice

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To reduce persistently elevated nitrate concentrations in groundwater bodies, Germany introduced stricter fertiliser regulations in 2017 and 2020. Improvements in groundwater and surface water quality become apparent only after long time lags due to long flow paths and residence times. Therefore, a monitoring based on farm- and field-level indicators was established to assess nitrate leaching potential more directly. The indicators include field nitrogen balances, nitrogen use efficiency, soil mineral nitrogen contents, and nitrate concentrations in soil water to a depth of 300 cm. Data were collected from 48 arable farms with 576 monitoring fields (2014–2023). Results showed a significant reduction in fertiliser inputs leading to improved nitrogen use efficiencies and reduced nitrogen surpluses on arable farms. However, these improvements have not yet resulted in lower residual soil mineral nitrogen levels in autumn. Mineral nitrogen contents frequently increased between harvest and autumn. With a random forest analysis, we identified the timing of sowing the subsequent crop, and thus, the type of subsequent crop and the intensity of soil tillage as the most influential management factors affecting this increase. Additionally, soil and weather conditions were important. The results indicate that (1) reductions in nitrogen inputs are likely to decrease nitrate leaching within the root zone only after a time lag, as no consistent decline in average autumn soil mineral nitrogen has yet been observed; (2) the post-harvest period is a critical phase for nitrate leaching; and (3) targeted post-harvest management offers considerable potential to improve nitrate leaching mitigation strategies.

Poster presentation 13

A 3D-printed microneedle platform for nitrate sensing: towards nutrition and stress monitoring in plants

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Profiling the concentration of electrolytes such as sodium, potassium, calcium, and nitrate can provide a sensitive tool for evaluating plant health status and optimizing nutrient management in agriculture.[1] As a primary nitrogen source for plants, nitrate (NO_3^-) serves as both a nutrient and a signaling molecule regulating metabolism and plant development.[2] Therefore, it is instrumental to develop low-cost, scalable platforms for continuous nitrate monitoring to meet the ever-rising demand for agricultural products. Recently, potentiometric electrochemical platforms with microneedle arrays have proven to be an effective method for minimally invasive, continuous plant health monitoring.[3] Herein, we develop a low-cost, flexible microneedle sensor for continuous monitoring of NO_3^- in plants. Microneedles of different lengths (300–1000 µm) enables selective access to distinct tissue depths and vascular regions across various plant species, allowing sampling different biological fluids for localized plant health monitoring. Our microneedle platform demonstrates high sensitivity and selectivity towards NO_3^- detection, underlining its potential for measuring NO_3^- levels in plants. The irregular and non-uniform morphology of plant surface necessitates the use of a flexible microneedle platform to establish conformal contact with the plant interface and facilitate reliable penetration of all needles across different plant species and organs. The developed microneedle patch consists of individual microneedles integrated into a flexible substrate through serpentine-shaped interconnects. Overall, our microneedle patch provides a scalable and cost-effective platform for NO_3^- monitoring, addressing a critical need for precise and resilient agricultural practices.

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Poster presentation 14

Investigation of the association of barley with endophytic nitrogen-fixing cyanobacterium (*Nostoc punctiforme*)

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Due to the environmental impact associated with synthetic nitrogen fertilizers, nitrogen supply to economically important crops, such as cereals, remains a major obstacle to the development of sustainable agriculture. Unlike diazotrophic rhizobia and *Frankia* spp., which establish symbioses specifically with legumes and actinorhizal plants, respectively, cyanobacteria from the order Nostocales are potential candidates for supplying of non-leguminous crops with biologically fixed nitrogen because of their ability to interact with a broad range of plant species.

In this study, we investigated the association between *Nostoc punctiforme* and barley. The cyanobiont isolate SAG 67.79 was previously characterized as a symbiont of the liverwort *Blasia pusilla*. On a solid surface, the cyanobacteria moved chemotactically towards barley roots. Confocal and transmission electron microscopy revealed that they colonized barley roots endophytically under low-nitrogen conditions, entering through root hairs, similar to rhizobial infection, as well as through natural openings and weakened regions of the cell wall, which may represent an ancestral mode of colonization. Internalized cyanobacterium developed heterocytes, specialized nitrogen-fixing cells, under nitrogen-limited conditions, suggest the establishment of a beneficial symbiotic interaction. Furthermore, colonization enhanced plant biomass and increased total nitrogen content in barley plants.

Our findings suggest that barley–*Nostoc* interaction enhances nitrogen uptake in cereals and may reduce dependence on synthetic fertilizers. Future work will assess nitrogenase activity using acetylene reduction assays to support the functionality of the symbiosis. Barley lines expressing a Ca^{2+} reporter will be employed to study the role of calcium signalling as the second messenger during initiation of this interaction.

Poster presentation 15

Compounds derived from asparagus by-products and their effect on cauliflower under drought stress

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In order to utilise residual materials from food production and thus prevent waste along the supply chain, post-harvest asparagus waste and asparagus peelings generated during preparation in commercial kitchens are to be developed into an innovative plant fortifier. Higher temperatures and longer dry spells lead to water and nutrient shortages as well as increased susceptibility to pests and diseases and, thus, are major contributors for yield decline in agriculture and horticulture. This project focusses therefore on producing an extract from asparagus residues, analysing its chemical composition (e.g., carbohydrates, amino acids, plant secondary compounds) and testing it in pot trials with vegetables to assess its ability to increase drought tolerance.
To this end, asparagus-based extracts were prepared from dried asparagus residues using water or ethanol as solvents. Asparagine, GABA, proline, citrate, fructose and sucrose were the most representative primary metabolites detected, while their composition was similar between water and ethanol extracts. In a pot experiment, cauliflower plants were grown in a greenhouse at 80%, 60% and 30% soil water saturation and their leaves were sprayed with the asparagus-based extracts and respective control treatments. During cultivation, the chlorophyll and flavonoid contents of the various treated variants were recorded. At the end of the experiment (at the start of head formation), the fresh and dry weights were determined, the plants' macro- and micronutrients were analysed, and the proline content of the plants was measured as a stress indicator. Results are presented here and discussed in the context of the ongoing product development.

Poster presentation 16

A Senescence-Induced Transporter linking metal homeostasis and senescence in Arabidopsis

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Nitrogen (N) is a fundamental macronutrient critical for plant growth and development, serving as a key component of nucleic acids and amino acids. N deficiency leads to reduced growth and the initiation of senescence, a process that involves the accumulation of reactive oxygen species (ROS) and the phytohormone abscisic acid (ABA). It eventually leads to a transcriptional reprogramming, including the upregulation of senescence-associated genes (SAG) [1-3]. This senescence process facilitates the remobilization of nutrients from older leaves to younger, developing tissues, thereby optimizing resource allocation under nutrient-limited conditions. Here, we identify a novel transport protein that we name Senescence-associated Metal Transporter 1 (SMT1). Its expression is markedly increased under nitrogen deprivation as well as during natural senescence. Yeast complementation assays demonstrated that SMT1 facilitates manganese (Mn) and iron (Fe) transport, highlighting a previously unrecognized link between senescence and metal homeostasis. In Arabidopsis mesophyll protoplasts, SMT1 localized to the ER under standard conditions, but showed a relocalization to peroxisomes upon ROS treatment. T-DNA insertion mutants of *SMT1* exhibited premature senescence correlating with increased ROS accumulation and altered SAG expression compared to the wild type. We are in the course of elucidating the physiological relevance and molecular mechanisms underpinning SMT1-mediated Fe and Mn transport during senescence in Arabidopsis, as well as of assessing the conservation and significance of this mechanism in crops like barley. The characterization of SMT1 advances our knowledge of the interplay between metal homeostasis and senescence, especially under nitrogen-limited conditions, and may provide novel targets for breeding N-efficient crops.

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Poster presentation 17

Designing pot experiments to detect early effects of drought stress and nutrient deficiency on rye (*Secale cereale* L.)

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The term functional ionome refers to the elemental composition of a plant and its organs in regard to the 14 essential mineral nutrients [1]. Here, we describe the design of an experiment that allows studying short-term effects of drought stress and nutrient deficiencies on shoots and roots of rye. The setup includes an establishment phase in which all plants are supplied adequately with nutrients and water, followed by a treatment phase where plants are subjected to contrasting nutrient treatments (adequate supply, deficiency of N, P or K) and irrigation (adequate, drought). This is achieved by adapting nutrient solutions proposed for hydroponics experiments [2] and by fertigating pots filled with washed quartz sand individually. Specific concentration factors of the nutrient solutions were chosen to ensure the same supply of nutrients across irrigation levels. A system of digital scales was used to determine the required fertigation amounts by calculating the average water content of each irrigation level on a weight basis. The pot sizes were chosen to enable growing four plants per pot to account for genotypic differences between individual rye plants in population cultivars. Preliminary results show that canopy temperatures and shoot : root ratios of plant dry matter were affected by the irrigation treatments, whereas total biomass production was not affected. This indicates that our setup may be used to characterise early ionomic signatures for nutrient deficiencies under different fertigation levels, before biomass reductions occur.

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Poster presentation 18

Microalgal Spent Medium as a Sustainable Biostimulant for Crop Growth under Nitrogen Deficiency and Drought Stress

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Biostimulants are a vital part of sustainable agriculture, as they improve plant growth and nutrient uptake, as well as increasing tolerance to abiotic stresses such as heat and drought. Among non-microbial biostimulants, products derived from algae are considered particularly promising. Although commercial products are primarily derived from marine macroalgae, microalgae offer several advantages, such as consistent quality and year-round production. This study therefore investigated the biostimulatory potential of experimental microalgal products on agricultural crops.
Algal cultures, algal powder, and spent medium from *Chlorella spp*. production were evaluated in different experimental systems under controlled conditions in ryegrass, spring barley, and maize. In hydroponic and pot experiments, the tested microalgal samples were found to have a positive effect on the formation of shoot and root dry matter. Under nitrogen deficiency and drought stress, algal powder was found to significantly increase shoot dry matter in hydroponically grown ryegrass. In contrast, algal spent medium enhanced root growth under nitrogen deficiency in hydroponics. Foliar application of algal spent medium also increased shoot and root growth in a maize pot experiment under drought stress. However, in barley, positive effects of the spent medium were only observed under optimal irrigation and were limited to root dry matter without affecting root architecture.
These results suggest that microalgal spent medium has considerable biostimulatory potential. Reusing it as a by-product of algal biomass production is a promising approach to circular resource use. However, identifying the exometabolome compounds responsible for the observed growth-promoting effects is necessary for targeted application.

Poster presentation 19

Nitrogen form modulates plant immunity against rust fungi

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The economic, societal and environmental demands towards reducing chemically synthesized plant protection in agriculture without significant yield loss require new, innovative crop production systems. The joint research project "Agriculture 4.0 without chemical synthetic Plant Protection" aims to establish such a system by cultivating resilient crops through an optimized mineral fertilization strategy. Against this background, understanding the role of nitrogen (N) nutrition in plant immunity is crucial for managing biotic stress tolerance.

We conceptualize the immune system as a multi-layered mechanism which is modulated by both the N-status and the available N-form, namely ammonium and nitrate. We grew hydroponically cultivated soybeans under contrasting N-treatments and inoculated them with the biotrophic rust fungi *P. pachyrhizi.* One week post-infection, we assessed phenotypic indicators and conducted comprehensive proteome analysis.
Ammonium supply resulted in no pathogen-related necrosis but also reduced growth and biomass accumulation in contrast to nitrate-supplied plants. This suggests pathogen suppression primarily arose from ammonium-induced toxicity, consistent with proteomic data showing high salt stress in ammonium-supplied plants. However, in nitrate-supplied plants, pathogen stress leads to increased necrosis and stronger scavenging of reactive oxygen species. In proteomic data, increased activity of the endoplasmic reticulum and the ubiquitin-proteasome-system under pathogen stress is observed. Therefore, a nitrate-specific immune response eventually leads to an increased hypersensitive response. These findings indicate that N-form fundamentally shapes both the host metabolism and host-pathogen interaction outcomes through distinct metabolic and immune response pathways.

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Poster presentation 20

Beyond Single Compounds: How do PFCA Mixtures Affect Uptake and Distribution in Barley?

