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Oral Presentations

Poster Presentations

K1 **Global impacts of nitrogen in the environment: the need to improve nitrogen use efficiencies in food production and beyond**

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The “nitrogen cascade” describes the behaviour of nitrogen compounds in the environment. These compounds, in exchange between different environmental pools and in conversion between different chemical forms, are responsible for multiple impacts on ecosystems, the human health and the climate. Disentangling the complex relationship between sources and impacts is challenging but necessary to identify pathways that bring out co-benefits between simultaneously improving different environmental threats. Here I provide an overview on our understanding of the global and of regional nitrogen cycles. Using structured nitrogen budgets it is possible to regain an understanding of the flows of nitrogen compounds in the environment and their transformation. Specific sectors, such as the food production, can be brought in context with all other contributing sectors (combustion, industry). The method allows to isolate intervention points and to quantitatively assess the potential impacts of mitigation measures. With agronomy and animal husbandry strongly contributing to the release of nitrogen compounds, these economic sectors will need to also contribute to the solutions. Taking overarching perspectives, such as in nitrogen budgets, allows for joint-up approaches and policies leading to optimized results fostering co-benefits between different impact categories. Integrated models exist that also consider the economic perspectives, based on scientific approaches to look for and perform optimizations. Increasing the nitrogen use efficiency and reducing nitrogen waste, by a number of specific change of practices, are generalized approaches that not only reduce environmental impacts generally, but moreover can provide economic advantages to farmers in saving mineral fertilizer inputs.

Wilfried Winiwarter is a Senior Research Scholar at IIASA, Austria, and a Professor of Environmental Engineering at the University of Zielona Góra, Poland. Trained as an environmental engineer, he has been intrigued by the complexity of the nitrogen cycle and its impacts on global change, which – together with exploring options to find solutions – determines his scientific interest. His contributions to IPCC earned him a personalized certificate acknowledging contributions leading to the IPCC’s award of the 2007 Peace Nobel Prize. With extensive experience as a work package leader, member of leadership boards or coordinator of international projects, he provided core contributions to several assessment reports, such as the European Nitrogen Assessment (2011), the Nitrous Oxide Assessment (2024), or the International Nitrogen Assessment (2025).

T1

Soil Organic Carbon to Clay Ratios as Determinant of Nitrogen Retention and Fertilizer Use Efficiency

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Recent evidence suggests that the ratio of Soil Organic Carbon (SOC) to clay, rather than SOC alone, plays a crucial role in soil Nitrogen (N) dynamics by controlling mechanisms of organic matter stabilization [1,2]. In principle, clay particles promote mineral-associated organic matter (MAOM) formation and increase N retention in soils due to physical and chemical protection [1]. At low SOC:Clay ratios, soils show a high capacity for N stabilization in the MAOM fraction [3,4]. However, as SOC:Clay ratios increase, binding sites may reach saturation and additional inputs would accumulate as particulate organic matter (POM), leaving them more susceptible to turnover [3,4,5,6]. This shift would increase N mineralization rates and N availability for plants, while at the same time reducing the fertilizer N retention capacity of the soil.

We hypothesized that increasing SOC:Clay ratios reduce N stabilization potential, accelerating N cycling rates, enhancing microbial activity and ultimately improving plant productivity and fertilizer use efficiency. In a pot experiment, summer wheat was grown in ten organically managed arable soils from Western Switzerland spanning a range of SOC:Clay ratios, either under N-limited or under non-N-limited conditions, using $(^{15}NH_4)_2SO_4$. In parallel, microbial activity of the different soils without plants was investigated in an incubation study. The fate of fertilizer N was followed into plant tissues (grain, shoot, root), microbial biomass and soil fractions (MAOM, POM). The results will help to mechanistically clarify how SOC:Clay ratios mediate soil N dynamics and plant uptake and inform site-specific nutrient strategies.

References:
[1] Geisseler D et al. (2024). The multi-faceted relationship between nitrogen mineralization and soil texture. Soil Sci. Soc. Am. J., 88, 1792–1807.
[2] Soinne H et al. (2021). Soil organic carbon and clay content as deciding factors for net nitrogen mineralization and cereal yields in boreal mineral soils. Eur. J. Soil Sci., 72, 1497–1512.
[3] Castellano MJ et al. (2015). Integrating plant litter quality, soil organic matter stabilization, and the carbon saturation concept. Glob. Change Biol., 21, 3200–3209.
[4] Poffenbarger H et al. (2018). Legacy effects of long-term nitrogen fertilizer application on the fate of nitrogen fertilizer inputs in continuous maize. Agric. Ecosyst. Environ., 265, 544–555.
[5] Deluz C et al. (2024). Soil organic matter thermal pools as influenced by depth, tillage, and soil texture – A Rock-Eval® analysis study on the cropland soils of the Swiss Plateau. Geoderma, 445, 116871.
[6] Six J et al. (2002). Stabilization mechanisms of soil organic matter: Implications for C-saturation of soils. Plant Soil, 241, 155–176.

T2

Integrating Soil Biodiversity and Rhizosphere Processes for Climate-Resilient, Nutrient-Efficient Cropping Systems: Insights from Four EU Projects

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Climate change, extreme weather, and the need to reduce fertilizer inputs pose growing challenges for sustainable crop production [1]. Enhancing soil biodiversity and optimizing rhizosphere processes are key to improving resilience, nutrient use efficiency, and overall agroecosystem performance. This abstract synthesizes results from four EU-funded projects, SolACE, BioFector, BioFAIR, and KLIMACrops, each contributing complementary insights into soil-plant interactions under stress.
SolACE focused on wheat and potato under limiting water and nutrient availability. It identified diverse root traits linked to improved resource uptake and demonstrated the potential of microbial inoculants to reduce disease incidence and maintain yields under reduced inputs [2].
BioFector evaluated 38 bio-effectors, including beneficial fungi, bacteria, and plant extracts, in over 150 trials across Europe. These treatments promoted root growth, phosphorus mobilization, and yield gains, particularly in maize, wheat, and tomato, in combination with alternative plant nutrition strategies [3].
BioFAIR examined the impact of farming practices and climate scenarios on soil biodiversity and crop performance in wheat systems. Reduced tillage and organic fertilization supported beneficial soil fauna and microbial networks, enhancing nutrient cycling, drought resilience, and grain quality [4].
KLIMACrops developed regionally adapted cropping systems, integrating cover crops, rotations, and agroforestry. These approaches improved soil structure, nitrogen retention, and yield stability, while buffering against climate variability [5].
Together, these projects illustrate how promoting soil biodiversity and rhizosphere functionality through adapted genotypes, bio-based inputs, and system-level practices can drive the transition to climate-resilient, nutrient-efficient agriculture [6].

References:

[1] Neumann G., Nawaz F., Weinmann M.,.Arbona V., Balestrini R., Pagliarani C., Gonzalez-Guzman M. (2024). Editorial: Enhancing sustainable crop production: biostimulants and biotechnological approaches in challenging climates. Front. Plant Sci. 15:1534774.
[2] Al Mamun A., Neumann G, Moradtalab N., Ahmed A., Nawaz F., Tenbohlen T., Feng J., Zhang Y., Xie X., Zhifang L., Ludewig U., Bradáčová K. and Weinmann M. (2024).Combination of silicate-based soil conditioners with plant growth-promoting microorganisms to improve drought stress resilience in potato. Microorganisms 12(11), 2128.
[3] Nkebiwe P. M, Stevens Lekfeldt J. D., Symanczik S., Thonar C., Mäder P., Bar-Tal A.,.Halpern M., Biró B., Bradáčová K., Caniullan P. C., Choudhary K. K., Cozzolino V., Di Stasio E.,.Dobczinski S., Geistlinger J., Lüthi A., Gómez-Muñoz B., Kandeler E., Kolberg F.,.Kotroczó Z., Kulhanek M., Mercl F., Tamir G.,.Moradtalab N., Piccolo A., Maggio A., Nassal D.,.Szalai M. Z., Juhos K., Fora C. G., Florea A., Poşta G., Lauer K. F., Toth B., Tlustoš P., Mpanga I. K., Weber N., Weinmann M., Yermiyahu U., Magid J., Müller T., Neumann G., Ludewig U. and de Neergaard A. (2024). Effectiveness of bio-effectors on maize, wheat and tomato performance and phosphorus acquisition from greenhouse to field scales in Europe and Israel: a meta-analysis. Front. Plant Sci. 15:1333249.
[4] Waibel M., Michel J., Antoine M., Balanzategui-Guijarro I., Cao D., Delaplace P., Le Gouis J., Alvarez D., Léon C., Manfroy S., Moya-Laraño J., Perrochon S., Sanchez-Moreno S., Santin-Montanya I., Tenorio J. L., Thonar C., Vanderschuren H., Van Der Straeten D., Verlinde T., Weinmann M., Symanczik S. (2024). Tensions in tillage: Reduction in tillage intensity associates with lower wheat growth and nutritional grain quality despite enhanced soil biological indicators. Agric., Ecosyst. Environ. 389: 109675
[5] Weinmann M., Anicker F., Armbruster M., Bradáčová K., Nkebiwe M, Weber N. F., Morad-Talab N., Fora G. C., Poșta G., Goetz M, Raupp M. G., Ludewig U., Müller T., Neumann G. (2024). Biostimulanzien – Chance und Herausforderung für nachhaltige Pflanzenproduktion. VDLUFA-Schriftenreihe 81, pp. 170-181.