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Perfluorinated carboxylic acids (PFCAs) are ubiquitous environmental contaminants that may enter the food chain through plant uptake [1]. While it is known that chain length significantly influences the uptake and distribution of PFCAs in plants [2], studies addressing long-chain compounds and their behavior in complex mixtures are scarce.

In this study, the uptake and distribution of 11 PFCAs (C_4 to C_{14}) in brewing barley were investigated using a pot experiment. Three soil-spiked treatments were compared at a concentration of 0.25 mg PFCA per kg soil: a short-chain mix (C_4-C_7), a long-chain mix (C_8-C_{14}), and a full-mix (C_4-C_{14}). At maturity, barley plants were harvested and PFCA concentrations were analyzed in roots, straw, and grains.

The results demonstrated that accumulation in barley grain was minimal, with less than 0.1% of each applied compound being transferred to the grain, while predominantly short-chain PFCAs were translocated in higher amounts to above-ground plant parts. More than 99% of the longer-chain PFCAs (C_7-C_{14}) remained in the soil. Notably, plants treated with the full-mix exhibited a significantly higher uptake of certain longer-chain PFCAs (C_8 to C_{12}) compared to those treated exclusively with the long-chain mix.

These findings suggest that interactions between different PFCA chain lengths during soil mobilization and plant uptake significantly influence their bioavailability. Consequently, these effects should be incorporated into environmental risk assessments to improve the prediction of PFCA movement through the food chain.

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Poster presentation 21

Long-term field management and fertilization in chernozem soil shape the legacy soil phosphorus accumulation and availability

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Long-term fertilization can cause legacy phosphorus (P) accumulation in agricultural soils, while field history may modify its availability. Using the Static Fertilization Experiment at Bad Lauchstädt, Germany, established in 1902, we investigated six combinations of mineral NPK fertilizer and farmyard manure (FYM) across four field strips forming two paired comparisons of liming and legume integration. In total, 144 soil samples collected between 1996 and 2018 were analyzed for total P (TP) and calcium-acetate-lactate-extractable P (CAL-P). The P activation coefficient (PAC) was calculated as CAL-P/TP.
Both mineral NPK fertilizer and FYM significantly increased TP, with the highest concentrations under high FYM inputs. The combined fertilizers produced a non-additive TP response, as the increase associated with NPK was smaller in FYM-amended soils. PAC remained stable over the 22-year period, and NPK increased PAC only in the absence of FYM. CAL-P also varied markedly between paired strip backgrounds, including under unfertilized conditions.
These results demonstrate that legacy P is shaped by both fertilizer inputs and long-term field management. Importantly, total P accumulation did not necessarily translate into further increases in relative P availability. Thus, evaluating the contribution of legacy P to future soil P management requires joint consideration of P accumulation and availability, using matched historical or rotational backgrounds for interpretation.

Poster presentation 22

Microalgae-Based Wastewater Treatment: Assessing the Algal Biomass as an Alternative Fertiliser in Spring Wheat

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From 2029, the amended Sewage Sludge Ordinance (AbfKlärV) will require phosphorus recovery at treatment plants serving 100,000 population equivalents or more, replacing direct use of sewage sludge as fertiliser. Conventional phosphate precipitation with iron or aluminium salts ensures compliance with discharge limits but yields poorly soluble compounds with low plant availability [1,2]. Moreover, the activated sludge process for nitrogen removal is one of the most energy-intensive processes in the field of conventional wastewater treatment [3].

As an alternative, microalgae-based nitrogen and phosphorus removal is currently being tested in a pilot plant [4]. The algae take up the nutrients and incorporate them into their biomass, which is expected to offer higher nutrient availability than sewage sludge when used as fertiliser, thereby reducing mineral fertiliser demand and closing local nutrient cycles [5,6].

To evaluate the suitability of microalgal biomass from wastewater treatment as a fertiliser, a pot experiment with spring wheat was conducted under standardised greenhouse conditions. Several treatments were established using different combinations of microalgal biomass and mineral fertilisers at two fertilisation levels. In addition, the effect of varying microalgal incubation periods in the soil on plant development was assessed. The experiment confirmed the fertilising effect of the microalgae, with various fertiliser combinations positively influencing plant growth and yield. For all treatments, yield parameters and plant nutrient content were determined to calculate nutrient uptake and nutrient efficiency. These results provide a foundation for a comprehensive evaluation of wastewater-derived microalgal biomass regarding its suitability as a fertiliser.

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Poster presentation 23

Mulch affects/ameliorates physical and chemical soil characteristics and crop responses of cabbage grown in microlysimeters

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Mulching can improve hydraulic and agronomic properties of irrigated cropping systems [1,2]. Reduced evapo(-transpi)ration [1] may explain higher water and nutrient use efficiencies (WUE, NUE), often bringing higher yields [2]. To better understand involved water and nitrogen (N) fluxes, microlysimeter experiment with transfer mulch and cabbage in sandy loam soil was conducted in 2025. Irrigation and N supply were standardized across treatments (irrigation threshold: -20 kPa in 20 cm in 6 of 10 plots; nitrogen demand: 245 kg N ha^{-1} (0–60 cm), adjusted for soil N_{min} and mulch-N contributions. In an RCBD with five replicates, mulch effects (control (C), mulched (M)) were analysed on soil infiltration rate (IR), soil water content in 20 cm depth (VWC), soil nitrate, and plant gas exchange. At harvest, yield (FM and DM) and N Utilization Efficiency (NutE, yield per plant N content, [3]) were determined. IR in M was consistently 511.7 cm*d^{-1} higher than C. VWC in mulched soil exceeded C by 3.48 Vol% on average. Notably, stomatal conductance was higher in M plants (p=0.015) and particularly affected by VWC at measurement (MP). Assimilation A (p=0.314) and transpiration (p=0.179) were affected exclusively by $VWC_{\_MP}$ (p<0.001); intrinsic WUE (A/gs) was unaffected. However, FM and DM in M were higher by 14.05 t/ha or 0.93 t/ha. NutE was higher in M (0.657 kg FM g^{-1} N) than in C (0.548 kg FM g^{-1} N). Results suggest causal relationships between soil physical and plant physiological traits caused by organic mulch.

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Poster presentation 24

Evaluation of Cattail (*Typha latifolia*) Plant Parts as Growing Media Components

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Cattail (*Typha* spp.) biomass from paludiculture is considered a promising renewable resource for producing sustainable growing media. However, previous studies using chopped whole-plant cattail material revealed an unstable nitrogen balance, which may limit its horticultural suitability. Therefore, the objective of this study was to evaluate the suitability of different cattail plant parts as growing media components. The harvested aboveground biomass was dried and separated into leaves, stems, and shoots without inflorescences. The inflorescences were excluded because of their hydrophobic properties, making them unsuitable for substrate use. The individual fractions were chopped and incorporated into substrate mixtures consisting of 50% (v/v) white peat and 50% (v/v) cattail material. Nitrogen immobilization was assessed in an incubation study. In addition, plant performance was investigated in greenhouse trials with Chinese cabbage and petunia. The stem fraction exhibited substantially higher nitrogen immobilization than the leaf fraction, both in the incubation test and in the greenhouse trial. While the leaf-based substrate resulted in only a 3% reduction in shoot fresh weight compared with the peat control, the stem-based substrate caused a yield reduction of 20%. The results demonstrate clear differences among cattail plant fractions in their suitability as growing media components. In particular, the leaf fraction showed considerable potential for substrate production, whereas the stem fraction appeared less suitable due to its pronounced nitrogen immobilization. These findings support the selective utilization of cattail fractions within future value chains.

Poster presentation 25

Tolerance of *Brassica napus* L. to boron limitation relies on the additive effects of multiple genetic loci and is a product of both transport and utilisation efficiency

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Boron (B) limitation has detrimental effects on the development of *Brassica napus*. To improve B efficiency of this crop species, it is crucial to identify mechanisms and genetic loci conferring tolerance to B limitation. We employed a *B. napus* doubled-haploid (DH) population derived from accessions contrasting in B-deficiency tolerance, which we subjected to automated phenotyping at the vegetative stage in both nutrient-replete and severe B-limiting conditions to identify quantitative trait loci (QTLs) associated with B efficiency. At experiment end, shoot biomass was, on average, 92% lower under B-deficient compared to B-sufficient conditions across the population. Meanwhile, seven highly B efficient lines (5% of the population) were identified which maintained >27% of their shoot biomass under B-limiting conditions on average, more than four-times higher, on average, than the remaining lines. Only small differences in the response of shoot B concentration to B limitation were observed between B-efficient and B-inefficient genotypes. However, the 10 DH lines with the highest shoot DW under B limitation exhibited five-times higher B content, on average, than the remaining lines. Meanwhile, B-utilisation efficiency varied 3.8-fold between B-efficient lines, additionally indicating a B-utilisation component to B efficiency. QTL hotspots for B efficiency were defined on chromosomes A09, C01 and C06, which co-localised with genes for B uptake and B utilisation. Marker identity analysis indicated multiple B-efficiency alleles across chromosomes are required to confer B-limitation tolerance in *B. napus*. An ongoing fine-mapping approach comprising repeated backcrossing of B-efficient DH lines to the B-inefficient background has reduced hotspot confidence intervals.

Poster presentation 26

Long-term effects on silicon availability through straw incorporation and phosphorus fertilization

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Silicon (Si) is the second most abundant element in the Earth's crust, and many plants, especially grasses, exhibit high silicon concentrations. Silicon accumulates primarily in the aboveground parts of plants in the form of silicon dioxide bodies (SiO_2), also known as phytoliths [1]. The regular removal of crop residues and straw leads to a continuous silicon depletion from the soil, which can result in a long-term depletion of the soil silicon pool [2]. Simultaneously, silica (H_4SiO_4) and phosphate compete for sorption sites on mineral soil surfaces, and increased Si concentrations in the soil solution can mobilize phosphate-rich fractions [3]. The aim of this study is to investigate the extent to which straw removal and phosphorus fertilization influence silicon uptake by plants. We analyzed two long-term field trials conducted by the Austrian Agency for Health and Food Safety (AGES) investigating (a) long-term silicon depletion due to straw removal and (b) phosphorus fertilization (0, 33, 65, and 131 kg P ha^{-1}) in triticale. The results showed that straw removal for 38 years (Rottenhaus site) and 42 years (Rutzendorf site) led to a significant depletion of soluble silicon in the soil, reflected in reduced silicon concentrations in plant tissue. In contrast, the combination of phosphorus fertilization and straw incorporation increased the soluble silicon content in the soil. At the Rutzendorf site, straw incorporation resulted in a yield increase of up to 22%. We conclude that long-term incorporation of crop residues counteracts soil silicon depletion and that phosphorus fertilization influences silicon concentrations in both plants and soil.

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Poster presentation 27

Black Soldier Fly Larval Frass as a Promising Resource for Biostimulant Fertilizers in Viticulture

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Black soldier fly frass—a by-product of insect bioconversion by larvae of *Hermetia illucens*—has potential as an organic fertilizer for viticulture. The material is characterized by a high content of organic matter, a balanced nutrient composition, and naturally occurring biostimulatory compounds, including humic and fulvic acids, amino acids, chitin, and plant-beneficial microorganisms.

The EU-funded project LIFE Waste4Growth (06/2025–05/2029) develops and evaluates solid and liquid frass-based biostimulant fertilizers to improve nutrient use efficiency, drought tolerance, and plant health in grapevines while partially replacing conventional fertilizers.

Preliminary pot experiments identified 1.5% (v/v) frass incorporation as an effective and plant-tolerated application rate, whereas higher concentrations caused phytotoxic effects. Frass-treated grapevines showed enhanced biomass production and increased shoot and root growth. Laboratory and greenhouse experiments further demonstrated suppressive effects against grapevine downy mildew (*Plasmopara viticola*), supporting the proposed plant-protective potential of frass.