[6] Weinmann M. and Neumann G. (2020). Bio-effectors to optimize the mineral nutrition of crop plants. In: Rengel Z. (ed.). Achieving sustainable crop nutrition. Burleigh Dodds Science Publishing, Cambridge, UK, pp.589-690.

T3

Phospho-switch from potential driven NH_4^+ accumulation to gradient dependent NH_3 transport

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Phaseolus vulgaris the common bean can acquire nitrogen through direct root uptake or by the symbiosis with bacteria forming nodules in the plants root. Therefore, a multitude of specified transport processes for nitrogen and especially ammonium is needed in the bean plants. Next to direct root uptake, these need to ensure the transfer of the fixed ammonium from the bacteria to the plant and the efficient distribution within the plant.
Therefore, we addressed the ammonium transporter (AMT) inventory in the bean genome, we determined their expression pattern throughout the plant and their nitrogen dependent expression in the plant root. Four *PvAMT1*s were identified and showed ammonium transport capacity in yeast. PvAMT1;1 elicited a pH independent current by high affinity ammonium transport.

Interestingly not only PvAMT1s showed the known TRHG phosphorylation motive in the conserved part of their C-termini but the same motive was as well found in the C-termini of some PvAMT2s. While PvAMT1s were inactivated, PvAMT2;7 was activated by the phosphor-mimic. This provides the plant with a mechanism to react to changing ammonium conditions and to switch between potential driven accumulation of NH_4^+ and gradient driven NH_3 transport.

K2

Plasma membrane H^+-ATPases in plant nutrition and crop improvement

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Plasma membrane H^+-ATPases is a primary active transporter protein in higher plants. It hydrolyzes ATP and pumps H^+ out of the cytoplasm into apoplast. As the consequence, this pump action of PM H^+-ATPase results in the H^+ electrochemical gradient across the plasma membrane and thereby supplies proton motive force (PMF) for various secondary transport of plant nutrients through the plasma membrane. In this way, plasma membrane H^+-ATPase is deeply involved in nutrient uptake and translocation in plants. In addition, plasma membrane H^+-ATPase facilitates nutrient mobilization and acquisition in soil by acidification of rhizosphere and facilitation of root exudation. We previously found that rice prefers NH_4^+ to NO_3^- as the N source in paddy soil, and this is attributed to up-regulation of plasma membrane H^+-ATPase activity in rice roots which adapt to strong rhizosphere acidification caused by NH_4^+ uptake and assimilation. We overexpressed a plasma membrane H^+-ATPase gene, *OSA1*, in rice and found that NH_4^+ absorption and assimilation in roots is enhanced and stomatal opening and photosynthesis in leaves are promoted. This increased rice grain yield by more than 30% with enhanced N use efficiency, compared to the wild type. Additionally, we found that PM H^+-ATPase activity in the rice flag leaf is higher than that in older leaves, which is related to promoting stomatal opening and photosynthetic activity. It is assumed that PM H^+-ATPase contributes significantly to carbohydrate accumulation in rice grain during reproductive growth stage. Overexpression of *OSA1* can also stimulate the uptake of P and K etc. Recently, we found that modulation of *OSA1* strongly influenced the soil microbiome and metabolome of root exudates in the rhizosphere, especially in the alkaline soil. Moreover, we found that the regulation of stomatal opening by modification of plasma membrane H^+-ATPase is also important for the long-distance transport of nutrients from underground to aboveground driven by the transpiration. Our findings indicate that plasma membrane H^+-ATPase plays multiple roles in the mobilization, acquisition, translocation and long-distance transportation of nutrients in higher plants. The understanding of plasma membrane H^+-ATPase in depth will help to improve the use efficiency of plant nutrients via biotechnological methods in the future, which is essential for the sustainable development of agriculture.

Prof. Yiyong Zhu is from Nanjing Agricultural University, China. He has studied soil science and plant nutrition at this university as bachelor and master student from 1992-1999. He came to Jusuts Liebig University Giessen in 1999 and did his PhD work at the Institute of Plant Nutrition, supervised by Prof. Sven Schubert and Dr. Feng Yan. In 2004 he obtained a PhD in agricultural sciences and returned to Nanjing Agricultural University. His research topic is the role of the plasma membrane H^+ ATPase in agriculture. He has studied plasma membrane H^+ ATPase in agriculture to improve the crop yield via promotion of nutrients uptake by roots and photosynthesis in leaves. He has published articles in major journals in the field like Nature Communications and Trends in Plant Science.

T4

Endoplasmic reticulum-localized cation transporters - crucial for plant development, fertility and nutrition

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Manganese (Mn^{2+}) and Calcium (Ca^{2+}) are essential nutrients for plants. Mn^{2+} is crucial for photosynthesis given its role in the oxygen evolving complex but also serves as cofactor for multiple enzymes involved in diverse processes, like glycosylation or hormone deconjugation. Ca^{2+} is a major second messenger in cells. Upon sensing environmental and developmental stimuli, spatiotemporally defined changes in free Ca^{2+} concentrations appear in cytosol and organelles and modulate downstream responses. In addition to Mn^{2+}, Ca^{2+} also acts as cofactor for proteins such as calreticulin and calnexin. Although Mn^{2+} and Ca^{2+} fulfil different and specific functions in plants, given their similarity in geometry and ionic radii they share a common feature: they are usually transported by the same transporters.
We have characterized two members of a newly described family of transporters that localize to the ER and are predicted to load Mn^{2+} and Ca^{2+} into this compartment. Mutants lacking these transporters showed an altered plant development, a defect in fertility, decreased Mn content in seeds, and a distinctly altered photosynthetic efficiency under Mn deficiency. Some of these defects might be linked to a misregulated homeostasis of Mn^{2+} and Ca^{2+} in the ER. Previous work done on other members of this protein family has identified them as core regulators of organellar Mn^{2+} and Ca^{2+} homeostasis. In this talk we will present our new findings on the role of this family in Mn^{2+} and Ca^{2+} homeostasis in the ER and beyond.

T5

Exploring the role of inositol pyrophosphates in rice phosphate homeostasis

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Inositol pyrophosphates (PP-InsPs) are emerging as critical regulators of phosphate (Pi) homeostasis in plants. These signaling molecules function in the sensing of Pi availability and mediate downstream responses that influence Pi uptake, transport, and utilization. By interacting with Pi transporters and transcriptional repressors, PP-InsPs contribute to the optimization of Pi acquisition and phosphate use efficiency (PUE) under both Pi-deficient and Pi-sufficient conditions. Our research group has extensively investigated the role of PP-InsPs in Pi homeostasis using the model plant *Arabidopsis thaliana*. Building upon these findings, we are currently working to translate this knowledge to rice, with the goal of elucidating the role of PP-InsPs in regulating Pi dynamics in this important crop. In this line, we have successfully developed a transformation protocol for agronomically relevant rice varieties that are more recalcitrant to transformation; and are employing this approach to generate genome edited plants to further investigate the role of PP-InsPs in enhancing crop yield. Ultimately, we aim to provide insights into how PP-InsPs modulate not only PUE and grain yield, but also plant immunity and the micronutrient composition and availability in rice grains.