Based on these findings, current lysimeter experiments compare frass (50 g plant^{-1}), a 50:50 frass–mineral fertilizer combination (25 g frass plant^{-1}), larval protein (30 g plant^{-1}), and mineral fertilization under controlled drought stress, including a fully irrigated mineral-fertilized control. Grapevine responses are continuously monitored with the PlantArray gravimetric lysimeter system (Plant-DiTech, Israel) to quantify whole-plant transpiration. Physiological responses are assessed by predawn leaf water potential, stomatal conductance, chlorophyll and flavonoid indices (Dualex), while leaf nutrient and proline analyses complement growth measurements. Planned field trials will evaluate selected frass formulations under vineyard conditions.

This contribution presents the objectives, experimental approaches, and current findings of the project towards resource-efficient and climate-resilient vineyard management.

Poster presentation 28

Reused substrate amendments increase soil carbon and phosphorus but trigger nitrogen immobilization in onions?

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Optimal crop production relies on highly synchronized soil-plant nutrient dynamics. While reused substrates applied as organo-mineral amendments offer a sustainable method to enhance baseline soil fertility, their complex composition can significantly alter soil nutrient cycling, directly impacting immediate nutrient availability and subsequent plant uptake pathways.

To comprehensively evaluate these effects, an open-field trial was conducted in 2024 at Hochschule Geisenheim University using a RCBD to test three distinct application rates (0 g, 694 g, and 1.389 g) of reused wood substrate. Detailed soil physicochemical properties (including soil organic matter, electrical conductivity, and pH) and plant tissue nutrient profiles (nitrogen, phosphorus, and potassium) were subsequently evaluated. Multivariate statistics were utilized to determine system-wide agronomic dynamics and nutrient pathways.

Principal Component Analysis demonstrated that the highest amendment dose successfully drove significant, positive increases in soil humus, total carbon, and soil phosphorus banks. However, this massive carbon influx significantly widened the soil C:N ratio, triggering intense nitrogen immobilization. Consequently, this process reduced plant-available soil nitrate and total plant tissue nitrogen compared to the unamended control plots. Although the fresh and dry biomass were significantly higher in substrate amended plots as compared to the control indicating high uptake and utilization of nitrogen resulting in bigger onions and high yield. Additionally, the highest dose elevated soil salinity and suppressed overall potassium uptake, highlighting the complex nutrient antagonisms introduced by the amendment.
Reused substrates not only demonstrate significant potential to immediately elevate soil carbon and phosphorus reserves, but also increase nitrogen uptake which could be misinterpreted as depleted N pools in top soil implying immobilization.

Poster presentation 29

Phenology, Yield, and Fruit Composition of Diverse Grapevine Varieties

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Physiological diversity in grapevines is a key resource for developing climate-resilient varieties with adaptive traits that help maintain must and wine quality under changing environmental conditions [1]. More than 50 grapevine varieties from a repository of historic and fungus-resistant cultivars traditionally grown in Central Europe were evaluated. Across two vintages, yield, 100-berry weight, organic acids, must pH, free amino acids, and mineral cations in berry must were assessed. Overall, the varieties displayed substantial physiological and biochemical diversity. Variation in bud break was lower than that observed for flowering and veraison, indicating that phenological differentiation relevant for ripening occurs mainly after flowering [2]. Several late-veraison varieties were identified. Yield and berry weight varied up to 19-fold, with some varieties showing high or low productivity, whereas others demonstrated greater yield stability. Amino acid profiling revealed a 27-fold variation, largely driven by proline accumulation, which functions not only as a nitrogen reservoir but also as a heat- and drought-related osmoprotectant [3]. Mineral analysis confirmed potassium as the dominant cation across all samples and highlighted varietal differences in must-related ion balance [4]. Overall, varietal performance and adaptation were closely linked to functional traits such as ripening speed, yield stability, nitrogen partitioning, and potassium regulation. No consistent patterns emerged when varieties were grouped by historical origin or breeding background. These findings highlight grapevine diversity as a resource for understanding trait variation and for selecting resilient genotypes for future viticulture.

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Poster presentation 30

Reducing Nitrogen Input without Yield Penalty: Evidence for Improved Nitrogen Use Efficiency in Starch Potato Systems

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Improving starch potato nitrogen use efficiency (NUE) is essential to reduce environmental impacts and comply with strict regulations in nitrate-vulnerable zones. However, it remains unclear whether fertilization below recommended rates can reliably maintain yield and starch content in modern cultivars under present-day production conditions.

To address this, multi-site field experiments were conducted across four years (2021–2024) in northern Germany (Suderburg, Emsland, Göttingen, Dedelow). Trials were carried out using a randomized block design with three cultivars (Eurotonda, Euroviva, Axion), an unfertilized control, and mineral (CAS) and organic (biogas digestate) fertilization at 80% (144 kg N ha^{-1}) and 100% (180 kg N ha^{-1}) of the recommended rate.

Across sites and years, reducing nitrogen fertilization did not result in a significant reduction in fresh matter or starch yield. The unfertilized control generally produced lower yields, although differences were not consistently significant and starch yields occasionally approached those of fertilized treatments. Slightly higher fresh matter yields at 100% were offset by higher starch contents at 80%, leading to equal or higher starch yields under reduced fertilization. Higher nitrogen uptake at 100% treatments, particularly in aboveground biomass, did not translate into yield gains, indicating reduced NUE. Starch yield variability between experiments was substantial and primarily driven by site and year rather than fertilization level.

Reducing nitrogen fertilization can maintain yield and starch content while improving NUE. This may reduce input costs and environmental risks such as nitrate leaching and N_2O emissions, and supports a more efficient allocation of nitrogen within cropping systems.

Poster presentation 31

Limited short-term effects of diatomaceous earth filtration sludge on silicon uptake and plant performance in wheat

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Diatomaceous earth filtration sludge (DEFS), an industrial by-product generated during beer filtration, contains considerable amounts of silicon (Si) and may represent a potential secondary resource for Si application in agriculture. However, its agronomic value depends on the plant availability of Si. This study evaluated DEFS in comparison with two Si sources, AEROSIL® 300 and sodium silicate, applied at three rates of 100, 400, and 1000 mg Si kg^{-1} soil in a pot experiment with spring wheat (*Triticum aestivum* L.). The three Si products differed markedly in water-soluble Si content, which was reflected in plant-available soil Si at harvest and plant Si uptake. Sodium silicate substantially increased plant-available soil Si and resulted in the highest shoot Si concentrations. However, the highest application rate reduced shoot biomass, likely due to sodium-induced stress. In contrast, AEROSIL® 300 only slightly affected plant-available soil Si but tended to increase Si uptake without influencing biomass production. DEFS showed the lowest Si availability and no significant effects on plant Si concentration and growth. Overall, none of the Si sources increased shoot dry matter in this experiment. These findings indicate that the effectiveness of Si amendments is primarily determined by product solubility and accompanying chemical properties. While sodium silicate efficiently supplies plant-available Si, potential side effects at high application rates need to be considered. The limited short-term effectiveness of DEFS suggests that its potential as a Si amendment should be further evaluated under long-term conditions, where gradual Si release may become more relevant.

Poster presentation 32

When do nutrients in foliar fertilizers become plant available? Linking humidity-driven phase transitions of magnesium deposits to uptake in wheat and faba bean

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After foliar application, nutrient solutions rarely remain in their initial liquid state. As spray droplets dry, dissolved salts form deposits that may repeatedly crystallize and re-dissolve e.g. with diurnal changes in humidity. While these phase transitions are expected to influence nutrient availability at the leaf surface, it remains unclear to which extent they determine the uptake velocity and efficiency of foliar-applied elements [1, 2]. To address this question, we tested foliar application of magnesium salts on wheat (*Triticum aestivum*) and faba bean (*Vicia faba*) and subsequently exposed them to contrasting humidity regimes (30–55% and 65–85% RH). Magnesium uptake was related to deposit hygroscopicity and phase behavior. Dynamic Vapor Sorption (DVS) characterized moisture sorption, deliquescence and efflorescence of the magnesium salts, while time-lapse digital light microscopy enabled us visualizing crystallization–re-dissolution on leaf surfaces. DVS revealed distinct phase transitions among salts, indicating differences in their ability to maintain hydrated deposits. Time-lapse imaging revealed phase transitions on wheat and faba bean leaves, with deposit persistence varying between humidity regimes and species, thereby altering exposure to dissolved Mg. Foliar Mg uptake differed markedly among fertilizer salts, humidity regimes and plant species, with $MgCl_2 \cdot 6H_2O$ and $Mg(NO_3)_2 \cdot 6H_2O$ generally promoting greater uptake than $MgSO_4 \cdot 7H_2O$. Integrating uptake measurements with microscopic observations and DVS showed that humidity-driven phase transitions, rather than hygroscopicity alone, regulate nutrient availability at the leaf surface. These findings suggest that transient hydration cycles generate dynamic windows of Mg availability, providing a mechanistic framework linking salt phase behavior with foliar uptake.

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Poster presentation 33

Determination of the Nitrogen Fertilization Status of Broccoli Using Different Optical Sensors

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Optical sensing enables site-specific optimization of nitrogen (N) fertilization by accounting for spatial variability in crop nitrogen status. While this approach is already well established in arable crop systems, comparable tools are currently not available for vegetable crops. The objective of this study was to evaluate the suitability of different optical sensing technologies for assessing the plant nitrogen status in broccoli (*Brassica oleracea* var. *italica*).

The field experiment was conducted from late April until mid-June 2025 near Cappeln, north-western Germany, on a silty sand soil. Broccoli cv. 'McLaren' was cultivated under three nitrogen supply levels (40 (unfertilized control), 70, and 100 kg N ha^{-1}) established by calcium ammonium nitrate (CAN) application. Between the fifth and eighth week after planting, weekly optical measurements were performed using the hyperspectral reflectance sensor 'FieldSpec' (Yara) and the fluorescence sensor 'Multiplex®' (ForceA), covering the potential period for nitrogen top dressing. Following each measurement, sampled plants were harvested to determine aboveground biomass, dry matter, and N content using the Dumas method, allowing calculation of area-based nitrogen uptake.

Among the investigated reference traits, area-based nitrogen uptake most reliably distinguished between nitrogen supply levels. In week seven, hyperspectral reflectance showed only minor differences in the red spectral region but pronounced variation in the near-infrared region among nitrogen treatments. Furthermore, sensor-derived indices were significantly correlated with nitrogen uptake, ranging from $r = 0.66$ for the fluorescence-based Nitrogen Balance Index to $r = 0.93$ for the reflectance-based Red-Edge Chlorophyll Index.

Poster presentation 34

Root system architecture and nitrogen uptake capacity of semi-dwarf rye

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The reduction of stem length by dwarfing gene alleles has been widely exploited in plant breeding to improve harvest index, increase lodging resistance, and enhance grain yield. However, compared with other small-grain cereals, the use of semi-dwarfism in rye (*Secale cereale*) remains limited. A promising approach is the introduction of the dominant, gibberellin-sensitive dwarfing gene *Ddw1*, although its effects on root system architecture and nitrogen (N) uptake remain poorly understood. In this study, we used rhizoboxes, soil-filled columns, and hydroponics to evaluate root traits of semi-dwarf and tall rye inbred lines and winter rye hybrids. At the seedling stage, hybrids developed larger root systems than inbred lines, with no significant differences in total root length between tall and semi-dwarf genotypes. In hydroponics, semi-dwarf hybrids exhibited rooting depths comparable to their tall counterparts. Soil column experiments at the stem elongation stage showed that hybrids also produced greater root biomass than inbred lines. Although shoot length was reduced in semi-dwarf genotypes, root biomass across soil depths remained similar to that of the corresponding tall genotypes. Under N-limited conditions, the introduction of *Ddw1* did not impair the ability of plants to stimulate root growth in response to low N. Likewise, shoot and root N concentrations and root N uptake capacity were comparable between semi-dwarf and tall hybrids. Overall, our findings indicate that *Ddw1* primarily affects shoot growth while having only minor effects on root architecture, growth, and function, particularly in hybrid rye, supporting its potential use in breeding programs without compromising root performance.

Poster presentation 35

Biofortification of Oat with Iodine and Selenium by Foliar Fertilization

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Iodine and selenium are essential micronutrients for humans, yet their dietary intake is often inadequate. Agronomic biofortification is a promising strategy for improving the iodine and selenium status of the population, but little is known about its effectiveness in oat. This study investigated the effect of foliar applications of potassium iodate and sodium selenate on iodine and selenium enrichment in oat.