T6

Phosphorus deficiency affects early root development in Triticum turgidum ssp.

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As mineral phosphate reserves decline, the low phosphorus (P) acquisition efficiency of cereals is making P shortages a growing problem. One way to increase the P efficiency is to gain a better understanding of root development to be able to select and/or engineer cereals with P-efficient root system architecture. To this end, 19 durum wheat (*Triticum durum* L.) genotypes were studied in pouch experiments with limiting (0.97 mg L-1) and sufficient (3.88 mg L^{-1}) P concentrations, where plants grew along filter paper within a plastic sheath hanging in nutrient solution, until their roots reached the bottom edge of the pouch. All root systems were digitised after 26 days of growth and analysed using RootNav 1.8.1 (https://www.quantitative-plant.org/software/root-nav). While none of the plants showed symptoms of phosphorus deficiency in terms of P concentration in the shoot, most of the root parameters examined were significantly influenced by P supply. In particular, the convex hull area and branching start distance showed a strong, genotype-dependent response. A classification into old, modern and landraces suggested that some of the parameters examined were conserved across all groups, although old varieties tended to have more pronounced root systems, especially regarding the number of lateral roots and convex hull area.

In combination with ongoing experiments on P uptake, these results will be used to select varieties for low and high P acquisition efficiency. In upcoming experiments, the selected varieties will be studied for their carboxylate exudation behaviour using a novel, low-invasive diffusive gradients in thin-films (DGT) sampling approach to shed light on the relationship between root morphology, carboxylate exudation and P acquisition behaviour in Durum wheat.

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T7

Mineral nutrients composition and leaf surface wetness of atmospheric aerosols collected from Germany and Israel.

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Atmospheric aerosols have been shown to function as nutrient source for plants. The long atmospheric lifetime of fine aerosols enables intercontinental nutrient transport. Important ecosystems such as the Amazon are dependent upon mineral input by deposition from remote sources. In addition, bio-aerosols and dust have been shown to be a significant source of phosphorus in atmospheric particles.
Diverse microbial communities inhabit the phyllosphere, among them bacteria, fungi, yeasts, protozoa, and viruses. However, microbes of leaf surfaces are faced with harsh environmental conditions. Wetness is a key environmental variable affecting microbial life on leaf surfaces. Leaf wetness varies considerably over the time of the day and during the dry daytime bacteria are prone to desiccation risk. Another major challenge of leaf microbiome is dealing with a nutrient-poor environment.
In the collaborative research project between Germany and Israel “The surprising roles of atmospheric aerosols: supporting microbial life on plant leaf surfaces”, we aim to collect and analyze aerosols from different sources within Germany and Israel and evaluate how aerosol concentration gradients will affect leaf surface microbial population. In this paper, we will present mineral nutrient compositions of aerosols collected from different sources (rural vs urban, agriculture vs forest, sea vs higher altitudes) within Germany and aridity gradients (coastal hyper-arid and urban semi-arid) background sites within Israel, and their wetness characteristics (deliquescence / efflorescence) and deposition patterns on plant (*Arabidopsis thaliana*) leaf surfaces.

Formation pathways of biosilica in sorghum

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Plants are planted in silicate soils, and thus absorb this mineral in significant quantities, accumulating to 0.1 – 10% of their dry weight. Silicic acid, the soluble form of silicates, is absorbed through the roots with the soil solution, moves with the transpiration stream to the shoot, and polymerizes into hydrated silica. The quantity of silica within plants is directly related to the amount of water passed through their bodies. However, the locations in which we find silica do not correlate with highest transpiration loci. Therefore, there must be an additional mechanism which controls the polymerization of silicic acid. In my seminar I will present the two known mechanisms for plant silica deposition, discovered in my lab: (1) A protein- Siliplant1, which catalyzes silica formation in epidermal cells termed silica cells; and (2) Lignin- a polyaromatic cell wall polymer, on which silica may form. Our results highlight the variability in plant silica formation and call for research on the role of silica in plant biology.

Prof. Rivka Elbaum completed her PhD in chemistry, studying plant DNA preservation in archeological sites (2005). She then moved to Germany, where she worked on hygroscopic movement in wheat awns in the group of Prof. Peter Fratzl, Max Planck Institute for Colloids and Interfaces in Potsdam (2006-2007). Following a second postdoc on silica deposition in wheat awns at the Weizmann Institute of Science (Rehovot, Israel; 2008), she received a PI position at the Hebrew University of Jerusalem (Rehovot, Israel; 2009 - today). She is working on the characterization of cell wall in two contexts: silica bio-mineralization in plants and hygroscopic movement for seed dispersal. In both fields, she defined basic novel concepts.

T8

Slow-release mineral fertilizers with compostable plastic coatings

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In slow-release fertilizers, coatings made of plastics such as polyethylene or polyacrylates must be replaced with materials whose organic polymer content is 90% converted to CO_2 within 48 months after the end of the functional phase (nutrient release) in the soil (EU fertilizer product regulation). One of the first compostable plastics on the market was PLA. PLA coatings make paper cups waterproof. Fungal enzymes lead to the decomposition of PLA [1], but temperatures of 50 °C are applied in industrial composting. To support decomposition in the soil through ubiquitous hydrolases, IWKS has produced a hybrid material by linking PLA chains with hemicelluloses (mass fraction of hemicelluloses about 10%) [2]. The hemicelluloses are extracted from apple pomace with the IWKS extraction pilot plant using pressurized hot water [3]. In a feasibility study, the hybrid material was applied to a commercially available NPK fertilizer granulate, and the kinetics of nutrient release were investigated in vitro. From the uncoated granulate, nitrate, phosphate, and sulfate were completely released in the first four additions of water. In the case of coated granulate, the release was slow until the 20th addition, after which it increased significantly. Translated to a field application of 500 kg/ha, a precipitation of 400 L/m² would be required before the nutrient release increases. Processes for further stabilization of the coating and the economic feasibility of material substitution are discussed.

References:
[1] Urinov E et al. (2022). Enzymatic degradation of fiber-reinforced PLA composite material. Macromol 2, 522-530.
[2] Saadatmand S et al. (2011). Compatibilizers of a purposely designed graft copolymer for hydrolysate/PLLA blends. Polymer 52, 4648-4655.
[3] Wolf M et al. (2022). Hot-water hemicellulose extraction from fruit processing residues. ACS Omega 7, 13436-13447.

T9

Novel slow-release seed coatings for improved micronutrient supply to crops

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Zinc (Zn), boron (B), and molybdenum (Mo) are essential crop micronutrients that can be efficiently delivered via seed coatings. However, fast micronutrient release from soluble coatings can cause seedling toxicity due to high local concentrations. This study developed novel Zn-B-Mo slow-release seed coating compounds using nanostructured Zn_2Al or Zn_2Al layered double hydroxides (LDHs) loaded with (poly)borate and molybdate, aiming to prevent toxicity and enhance micronutrient delivery.
Chemical incubation experiments assessed two release mechanisms for Zn_2Al-B-Mo and Zn_3Al-B-Mo LDHs, i.e. anion exchange and LDH dissolution. Subsequently, chickpea seeds coated with these LDHs were evaluated in a seedling establishment trial for potential toxicity and compared to soluble micronutrient coatings at equal doses.
Both LDH compounds gradually dissolved at pH ~4.5, releasing Zn, B, and Mo. Zn_3Al-B-Mo released Mo more slowly than Zn_2Al-B-Mo via anion exchange at pH ~7. Owing to its slower nutrient release, Zn_3Al-B-Mo was selected for further seed coating evaluation.
In the seedling trial, LDH coatings did not cause toxic effects during seed emergence or early growth, even at elevated micronutrient doses, unlike their soluble counterparts. This was attributed to the controlled Zn release, as reflected in lower Zn levels from LDH-coated seeds. B and Mo levels were similar or higher than with soluble coatings, yet high early exposure may have been avoided.
In conclusion, the Zn_3Al-B-Mo LDH effectively controlled micronutrient release, minimizing toxicity risks while ensuring sufficient nutrient supply. Taken together, this new material shows strong potential as a slow-release seed coating material for Zn, B, and Mo delivery.