A field experiment with the oat cultivar 'Delfin' was conducted using four replicates. Application rates ranged from 0.9 to 2.1 kg I ha^{-1} and 30 to 90 g Se ha^{-1}. Foliar treatments were applied once during stem elongation, panicle emergence, or grain filling, or split across these growth stages. Iodine and selenium contents in grain, hulls, leaves, and culms were determined on a dry matter basis by inductively coupled plasma mass spectrometry (ICP-MS).

In the control, grain iodine and selenium contents were 20 and 71 µg kg^{-1}, respectively. A single KIO_3 application during grain filling increased the grain iodine content to 80 µg kg^{-1}, whereas earlier and split applications were less effective. Split selenium fertilization resulted in the highest selenium content in grain (1,502 µg kg^{-1}), corresponding to 21-fold increases over the control. Selenium contents in leaves and culms were comparable to those in grain and hulls, whereas iodine accumulated predominantly in leaves (up to 28,434 µg kg^{-1}). These findings suggest that iodine is transported predominantly via the xylem, whereas selenium exhibits greater phloem mobility. Neither grain nitrogen content nor grain yield was significantly affected by biofortification.

Poster presentation 36

Promoting vitality of urban climate trees in Hamburg – a fertilization experiment with Turkey oak (*Quercus cerris*)

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Urban trees are exposed to many interacting environmental stress factors, e.g. poor soil conditions, limited rooting space, drought stress, diseases and pests [1]. Climate change even exacerbates the severity of such factors. Non-native tree species are sometimes better adapted to these stress factors. Turkey oak (*Quercus cerris*) originates from the Mediterranean region and is supposed to be more tolerant to drought stress than English oak (*Q. robur*), which is native in large parts of Europe [2]. It is thus a promising candidate as a future urban tree species in Central Europe. However, little is known about its fitness in Central European urban environments [3].
(Co. Compo Expert)
Within a project on suitability and sustainable care of climate trees in the city of Hamburg (funded by Ministry of Economy, Labour and Innovation) a fertilizing-experiment with urban *Q. cerris* trees is conducted. It is aimed to improve tree vitality by application of mineral fertilizers and/or biostimulants.
In April and May 2026, 120 trees, growing all in the same street in Hamburg were treated according to the following variants:

- (i) "Baumkraft fluid" (Co. Compo Expert) and "Epsotop" (Co. K+S), including irrigation
- (ii) "Baumkraft fluid", "Vitanica" (Co. Compo Expert) and "Epsotop", including irrigation
- (iii) "Waldleben" (Co. Waldleben), including irrigation
- (iv) Solely irrigation
- (v) No treatment.

Frequent measurements on stem diameter, nutrient concentrations in leaves and soil, and assessments of disease symptoms and pest infestations will be conducted in the following vegetation periods in order to monitor tree growth as well as nutritional and health status. Preliminary data will be presented and discussed.

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Poster presentation 37

Can Diazotrophic Bacteria Reduce Nitrogen Fertilizer Requirements in Broccoli?

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Biostimulants based on diazotrophic bacteria are considered a promising approach to reducing mineral nitrogen fertilization, but their efficacy in vegetable production remains largely unexplored. This greenhouse study investigated the effects of inoculating broccoli (*Brassica oleracea* var. *italica* cv. 'Parthenon') with *Methylobacterium symbioticum* or *Azotobacter salinestris* under three nitrogen supply levels (3.5, 5.7, and 7.9 g N plant^{-1}). The bacteria were applied once or twice during early plant development. Plant growth, SPAD values, fresh and dry biomass, nitrogen content of individual shoot organs, and nitrogen efficiency parameters were determined.

Overall, bacterial inoculation did not consistently improve plant performance, although sporadic positive effects were observed. Under high nitrogen supply, two applications of *M. symbioticum* significantly increased shoot yield by 3.3%. 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 shoot fresh mass. However, bacterial inoculation had little effect on nitrogen efficiency parameters. Only the inflorescence showed a slight tendency towards improved nitrogen uptake efficiency and nitrogen use efficiency following two applications of *M. symbioticum*. Both efficiency traits were closely correlated with inflorescence fresh mass. Further research under field conditions is required to assess the potential of diazotrophic bacterial biostimulants in broccoli production.

Poster presentation 38

Effects of Nano-Hydroxyapatite and Phosphate-Solubilizing Bacteria on the Phosphorus Nutrition of Maize (*Zea mays* L.) under Moderate Temperature Conditions

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Phosphorus (P) scarcity and the low efficiency of conventional P fertilization challenge sustainable crop production. Nano-hydroxyapatite (nHA) represents a potential recycled P source, but its low solubility can limit plant availability. This study evaluated whether phosphate-solubilizing bacteria (PSB) enhance P mobilization from nHA and improve maize (*Zea mays* L.) nutrition and growth under moderate temperatures. *In vitro* assays quantified nHA solubilization by six bacterial strains and assessed the contribution of organic acids (OAs) to P release. In addition, a climate chamber pot experiment with maize tested nHA, PSB, and combined applications under low and moderate P supply.

Several PSB strains strongly increased dissolved P concentrations *in vitro*. *Pseudomonas rhodesiae* released up to 133 mg P L^{-1}, corresponding to 90.1% of total nHA-derived P in suspension. OA-mediated nHA solubilization increased with decreasing pH, but differences among individual OAs indicated that P release was affected not only by proton activity, but also by OA-specific mechanisms such as calcium complexation. In the pot experiment, P supply level was the main factor controlling soil P availability, shoot P uptake, and dry matter production. Under low P supply, combined nHA and PSB application increased shoot P uptake from 2.86 to 4.20 mg P pot^{-1} compared with the control. Under moderate P supply, nHA alone most consistently improved P uptake and dry matter, recovering 6.6% of applied nHA-derived P, whereas PSB provided no additional benefit. Overall, strong *in vitro* nHA solubilization showed limited transferability to buffered soil systems under moderate temperatures.

Poster presentation 39

Silicon improves wheat performance under multi-stage waterlogging through root stabilization and nutrient redox balance

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Waterlogging represents a major constraint to wheat productivity because root hypoxia impairs nutrient uptake and alters rhizosphere redox conditions. Although silicon (Si) is recognized as a beneficial element that enhances plant tolerance to abiotic stress, its effects under contrasting waterlogging scenarios and their interaction with nutrient dynamics and redox processes remain poorly understood. A pot experiment was conducted to evaluate the effects of Si application under simulated early (EWL), late (LWL), and repeated (E + L) waterlogging. Root dry weight and grain yield were the most affected traits, with the strongest reductions observed under repeated waterlogging. Silicon application enhanced root growth and partially restored grain yield across all stress treatments. In addition, Si significantly improved plant recovery, particularly following early and repeated waterlogging. Increased leaf Si concentrations confirmed effective Si uptake and were accompanied by an enhanced recovery capacity after waterlogging. Root nutrient analysis revealed a pronounced Fe–Mn imbalance under waterlogging, reflecting altered rhizosphere redox conditions. Silicon supply mitigated these imbalances and contributed to a more balanced nutrient profile. Overall, the results indicate that silicon improves wheat tolerance to waterlogging by maintaining root function, stabilizing nutrient and redox balance, and promoting yield recovery under stress.

Poster presentation 40

Nitrogen Nutrition of Maize and Soybean in Organic Strip Intercropping

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Intercropping has been proposed as an alternative to conventional monocultures by improving water-use efficiency through canopy microclimate modification (Gollobich et al., 2026). In organic systems, sustaining crop nitrogen (N) nutrition while reducing external N inputs is a key priority (Salehi et al., 2025). Legume–non-legume intercrops can contribute to this goal via biological N_2 fixation and complementary soil N uptake. Maize and soybean are important European feed crops, yet most soybean is imported, and the N dynamics of maize–soybean intercropping under European conditions remain poorly characterized. A two-year experiment (2023–2024) was conducted at the BOKU research farm in Raasdorf, Austria, comprising sole maize, sole soybean, and a strip intercrop under three organic N levels (0, 50, 100% of recommended N, applied to maize only. Nitrogen concentration in biomass and grain was determined at harvest.

Grain and biomass N concentration of both crops were largely unaffected by N level or cropping system. Maize grain N tended to be higher in the intercrop than in the sole crop in 2023, possibly related to the reduced near-canopy wind velocities documented in our companion wind study (Gollobich et al., 2026), which may have altered transpiration-driven N transport. Soybean grain N remained stable across systems and N levels, independent of cropping system or fertilization, consistent with its capacity for biological N_2 fixation. Overall, these results indicate that organic maize-soybean strip intercropping can maintain, and in maize potentially enhance, crop N status without additional N fertilizer input, supporting its value as a resource-efficient strategy for organic production.

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Poster presentation 41

Interactive Effects of Boron and Silicon on Yield Components and Chlorophyll Content in Wheat (Triticum aestivum L.) under Early- and Late-Watering Conditions

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Waterlogging is a major abiotic stress limiting wheat productivity by restricting oxygen availability in the rhizosphere, thereby impairing root function, reducing chlorophyll content, and decreasing yield formation. Although both silicon (Si) and boron (B) have individually been associated with improved stress tolerance, their combined effects under waterlogging remain insufficiently investigated. This greenhouse experiment evaluated the effects of soil and foliar applications of B and Si on wheat exposed to early (BBCH 31) and late (BBCH 51) waterlogging.
Waterlogging significantly reduced chlorophyll content and yield-related traits, with late waterlogging causing more pronounced reductions than early stress. Across both developmental stages, combined B and Si applications generally resulted in higher SPAD values and improved yield components compared with untreated waterlogged plants and were more effective than individual nutrient applications. Foliar application during the reproductive stage was particularly effective in alleviating the adverse effects of late waterlogging, whereas both soil and foliar treatments contributed to improved plant performance under early waterlogging.
Overall, the results demonstrate that combined B and Si fertilization can mitigate the negative effects of waterlogging on wheat growth and productivity. The consistently improved chlorophyll retention and yield-related parameters observed in the combined treatments suggest enhanced physiological stress tolerance compared with individual nutrient applications. These findings indicate that integrated B and Si management represents a promising nutritional strategy to improve wheat performance under temporary waterlogging conditions.

Poster presentation 42

Beyond K^+/Na^+ Ratio: Cl^- Toxicity and Osmotic Effects Shape Genotype-Specific Salt Tolerance in Maize and Faba Bean

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Salinity severely constrains crop productivity, yet the physiological mechanisms driving tolerance vary markedly between species and genotypes. Distinguishing specific ionic from osmotic effects is essential for interpreting plant nutritional status and ion balance under salinity. We examined photosynthetic rates (A) and leaf Na^+, K^+, and Cl^- concentrations in two maize (LG30222, ES-Metronom) and two faba bean (Fuego, Scoop) genotypes under five treatments: control (1 mM NaCl), 50 mM NaCl, 100 mM NaCl, 50 mM Na_2SO_4, and 50 mM $CaCl_2$. Correlation analysis between A and $Log_{10}(K^+/Na^+)$ revealed that K^+/Na^+ homeostasis only partially explains salt tolerance in Fuego, showing a moderate positive Pearson correlation ($r = 0.67$). In contrast, Scoop ($r = 0.19$), LG30222 ($r = -0.04$), and ES-Metronom ($r = 0.38$) demonstrated that K^+/Na^+ imbalance is not the primary driver of their photosynthetic inhibition. Although these weak correlations were comparable, leaf Cl^- data highlighted fundamentally distinct stressors. In maize, photosynthetic declines under NaCl and $CaCl_2$ aligned with significant rises in leaf Cl^-, confirming that specific Cl^- toxicity is the dominant inhibitor. Conversely, Scoop suffered severe photosynthetic collapse under Na_2SO_4 while its Cl^- concentration remained at the lowest baseline, clearly indicating that osmotic stress, rather than ionic toxicity, governs its decline. These findings demonstrate that salt responses cannot be generalized; accurate physiological diagnosis requires disentangling K^+/Na^+ selectivity from genotype-specific Cl^- toxicity and osmotic constraints in the context of plant mineral nutrition.

Poster presentation 43

Inositol Pyrophosphate Signaling in Tef: Implications for Phosphate Starvation Responses and plant defense

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Tef (*Eragrostis tef*) is a nutritionally important, gluten-free cereal and a major staple crop in Ethiopia, accounting for approximately 27% of the country's cereal cultivation area. Its productivity is constrained by poor soil fertility and insect pests. More than 70% of Ethiopian soils have low available phosphorus, while shoot fly (*Atherigona hyalinipennis*) infestation can cause substantial yield losses. Improving both phosphorus-use efficiency and insect tolerance therefore represents an important breeding objective.

Inositol pyrophosphates (PP-InsPs) are conserved signaling molecules that regulate phosphate starvation responses and jasmonate-dependent defense against herbivores in Arabidopsis and other model species. . However, their functions in tef remain unknown.

This project aims to establish the experimental framework required to investigate PP-InsP function in tef. Candidate genes encoding key PP-InsP metabolic enzymes, including members of the ITPK and VIH families, are being identified, while tissue culture, plant regeneration and CRISPR/Cas9-based genome editing approaches are being developed for functional studies. These tools will enable future analyses of phosphate homeostasis, phosphate starvation responses and insect defense in genetically modified tef plants.

By extending knowledge from Arabidopsis to an important orphan crop, this work aims to provide the basis for understanding PP-InsP signaling in tef and may ultimately contribute to strategies for improving phosphorus-use efficiency and insect tolerance.

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Poster presentation 44

SISE, free LabView-based software for ion flux measurements

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Various electrophysiological techniques have been developed to study ion transport processes in plants, as well as their role in signal transduction pathways. An important non-invasive method is provided by Scanning Ion-Selective Electrodes (SISE), which are used to detect ion fluxes. These SISE-measurements depend on software that coordinates the continuous electrode movement between two positions, as well as data collection and analysis. We developed two LabView-based programs; the SISE-Monitor and SISE-Analyser that enable ion flux recordings and their analysis, respectively. These applications are freely available, both as windows-executable files that enable routine measurements, as well as the LabView source code that allows insights into the routines used for measurement and analysis. Moreover, the source code can be used to develop new functions, such as the combined measurement of extracellular ion fluxes with SISE and cellular ion concentrations with fluorescent dyes, or proteins.

Poster presentation 45

Boron-Tolerant *Pseudomonas* sp. Mediated Enhancement of Boron and Phosphorus Availability in Canola

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Boron (B) and phosphorus (P) application are essential as many agricultural soils with high calcium carbonate content, high pH and less organic matter content limit nutrients supply due to precipitation, fixation and adsorption phenomena. Although a few B tolerant bacteria have been reported in the literature, their significance in improving nutrient availability and plant growth remains rarely investigated. This study was conducted to isolate, screen and characterize B-tolerant plant growth promoting rhizobacteria from canola rhizosphere, and assess their potential for improving nutrient uptake and plant growth. Out of 100 strains obtained from different agroecological zones of Punjab, Pakistan, 23 isolates were selected for repeated B tolerance tests (0, 60, 120, 180, 240 and 360 mM of B). Four strains (IF6, IF11, PS-1 and PS-12) showed high B tolerance. *Pseudomonas* sp. (PS-1) exhibited maximum B tolerance at 360mM, efficient P solubilization (PSE=162.7%; PSI = 3.68) and indole-3-acetic acid production (4.99 mg/L). A controlled pot experiment demonstrated that the combined application of *Pseudomonas* sp. strain PS-1, B, P and L-tryptophan significantly enhanced plant dry biomass (42%), membrane stability index (26%), SPAD value (19%), B concentration (32%) and P concentrations (27%) in plant tissues compared to control (only mineral fertilizers). In conclusion, *Pseudomonas* sp. strain PS-1 represents an efficient bioinoculant for enhancing B and P availability and promoting sustainable canola production in alkaline calcareous soils through various plant growth promoting mechanisms.

Poster presentation 46

Effect of Citrus Peel Biochar for Reducing Cadmium Accumulation in Lettuce Plants

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Biochar, produced through the pyrolysis of organic materials such as plant residues and manure, has become an important soil amendment due to its positive effects on soil health, crop yield, and environmental sustainability [1]. Cadmium (Cd) contamination in agricultural soils is a critical global concern because of its high toxicity, persistence, and ability to enter the soil–plant system, causing risks to food safety and human health [2]. Citrus peel biochar (CPBC) has emerged as a promising material for the remediation of Cd-contaminated soils by reducing Cd mobility and bioavailability and consequently decreasing Cd accumulation in plants. This study evaluated the effects of raw citrus peel (RCP) and citrus peel biochar (CPBC) on Cd toxicity and lettuce growth. Four treatments were applied: control, Cd, Cd + RCP (20 g RCP kg^{-1} soil), and Cd + CPBC (20 g RCP kg^{-1} soil). Cadmium contamination was established by applying $CdCl_2 \cdot H_2O$ at a concentration of 20 mg Cd kg^{-1} soil. The experiment was conducted with four replications. Prior to plant cultivation, the structural and functional properties of the materials were characterized using RAMAN and FTIR. The highest lettuce biomass was obtained from the CPBC treatment. Cadmium accumulation was highest in Cd-treated plants, followed by Cd + RCP and Cd + CPBC respectively. The results indicate that CPBC effectively reduced Cd uptake and alleviated Cd toxicity. Therefore, converting citrus peel waste into biochar represents a sustainable approach for waste valorization and heavy metal remediation while improving soil quality and supporting environmentally friendly agricultural production.

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Poster presentation 47

Ammonium Transporters (AMTs) in *Vitis Vinifera* and their Role in Plant - Pathogen Interactions

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Vitis vinifera is a high-value perennial crop with stringent quality requirements that are closely linked to nutrient management. Nitrogen availability and the chemical form in which it is supplied markedly influences nitrogen assimilation and metabolism, alters metabolite profiles in grapevine leaves, and ultimately affects the sensory attributes and overall quality of wine. Notably, ammonium and nitrate fertilization result in distinct physiological and metabolic responses, indicating differential regulation of nitrogen uptake and downstream pathways. To elucidate the molecular basis of ammonium acquisition, we systematically analyzed the ammonium transporter (AMT) repertoire in the *Vitis vinifera* genome and identified twelve putative AMT-encoding sequences. We further functionally characterized the three members of the high-affinity AMT1 subfamily by heterologous expression in yeast and *Xenopus laevis* oocytes. For some AMT2 type transporters we identified variety and resistance related transcriptional upregulation during infection with *Plasmopara viticola* and *Phyllosticta ampelicida*. We hypothesize that these transporters are essential in the interaction and might represent potential targets for disease management.

Poster presentation 48

Post-harvest nitrogen fertigation in red currant 'Rovada' shows best nitrogen use efficiency

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Nutrient and water supply strongly affect yield and fruit quality of red currant, but fertigation strategies are rarely quantified. In a five-year field trial (2003–2007), the cultivar 'Rovada' (single-shoot training, 3.00 × 0.50 m, three plots of six to eight plants) was grown under six treatments: unirrigated, irrigated with water only, and four drip-fertigation regimes (dose relative to a 125 kg N ha^{-1} full dose): 100 % or 50 % applied until harvest, and 150 % or 75 % extended into autumn. Yield varied strongly between years, including a weak 2005; all five years are reported. Irrigation alone did not increase yield over unirrigated plants. Fertigation increased yield, berry size and strig weight (all $p < 0.001$). The highest yield (about 1810 g per plant, 29 % above water only) came from 75 % extended into autumn, that is with less total nitrogen than 100 % ending at harvest. Reaching the top yield group with the least nitrogen, it showed the highest agronomic nitrogen use efficiency (extra yield per kg N). The largest berries occurred with 100 % ending at harvest, the heaviest strigs with the autumn-extended 75 % dose. In red currant, best fruit quality, i.e. long strigs, low run-off and large berries, grows on one-year-old wood, so sufficient annual renewal shoots are essential, which the greater shoot length under later nitrogen may support. Where next-season flower induction follows harvest, as in currant and other berries, post-harvest nitrogen may benefit yield, quality and nitrogen use efficiency.

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Poster presentation 49

Azospirillum brasilense rewires iron deficiency responses through Fe-dependent transcriptome reprogramming in cucumber

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Iron (Fe) deficiency is a major constraint for crop productivity, particularly in calcareous soils. Plant growth-promoting rhizobacteria (PGPR) have emerged as promising tools to improve nutrient acquisition [1], although the molecular mechanisms underlying their interaction with plants under different Fe nutritional conditions remain poorly understood [2]. Here, we investigated the transcriptional and physiological responses of cucumber inoculated with *Azospirillum brasilense* under Fe-sufficient and Fe-deficient conditions.
Bacterial inoculation significantly enhanced root ferric-chelate reductase activity, confirming the stimulation of Fe acquisition [2]. Transcriptomic profiling revealed that *A. brasilense* modulated a similar number of genes under both Fe regimes, although only a small fraction of transcripts was commonly regulated, indicating a strong dependence on plant Fe status. Gene Ontology enrichment analyses highlighted distinct transcriptional programs. Under Fe sufficiency, bacterial inoculation attenuated stress-related pathways while promoting metabolic activity, nitrogen assimilation and growth-associated processes. Under Fe deficiency, *Azospirillum* induced a broader transcriptional reprogramming involving nutrient transport, transcriptional regulation, redox homeostasis, cell wall remodelling and stress adaptation.
Notably, genes typically associated with intrinsic Fe-deficiency responses, including those involved in riboflavin biosynthesis, nicotianamine production and nitrogen metabolism [3,4], were downregulated following bacterial inoculation. These findings suggest that *Azospirillum* alleviates the need for energetically expensive plant adaptive responses by promoting a microbe-assisted strategy for Fe acquisition.
Overall, this work demonstrates that *A. brasilense* reshapes cucumber Fe homeostasis through Fe-dependent transcriptional reprogramming extending beyond classical responses. These findings provide new insights into the molecular basis of PGPR-mediated nutrient use efficiency and support the development of sustainable bioinoculant-based agricultural practices.

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Poster presentation 50

Context-dependent effects of commercial arbuscular mycorrhizal inoculants on grapevine nutrition, growth, and physiology

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Arbuscular mycorrhizal fungi (AMF) may improve grapevine nutrition and resilience to abiotic stress, but responses are shaped by host genotype, fungal identity, and environmental context [1-3]. We conducted a controlled pot experiment to evaluate whether three commercial AMF inoculants influence the nutritional and physiological responses of the grapevine rootstocks Börner, SO4, and Vinto under contrasting water regimes. Root colonization, 18S rDNA AMF community composition, leaf mineral concentrations, biomass, midday leaf water potential, leaf optical traits, and proline were assessed. Inoculant treatment colonized the grapevine roots and significantly affected the root-associated AMF community across the investigated rootstocks. Leaf nutrient responses were strongly context-dependent. Under well-watered conditions, Vinto inoculated with inoculant B showed the most consistently positive profile across macro and micronutrients. Conversely, SO4 inoculated with inoculant A or C under drought showed marked reductions in Cu and Zn relative to the corresponding non-inoculated controls. Biomass responses were likewise restricted to particular rootstock-inoculant combinations, while inoculation did not alter leaf water potential or proline accumulation. These findings show that, under controlled pot conditions, commercial AMF inoculants did not produce uniform nutritional or physiological benefits across grapevine rootstocks. Their effectiveness depended on inoculant identity, rootstock genotype, and water regime. The results therefore support targeted screening of inoculant-rootstock combinations under controlled conditions, followed by validation under vineyard conditions before their integration into nutrient management strategies in viticulture.

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Poster presentation 51

Dual land use: Analysing simultaneous energy and crop production on an arable field

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As the demand for greenhouse gas emission reduction is growing, near-surface ground source heat pump (GSHP) systems offer an attractive alternative for cooling and heating of residential buildings due to their high energy efficiency [1,2,3]. The operation of GSHPs at shallow depths creates soil temperature gradients that can extend into the root zones of crop plants [4,5]. In 2020, a one-hectare-sized near-surface GSHP was installed in an arable field in Bad Nauheim, Hessia, providing heating and cooling for over 400 residential units. This "dual land use" of energy exchange and crop production necessitates the thorough investigation of the interaction of these two land use systems: Heat and cold production modify seasonal soil temperature dynamics, impacting crop development and growth, while crop water consumption may alter the specific thermal capacity and conductivity of the soil. This study uses the Bad Nauheim GSHP (1) as a "living lab" to examine distinct faba bean (*Vicia faba* L.) genotypes their performance under extreme soil temperature conditions and (2) to quantify interactions between GSHP energy production and crop development and growth. As the system's fixed geometry prevents full randomization, the trial design was adapted to allow for meaningful statistical analysis of the trial results. Key processes of crop production, such as soil-plant N-dynamics are assessed, acknowledging temperature-dependent N-mineralisation and genotype-specific N-fixation responses.

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Poster presentation 52

Chitosan and humic substances swap roles as soil pH shifts: a pH-contingency index resolves biostimulant efficacy for phosphorus nutrition in maize

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Struvite dissolution and the rhizosphere processes through which biostimulants act are both governed by soil pH, yet each has been evaluated almost exclusively within single soils. Maize was grown in rhizoboxes combining two soils (initial pH 4.2 and 8.1), three phosphorus (P) treatments (none, monocalcium phosphate, and struvite) and three biostimulants (none, humic substances, and chitosan), with four replicates. Struvite matched monocalcium phosphate for efficiency index, with no P effect ($P = 0.068$–0.197), and no interaction with soil pH, although available P under monocalcium phosphate fell from 4.68 to 3.40 mg 100 g^{-1} from alkaline to acidic soil, whereas struvite sustained 4.91 and 5.03 mg 100 g^{-1}, respectively. Biostimulants dominated efficiency (partial $\eta^2 = 0.69$) irrespective of P, but their efficacy reversed with soil pH (biostimulant × soil pH, $P = 0.003$). We therefore defined a pH-contingency index (PCI) as the difference between the log response ratios of a biostimulant in the acidic and the alkaline soil, positive values denoting greater efficacy under acidity. Chitosan was superior under acidity and humic substances under alkalinity, a reversal significant for both P-use efficiency ($\Delta PCI = +0.238$, $P = 0.021$) and apparent P recovery ($\Delta PCI = +0.317$, $P = 0.007$). Both biostimulants enlarged the fine-root system, yet only chitosan increased P uptake per unit root length. Struvite is therefore a robust substitute for mined phosphate across contrasting soils, whereas biostimulant selection should be matched to soil pH.

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Poster presentation 53

Unlocking the potential of Wheat Wild Relatives for increasing food production from Salt-affected lands

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Food security is a persistent challenge for humankind and is getting bigger under the changing climate as the environmental stresses are increasing. Soil salinization, water scarceness and high temperature events are increasing in scale as well as strength causing severe yield damages to crop. Salt-affected soils cover a vast area (833 mha;FAO 2021) and can be used to increase food production. The diverse genetic resources of crop wild relatives have survived these stresses through the history. From these genetic resources, stress resilient species can be identified for further use to develop stress resilient crop varieties. Wheat is reasonably salt resilient (Saqib et al. 2008) and a vital staple food for a large segment of the human population. Wheat wild relatives are less explored genetic resources and are promising genetic resources for increasing food production from salt-affected lands. Here we report relative salt resistance of wheat wild relatives and cultivated wheat species in hydroponics and salt-affected fields. There were significant differences among the species and accessions (Saqib et al. 2026). One accession of *Triticum dicoccoides* was highly salt resistant whereas it's another accession was at par with *Triticum aestivum*. On the basis of relative shoot fresh and dry weights, *Triticum dicoccoides* was followed by *T. durum*, *T. aestivum* and *T. araraticum* in salt resistance. This salt resistance of these species was correlated to Na^+ and K^+ concentration in shoot, leaf chlorophyll contents and stomatal conductance. These species have been further studied in salt-affected field conditions with genotypic differences among these wheat species.

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Poster presentation 54

Forchheim Long-Term Trial on Recycled Fertilisers: The Effect of Processed Recycled Fertilisers on Soil Nutrient Levels

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Global phosphorus reserves are limited and confined to a few regions. Legislators are therefore endeavouring to return a significantly higher proportion of circulating phosphorus to agriculture. The most important potential sources of phosphorus are sewage sludge, meat and bone meal, and organic municipal waste (organic garden and household waste). In future, sewage sludge is to be incinerated; like the phosphorus in meat and bone meal, it has only low plant availability (e.g. Möller et al. 2018). Struvite precipitation, acidification with sulphuric acid or treatment with sodium during the incineration process is intended to increase the phosphorus availability of these fertilisers. Organic household waste can be composted or digested in biogas plants. This results in the production of very different types of fertiliser (digestate, compost).
In 2022, a long-term trial was established in Forchheim, near Karlsruhe, involving twelve different phosphorus-recycling fertilisers, an untreated control, a TSP control and a raw phosphate treatment, with a crop rotation of grain maize, winter wheat, grain maize and winter rye, replicated four times. The results regarding soil chemistry after four years of the trial will be presented. In particular, the four treatments involving organic fertilisation show a certain increase in pH, Pcal and Kcal values, and humus content. At the same time, a significant increase in boron content in the soil was measured. The post-treatment of sewage sludge ash with sand and sodium is also showing initial effects on Pcal levels in the soil. Possible causes will be discussed.

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Poster presentation 55

Impact of Soil Nitrate-to-Chloride Ratios on Stomatal Traits and Water Use Efficiency in Barley and Broad Bean Under Contrasting Water Availability

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Nitrate (NO_3^-) and chloride (Cl^-) are mobile inorganic anions that contribute to cell turgor regulation, vacuolar solute accumulation, and charge balance, influencing plant water status [1]. Nitrate is assimilated into organic nitrogen compounds, although excess nitrate can accumulate in vacuoles, whereas chloride is not assimilated and remains available for osmotic adjustment. Thus, changes in the soil NO_3^-:Cl^- ratio may alter plant water relations, particularly under water-deficit [2]. To investigate this, we evaluated four NO_3^-:Cl^- ratios (24:1, 2:1, 1:2, and 1:24) on transpiration, stomatal traits, anatomical stomatal conductance (gs_anat) and whole-plant water use efficiency (WUE) in barley (*Hordeum vulgare*) and broad bean (*Vicia faba*) grown at 30%, 50%, and 70% of soil water-holding capacity (WC).
Transpiration was monitored gravimetrically and normalized to leaf area. Before harvest, stomatal images were acquired in vivo using microscopy, and traits were quantified using ImageJ to estimate gs_anat. WUE was calculated from shoot biomass and cumulative water consumption.
Our results showed greater water loss and lower WUE as the soil NO_3^-:Cl^- ratio decreased, with species- and WC-dependent responses. In barley, lower ratios increased nocturnal transpiration at 50 and 70% WC and daytime rates at 70% WC, whereas higher ratios promoted stomatal opening at 50% WC and higher gs_anat at 30 and 50% WC. Broad bean showed no corresponding stomatal response, but lower ratios increased night-time and daytime transpiration at 30 and 70% WC, respectively. WUE declined toward lower ratios in both species, predominantly in barley. These findings demonstrate that soil NO_3^-:Cl^- balance modulates plant water status where low ratios induce wasteful transpiration losses and impair structural WUE.

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Poster presentation 56

Impact of sodium content of potash fertilisers on yield, technological quality and sodium substitution in sugar beet

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Potassium fertilisers, obtained by processing natural crude salts, contain traces of Na, and switching to environmentally friendly processing causes the Na content in Korn-KALI® to increase further. Sugar beet (SB) is considered to benefit from Na and may substitute a high proportion of K with Na. The impact of moderately elevated Na contents [31.5 % K, 3.6 % Mg and 7.5 % Na of a Na-enriched test product vs. 33 % K, 3.6 % Mg and 4 % Na in Korn-KALI®] on nutrient supply, yield and quality of SB was evaluated in farmers' fields in multi-site field trials (D, PL, F) 2023 - 2025.
In all experiments, leaf analyses during growth showed a dose-dependent Na uptake, especially on sandy soils. Particularly at the German site, even the K-unfertilised control exhibited a K substitution by Na in the leaf blades of 6 - 52 %, also reaching up to 52 % with increasing supply of Na-enriched potassium fertiliser. Similar field experiments with other crops and nutrient solution culture confirmed relative K substitution by Na in the order sugar beet > rapeseed > maize. Our findings with SB also demonstrate that determination of K alone, as conventionally done for assessing the K nutritional status, is inadequate, resulting in serious misinterpretations. At harvest, the examination of the molasses formers (K, Na, α-amino N) showed no impairment of technological quality in response to Na-enriched K fertilisers at all locations in all years tested. At harvest SB preferentially maintains Na in the leaves (K/Na ratio 2/1), while K accumulates in the beet root (K/Na ratio 11/1).

Poster presentation 57

Poplar and grapevine under drought stress in a controlled rhizotron experiment

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Vitiforestry systems, which combine grapevines with trees, are discussed as a strategy for climate adaptation in viticulture. Grapevines are lianas and might have the ability to grow along with a tree with some benefit. Trees and grapevines may also compete for water, nutrients and light. The balance between competitive and synergistic interactions in tree–grapevine systems, particularly under drought, remains interesting. We investigate how the co-cultivation of grapevine (*Vitis vinifera* L. cv. Regent) with poplar (*Populus trichocarpa*) affects vegetative growth and drought response in controlled 50 L rhizotrons. Three planting systems were established: grapevine–grapevine, poplar–poplar and grapevine–poplar, combined with three soil water regimes in a two-week drought experiment. Vegetative growth was assessed at the end of the growing season. Stomatal conductance was measured during the drought experiment, and its relationship to soil water content was analyzed.
Grapevines co-cultivated with poplar showed reduced vegetative growth compared to grapevines co-cultivated with grapevines. Poplar growth was largely unaffected by the planting system. Grapevines co-cultivated with poplar maintained higher stomatal conductance with declining soil water content compared to grapevines co-cultivated with grapevines and could therefore potentially maintain photosynthetic activity at a higher level. Stomatal conductance of poplar did not differ significantly between the poplar–poplar and grapevine–poplar systems. These findings suggest competitive interactions with respect to vegetative growth, but a potentially beneficial effect of poplar on grapevine stomatal regulation under water limitation.
Ongoing analyses clarify the physiological mechanisms underlying grapevine growth reduction and delayed stomatal closure in grapevine–poplar systems.

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Poster presentation 58

Salinity-Driven Root Structural and Physiological Adaptations in Halophytic Barleys

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Salinity combined with waterlogging is a major abiotic constraint that severely impairs crop growth and productivity. Here, we investigated species-specific adaptive responses to these combined stresses in the wild halophytic barleys *Hordeum marinum* and *H. glaucum*, using cultivated barley (*H. vulgare*) as a reference [1, 2]. Root structural and physiological responses were characterized using magnetic resonance imaging, fluorescence microscopy, ^{13}C-uptake and distribution analysis, and comprehensive ionomic and metabolomic profiling.

Among the three species, *H. marinum* exhibited the greatest tolerance to saline waterlogging, maintaining tissue hydration, metabolic activity, and high rates of carbon fixation. It accumulated the lowest concentrations of Na^+ and Cl^- while retaining the highest K^+ levels in both roots and shoots. *H. glaucum* displayed intermediate tolerance, characterized by reduced tissue water content and partial metabolic impairment, whereas *H. vulgare* failed to survive under the combined stress.

Our results indicate that the exceptional tolerance of *H. marinum* is conferred by an integrated root-based adaptive mechanism. Well-developed root aerenchyma facilitates internal oxygen transport during waterlogging, while salinity-induced proliferation of lateral roots enhances sequestration of excess Na^+ within the lateral root cortex, thereby restricting ion translocation to photosynthetically active tissues. This coordinated aeration–sequestration strategy preserves root function under combined salinity and waterlogging stress, sustaining carbon assimilation and whole-plant performance. In contrast, this adaptive mechanism is only weakly developed in cultivated barley, contributing to its markedly lower stress tolerance [3].

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Poster presentation 59

Customized nitrogen-fixing microbiomes for environmental adaptation

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Legumes have evolved the ability to establish root symbioses with rhizobacteria that can convert atmospheric nitrogen into organic forms and share this fixed nitrogen with their plant hosts. However, these symbioses are strongly affected by environmental stresses. Under stress conditions, legumes activate adaptive signalling pathways that interfere with rhizobial colonization and nodulation. In addition to N-fixing rhizobia, legumes also recruit other beneficial microbes that protect against environmental stresses and may interact with N-fixing bacteria to facilitate root nodulation. Previous work reported that the highly efficient N-fixer strain *Sinorhizobium meliloti* WSM1022 reshapes the root microbiome by recruiting a high-efficiency nitrogen-fixation mini-microbiome (hereafter referred to as the "N-biome"). Additionally, we identified a beneficial α-proteobacterium that colonizes host root tissues and enhances plant adaptation to environmental stress. This project aims to establish this α-proteobacterium as a bio-protectant that supports N-biome symbiosis with Medicago truncatula under drought, a major climate-related stress. To evaluate the beneficial effects and robustness of the N-biome and the drought-resistance-inducing α-proteobacterium, we are currently conducting co-inoculation experiments under drought conditions using *M. truncatula* as a model. We assess plant performance using parameters such as growth, nodulation, and stress responses. In future work, we will investigate the effects of the N-biome on the root, rhizosphere, and nodule microbiomes under drought conditions, including changes in microbiome composition and function through transcriptomic analyses. Furthermore, using an integrative GWAS approach, we will identify plant genetic traits that facilitate symbiosis with the N-biome under drought stress.

Poster presentation 60

Shoot and root plasticity of winter cereals in response to nutrient omission

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Nutrient availability is essential for sustaining crop productivity and soil fertility, yet field studies examining shoot-root responses to nutrient deficiencies remain limited. We investigated nutrient omission effects on shoot performance and root traits of winter cereals at the long-term field experiment Dikopshof, Germany. Winter rye was assessed in the 2022 season, and winter wheat in the 2020 and 2021 seasons. Depending on the crop, selected treatments were considered: full fertilization with and without farmyard manure, N-, P-, K- or liming omission, and unfertilized control. Measured traits were shoot biomass, phenology, leaf area index, plant height, yield, and root traits including root biomass, root length, root length density, specific root length, root diameter, nodal root number, root angle, and root:shoot ratio.
In both cereals, the fully fertilized treatment with manure showed the highest shoot biomass and root development. In winter rye, nutrient omission effects varied strongly by developmental stage, with N and P omission reducing shoot biomass around flowering and resulting in the lowest root length density. In winter wheat, nutrient omission treatments, particularly the N omission and the unfertilized treatment, strongly reduced shoot and root biomass, leaf area development, plant height, and root length, while increasing root:shoot ratio, specific root length, and specific root length. Grain yield in both cereals was the highest in the fully fertilized treatment with manure, while nutrient omission reduced crop performance.
Overall, these findings demonstrate that nutrient deficiencies alter above and belowground crop performance, with strong interactions by crop species, developmental stage, and environmental conditions.

Poster presentation 61

Long-term reduced tillage alters greenhouse gas emissions, soil mineral N and water distribution under reduced rainfall

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Reduced tillage (RT) is often considered an agroecological practice that promotes soil organic carbon (C) sequestration. However, its long-term effects on soil mineral nitrogen (N) dynamics, crop yield, and greenhouse gas (GHG) emissions remain uncertain, especially under reduced rainfall. We used a field trial established in 1970 in Göttingen, Germany, to compare RT with conventional tillage (CT) under ambient rainfall (100%) and 50% rainfall exclusion. Soil CO_2 and N_2O fluxes, crop yield, crop and weed biomass, soil mineral N and water content were monitored during faba bean (2025) and winter wheat cultivation (2026). RT tended to increase N_2O emissions but reduced soil CO_2 efflux. In contrast, 50% rainfall exclusion decreased N_2O emissions, consistent with moisture limitation of N_2O production. During faba bean growth, soil mineral N was dominated by NO_3^--N, with CT showing higher season-averaged NO_3^--N availability than RT in 0-30 cm. Yield was highest under CT-100% and lowest under CT-50%. RT led to significantly increased weed biomass. After harvest, CT showed greater NO_3^--N accumulation in 20-60 cm, while RT retained more NH_4^+-N and soil water in 0-10 cm, indicating stronger topsoil N retention under RT. During winter wheat, soil mineral N in 0-10 cm increased after fertilization, mainly due to transient fertilizer NH_4^+-N accumulation, while mineral N in 10-30 cm remained low. Overall, long-term RT alters vertical soil mineral N and water distribution. The study highlights the need to develop an integrated conservation tillage, weed and nutrient management system that suits variable rainfall conditions.

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Poster presentation 62

Pyrolyzed pelleted softwood chips as an amendment for wood-fiber-based growing media

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Biochar (BC) is a promising amendment to improve aeration, increase the recalcitrant carbon fraction, and reduce nutrient leaching in growing media. However, its effects on potted plant growth are highly variable and mostly studied in peat-based growing media [1-3]. Since peat is increasingly substituted by wood fiber, the suitability of BC for wood-fiber-based growing media requires further evaluation [4].
Pyrolyzed pelleted softwood chips (500°C, 6×2 mm) were ground to <3.5 mm and incorporated at 0, 2.5, 5, and 10% (v/v) into a wood-fiber-based growing medium (50% (v/v) wood fiber). The effects on microbial activity (measured as CO_2 evolution) and nitrogen (N) immobilization were investigated in an incubation experiment. Furthermore, N dynamics and plant compatibility were assessed in cultivation trials using cress and Chinese cabbage.
Microbial activity did not differ among treatments. In contrast, N immobilization increased by 52±5 and 83±5 mg L^{-1} after 20 days at 5 and 10% (v/v) BC, respectively. This response may be related to changes in microbiome composition [5] or the adsorption capacity of BC [6]. Pure BC showed no phytotoxicity to cress and cress height exceeded that in peat (1.8±0.3 cm and 3.0±0.3 cm) eight days after sowing. In the substrate blends, BC had no effect on germination, plant growth or N uptake of Chinese cabbage.
In conclusion, BC proved to be plant-compatible but did not provide the desired reduction in N immobilization in wood-fiber-based growing media. Further research is needed to evaluate alternative application strategies that may better exploit the stabilizing properties of BC.

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Poster presentation 63

Effects of heat, drought and combined stress on source/ sink relations in wheat (*Triticum aestivum* L.)

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Challenges in crop production are expected to increase due to climate change–related high temperatures often accompanied by low water availability [1]. For wheat (*Triticum aestivum* L.), a heat-sensitive crop [2], prior studies have shown that combined heat and drought stress leads to reduced photosynthetic activity and biomass accumulation [3]. However, its effects on reproductive development in cereals remain poorly understood [3]. In a previous study on wheat plants, sink capacity was reduced under continuous heat stress, whereas no source limitation occurred [4]. Presently, we investigate the factors limiting wheat grain yield under heat and drought stress conditions during different growth stages. We hypothesize, that wheat grain yield is primarily sink-limited under stress conditions rather than source-limited.
In a recent experiment, conducted in climate chambers, plants were exposed to heat (30 °C/25 °C day/night) and/ or drought (35 % water-holding capacity, WHC), compared to optimal conditions (22 °C/16 °C day/night, 60 % WHC). An intermediate harvest at start of milk development was conducted. Sink-related parameters were evaluated by determining the number of ears per plant and kernels per ear (sink capacity), as well as by measuring sugar concentrations and acid invertase activity (sink activity) in the kernels.
So far, it can be concluded that heat stress had a greater negative impact on plant development than drought stress. Sugar concentrations in kernels were particularly reduced under the combination of heat and drought stress.
These findings contribute to a better understanding of crop responses to combined and individual stress conditions and in order to improve stress resilience and ensure stable yields under future climate scenarios.

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Poster presentation 64

Diurnal nutrient uptake patterns of tomato (*Solanum lycopersicum* L.) in a recirculating hydroponic production system

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Plant nutrient uptake is known to depend primarily on interactions between environmental conditions, photosynthetic carbon assimilation, transpiration, and nutrient availability in the root zone. Consequently, nutrient demand may vary throughout the day and among nutrients. Such temporal variation offers opportunities to improve nutrient management in recirculating hydroponic production systems through a better understanding of nutrient-specific demand and nutrient-to-water uptake relationships. The objective of this study was to characterize diurnal nutrient uptake patterns of tomato (Solanum lycopersicum L. cv. 'Avalantino F1') plants cultivated in an ETFE-foil greenhouse under contrasting seasonal climatic conditions.

Tomato plants were cultivated in a recirculating drip-irrigation production system in the greenhouse of the CUBES Circle research facility. Measurements were conducted during winter and summer periods. Nutrient concentrations in irrigation and drainage solutions were determined at multiple time points throughout the day, while monitoring water consumption and environmental parameters. Nutrient uptake rates were calculated from nutrient and water mass balances for nitrate-N (NO_3^--N), ammonium-N (NH_4^+-N), potassium (K^+), and calcium (Ca^{2+}).

We discuss (i) diurnal uptake patterns of individual nutrients under different climatic conditions, (ii) relationships between nutrient uptake and plant water uptake, (iii) similarities and differences among nutrient-specific uptake dynamics, and (iv) the extent to which observed uptake patterns agree with current understanding of nutrient acquisition by tomato plants. Together, these observations are evaluated with regard to their potential contribution to adaptive and predictive nutrient management in recirculating hydroponic production systems.

Poster presentation 65

Physiological and Nutritional Responses of Faba Bean (*Vicia faba* L.) to Elevated Temperature during Vegetative Growth

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Faba bean (*Vicia faba* L.) is a protein-rich legume of high agronomic importance in sustainable cropping systems [1]. In Germany, the increasing heat events of 28–30 °C during flowering time in faba beans (versus the current ~22 °C) are over the coming decade will dramatically limit production. The plants' responses to elevated temperature during vegetative stage remain unclear despite relevance for biomass, photosynthesis, and yield formation [2].

A greenhouse experiment with 25 faba bean accessions was conducted under control (22–25 °C) and elevated temperature (28–30 °C) conditions. Various traits including plant development, stomatal conductance, photosynthetic activity, chlorophyll *a* fluorescence, leaf cooling capacity, leaf carbon and nitrogen concentrations, C/N ratio, and mineral nutrients were intensively investigated to elucidate the plants' responses to elevated temperature

Elevated temperature induced an architectural shift leading to shorter and compact plants with increased number of nodes and leaves. Photosynthesis and stomatal conductance correlated positively with shoot water content but negatively with biomass, indicating a cooling–growth trade-off. Significant genotypic variations were observed in the leaf cooling capacity. Elevated temperature increased the C/N ratio, which were negatively associated with carbon association rate.

In conclusion, elevated temperature reshaped faba bean growth and physiology by increasing the dependence of photosynthesis on plant water status and C/N ratio, highlighting leaf cooling capacity and nutrient status as potential traits for heat adaptation. The contribution of mineral nutrients to these physiological responses remains an open question.

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Poster presentation 66

Using artificial roots to validate a novel, gel-based method for sampling carboxylate exudates

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Tiziani et al. [1] developed a ZrOH hydrogel-based diffusive gradients in thin films (DGT) technique that overcomes mineralization challenges and allowing localized imaging of root exudates. Utilizing this method in a rhizobox setup, Chibesa et al. [2] successfully performed 2D mapping of seven carboxylates. This study aims to evaluate the performance of this novel method using an artificial root. The performance will be assessed through experimental testing and numerical simulations. To simulate root exudation, microdialysis (MD) was used as an artificial root. Carboxylate recovery was evaluated in sterilized, bulk, and rhizosphere soils. After five hours, the ZrOH hydrogels were eluted and analyzed using ion chromatography (IC). In addition, numerical simulation using Comsol Multiphysics was used to validate the experimental part. The average recovery for citrate ranged from 4.4 to 9.1% in different soil treatments. For oxalate, recoveries ranged from 7.7 to 10%. Malate represents the highest recoveries, ranging from 19.3 to 23.2%. In addition, ZrOH hydrogels were cut to a size of 2 mm × 2 mm in order to have a spatial distribution of carboxylates within the hydrogels. The model incorporated carboxylate exudation rates, diffusion, sorption, and soil mineralization, also a zero-concentration boundary was included to represent the ZrOH hydrogel. The resulting 2D simulation was closely aligned with the experimental data. In conclusion, these results provide a reliable baseline for future studies using real plant roots. The observed low recoveries could result from the experimental setup, as the ZrOH hydrogel only covers one side of the artificial root.

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Poster presentation 67

Insect Frass as an Organic Fertilizer and Biostimulant in Potato Production: Results from On-Farm Field Trials

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Insect frass from black soldier fly larvae (BSFL) bioconversion contains key components of a fertilizer. It is rich in organic matter and provides a well-balanced spectrum of macro- (N, P, K, S, Mg) and micronutrients (Zn, Mn, Fe, B). In addition, frass is naturally enriched with humic and fulvic acids, chitin and plant-growth-promoting bacteria, all of which are potentially associated with biostimulating effects. Hence, we hypothesized that BSFL frass can at least match the performance of conventional fertilizers in potato production while providing additional benefits for quality and plant health.

In collaboration with farmers, BSFL frass was evaluated against locally used conventional fertilizers (mineral or organic fertilizer such as biogas digestate) in eight potato field trials at five locations across Germany. In conventional systems, 2 t/ha of BSFL frass were applied and supplemented with mineral fertilizer to meet crop demand, while in organic systems, the usual fertilizer was fully replaced by 3.5 t/ha frass. Smaller doses (0.5 and 1 t/ha) supplemented with mineral fertilizer were additionally tested to assess potential biostimulant effects. Depending on farm logistics, trials were set-up either as field-long strips (width according to the fertilizer spreader) with four subsamples per strip, or as randomized plot designs with four replicates per treatment. Subsamples of 3.6 m² were harvested by hand, and total yield, tuber size distribution, damage by wireworms (*Agriotes*) and fungi (*Rhizoctonia solani*), as well as starch content were recorded.

Results differed across sites, but in about 70% of the trials, insect frass matched or outperformed conventional fertilization. The strongest response was observed on a sandy site, where frass application increased yield by approximately 50%. Effects on wireworm damage depended on pest pressure and weather: under high wireworm abundance, frass did not reduce tuber damage, whereas under lower pressure and site-specific conditions, trends towards reduced infestation were apparent. On sandy soil, frass fertilization reduced fungal infestation to a similar extent as a standard fungicide treatment. With respect to product quality, starch content tended to be higher under frass fertilization, although differences were not statistically significant.

Overall, current results indicate that BSFL frass is not only a promising organic fertilizer that supplies nutrients effectively but also provides additional functional benefits. Future work should explore this biostimulating potential in more detail, for example with regard to quality improvement and possible enhancement of crop tolerance against drought stress.

Poster presentation 68

Baseline soil organic matter content and soil status in German commercial apple orchards: variation across farms and soil depths

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An increase in soil organic matter (SOM) usually is associated with positive properties, which in turn have a beneficial effect on soil fertility and crop performance. For instance, an increase in SOM has been reported to improve water holding capacity, nutrient status, or aggregate stability (Carter and Stewart, 1996; Loveland and Webb, 2001).
The soil in an apple orchard is barely cultivated or only along the tree rows. Typically, there is permanent cover plant between the rows, and the apple trees possess a deep, long-established root system. Therefore, it can be assumed that an apple orchard has greater potential for building up and storing SOM compared to annual crops. However, there is only limited knowledge on the actual soil status of German apple orchards and its potential to build up and store SOM.

Our results present baseline soil analyses from 2025 and 2026, based on data from eight commercial apple orchards, highlighting differences between the orchards and soil depths (0–30 cm and 30–60 cm). Across soil samples, mean pH was 6.4, organic carbon 1.1%, total nitrogen 0.1% and the C/N ratio 10. Mean SOM was 1.8%, with 2.4% in the upper soil layer and 1.1% in the deeper layer. The highest topsoil SOM content was found at one farm with in the upper layer with 4.5%. This field had been an uncultivated pear orchard for many years. The lowest SOM values occurred in the deeper layer of another farm with characteristic sandy soils, reaching 0.3%.

These are the results of a model and demonstration project named Climate Apples, funded by BMLEH**,** which aims to establish a five-year on-farm network with 32 commercial farms participating across three growing regions in Germany. The project aims to explore the advantages and limitations of various humus-promoting or conservation measures in apple-growing practice and to establish suitable measures as best practices within the fruit-growing sector.

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Poster presentation 69

Harnessing Halophyte Ionic Substitution Biology

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Abstract:
Halophytes represent a unique and underexploited system for understanding plant adaptation to saline environments. A central adaptive strategy is ionic substitution biology, in which Na^+ and Cl^- are not merely excluded or tolerated but actively utilized to replace metabolically expensive macronutrients, particularly K^+ and NO_3^-, without compromising core cellular functions [1]. This strategy is enabled by regulated ion transport, compartmentalization, and osmotic adjustment, allowing sustained growth under high salinity.
We propose a framework in which halophytes reprogram ion transport networks to enhance energetic efficiency under salt stress. A key feature is partial substitution of K^+ by Na^+, facilitated by transporters and vacuolar sequestration, maintaining cytosolic homeostasis, membrane stability, enzyme activity, and stomatal regulation. This rebalancing reduces the energetic cost of strict K^+ dependence while preserving function.
In parallel, we highlight partial substitution of NO_3^- by Cl^- as an underexplored mechanism contributing to osmotic balance and potentially lowering nitrogen assimilation costs, expanding nutrient economy in salt-adapted plants.
We argue ionic substitution is a regulated physiological trait rather than a passive consequence of salt exposure. This reframes ion homeostasis as an active optimization strategy. Leveraging these mechanisms offers a route to redesign crop ionomes for saline agriculture, particularly in marginal soils where nutrient-efficiency strategies are limited.
Integrating halophyte-inspired ion transport traits into crops may enhance salt resilience while reducing dependence on potassium and nitrogen inputs. This framework positions halophyte biology as a model for resource-efficient plant systems with implications for sustainable agriculture under increasing soil salinization.

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Poster presentation 70

Long-term effects of biochar on the living conditions of soil organisms: Reduction of pesticide stress or other anthropogenic stressors?

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In Germany, approximately 25,000 to 35,000 tonnes of active ingredients in plant protection products are applied annually. Residues of these compounds are regularly detected in soils and water bodies, where they are considered one of the major drivers of the decline of sensitive species.

The application of biochar to contaminated soils is regarded as an effective strategy for soil remediation. Because of its high specific surface area, porosity, and the presence of surface functional groups, biochar is well suited for the immobilisation of contaminants such as pesticides and heavy metals. Numerous ecotoxicological studies have demonstrated protective effects of biochar on non-target organisms and reduced contaminant concentrations in leachate. However, these studies have generally been conducted using freshly prepared soil–biochar mixtures.

In the PK-BodenABC project, two field soils that had received biochar applications more than ten years ago were used for terrestrial ecotoxicological tests. In addition, ISO artificial soil served as a standard reference substrate for further experiments. The effects of the insecticide lambda-cyhalothrin, the fungicide tebuconazole, and the herbicide phenmedipham on the reproduction of *Folsomia candida* and the avoidance behaviour of *Eisenia fetida* were assessed by comparing soils with and without biochar.

The results indicate that biochar had neither positive nor negative effects on the reproduction of collembolans in either the field soils or the artificial soil. The influence of biochar on pesticide toxicity was compound-specific. While biochar did not alter the toxicity of the insecticide, slight protective effects were observed for the fungicide, whereas increased toxicity was detected for the herbicide. The results of the earthworm avoidance tests are still pending and will be included within the coming months.

This research is part of the BMLEH-funded consortium project PK-BodenABC.

Consortium project:
PK-BodenABC (FNR website)
Long-term opportunities and risks of using biochar in soils: Analysis of changed soil fertility parameters, C storage behaviour and ecotoxicological and environmental effects
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Research institutions:
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Poster presentation 71

From Residue to Resource: Organo-mineral Residues Mitigate Cadmium Uptake in Chard and Tomato

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At the end of the cropping cycle, hydroponic tomato production generates large quantities of organo-mineral substrate residues (OMR). Returning these residues to arable soils could provide a sustainable disposal route while improving soil properties. Because organic amendments have been reported to lower the plant availability of heavy metals, this study investigated whether OMR can reduce the availability and crop uptake of cadmium (Cd) in a sandy soil.
A pot experiment was conducted on a sandy soil amended with 1.2 mass-% OMR. Tomato (*Solanum lycopersicum* L.) and Swiss chard (*Beta vulgaris* L. var. *vulgaris*) were grown under four treatments combining the presence or absence of substrate with the presence or absence of 1 mg Cd kg^{-1} soil. A preliminary trial additionally compared 0, 1.2 and 2.4 mass-% OMR with respect to ammonium-nitrate-extractable Cd.
Adding OMR reduced the ammonium-nitrate-extractable Cd concentration by 43 % (1.2 mass-%) and 64 % (2.4 mass-%). In the cropping experiment, OMR significantly lowered Cd accumulation in the edible plant parts, by 25 % in tomato fruits and by 55 % in Swiss chard leaves, relative to the control.
These results demonstrate that organo-mineral substrate residues effectively reduce Cd mobility in soil and Cd uptake by crops. The reuse of residues from hydroponic tomato production therefore offers a resource-efficient strategy to close nutrient cycles while lowering heavy-metal transfer in agriculture and contributing to safer food production.

Poster presentation 72

Differential Phosphorus Acquisition Strategies in *Triticum turgidum* ssp. *durum*: Roots of efficiency

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Phosphorus (P) use efficiencies remain low across cereals, while declining mineral phosphate reserves threaten to worsen P shortages in agriculture. To map P acquisition parameters in durum wheat (*Triticum turgidum* ssp. *durum*), 18 genotypes, including modern and old cultivars, landraces, and mutants, were cultivated under two fertilizer regimes (12.5 and 100 mg P kg^{-1} soil) in a low-P silty clay loam soil in the greenhouse. Plants were harvested when 60% of genotypes had reached the flowering stage and were analysed for dry matter yield and P concentrations.
While dry matter production and shoot nutrient concentrations showed little variation between genotypes, P acquisition efficiencies per root dry mass differed by up to 450% between fertilization regimes and 1100% between genotypes, linked to root biomass differences of up to 1200%, suggesting substantial variation in P acquisition strategies.
Modern genotypes differed significantly from old genotypes and landraces across all P efficiency parameters. Average root/shoot ratio was 0.14 in modern genotypes versus 0.28 in older ones, while P acquisition efficiency averaged at 19.3 mg g^{-1} in modern genotypes compared to 8.98 mg g^{-1} in older genotypes. These findings highlight the success of modern breeding programs and suggest further improvements are achievable. Upcoming experiments will use low-invasive ZrOH hydrogel sampling to investigate carboxylate exudation and its links to root morphology and P acquisition.
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Poster presentation 73

Applying urea foliarly to increase grape must YAN in Vitis vinifera L cv. Riesling

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Efficient nitrogen fertilization is imperative in viticulture for enhancing grape quality while reducing environmental impacts associated with nitrogen fertilization. A three-year field study evaluated different nitrogen forms and application methods for the perennial fruit crop *Vitis vinifera* L. cv. Riesling, including foliar, topsoil, and subsoil applications at a rate of 50 kg N ha^{-1}. The study focused on the impact of nitrogen fertilization on nitrogen content, nitrogen use efficiency (NUE) and amino acid concentrations in grape berries and must. Results show that foliar fertilization with urea is very effective, improving nitrogen levels in leaves and berries, NUE, and amino acid composition of the grape must. This way to apply N helps to maintain adequate yeast-assimilable nitrogen, essential for healthy fermentation of grape must to the alcoholic beverage wine. Findings suggest that foliar urea application can support fermentation quality in winemaking while offering a sustainable nitrogen management strategy adaptable to varying viticulturally conditions.