K4 ***Chenopodium quinoa*–a minor crop for future marginal soils**

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The pseudocereal *Chenopodium quinoa* Willd. (quinoa) has gained much attention in recent years as a “superfood” because of its nutritional value and remarkable abiotic stress resilience. Quinoa grains are rich in high-quality proteins, essential amino acids and contain high amounts of iron – compared to cereals - and are considered gluten free. From a plant nutrition perspective, quinoa offers unique advantages that make it suitable for cultivation in marginal environments that are characterised by low fertility, salinity, and drought. A reference genome and genotypic variation now allow to further investigate the mechanisms underlying quinoa’s resilience-mechanisms. Recent results suggest quinoa’s efficient use of nutrients, particularly for phosphorus, and distinguished mechanisms for tolerance to water deficit and high sodium levels. It appears that quinoa genotypes that are tolerant to water deficit have increased transpiration at night compared to susceptible genotypes, and its abiotic stress tolerance does not appear to be related to epidermal bladder cells, which have long been thought to be storage compartments for sodium. Taken together, quinoa poses an interesting model organism to investigate stress resilience mechanisms, and it provides opportunities to diversify agriculture in environments with marginal soils.

Sandra Schmöckel is Professor at the department Physiology of Yield Stability at the institute of Crops Science, University of Hohenheim since 2024. Between 2018 and 2024 she was Jun. Prof. at the same department. She is interested in understanding abiotic stress resilience of crop plants, which she investigates using physiology and -omics approaches, from the lab to the field. Her main focus is currently salinity, drought and heat. With her PRIMA project “Quinoa4Med” she coordinates a team of researchers from Germany, France, Spain, Morocco, Algeria and Tunisia to study how quinoa could facilitate the diversification of agriculture, particularly in the context of marginal lands and smallholder farming in North Africa. Resilience to abiotic stresses is also the main topic of the Excellence Cluster GreenRobust that Sandra is a PI in.

T10
Development of Zn-biofortified rice for Madagascar

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One-third of the human population consumes insufficient quantities of zinc (Zn) to sustain a healthy life. Increasing Zn concentrations in food crops, an approach termed Zn-biofortification, is one cost-effective option to address this problem. Our objective is to explore the genotypic variation present in the rice gene-pool for grain Zn concentrations [Zn], employ genomic prediction to identify new high-Zn donors among gene-bank accessions, and to determine whether their higher [Zn] is the result of superior Zn uptake during the reproductive stage, of higher Zn loading intensities or caused by an extended Zn loading period. Field experiments were conducted in Madagascar and [Zn] determined in 250 gene-bank accessions. For selected contrasting accessions tissue Zn concentrations and content were determined from heading to maturity to estimate Zn uptake and loading intensity. Local varieties had [Zn] in the range of 18-20ppm Zn, far below the breeding target of 30ppm Zn [1]. In gene-bank accessions [Zn] up to 40ppm were detected and genomic prediction identified several high-Zn donors [2]. Zn uptake between heading and maturity was not limiting [Zn] and neither did genotypes differ in the duration of Zn loading. Instead, the loading intensities during grain filling were twice as high in high-Zn donors compared to low-Zn varieties, and this resulted in a zinc harvest-index of 47.7% in the best donor compared to 26.1% for the local variety despite similar biomass HI and reproductive-stage Zn uptake [3]. Donors described here have been utilized to develop the first Zn-biofortified rice variety released in Madagascar.

References:
[1] Rakotondramanana M et al. (2024). Stability of grain zinc concentrations across lowland rice environments favors zinc biofortification breeding. FPS 15: doi.org/10.3389/fpls.2024.1293831.
[2] Rakotondramanana M et al. (2022). Genomic prediction of zinc-biofortification potential in rice gene bank accessions. TAG 135:2265-2278 doi.org/10.1007/s00122-022-04110-2
[3] Rakotondramanana M et al. (2025). The contribution of Zn uptake and grain Zn loading intensity to achieving Zn biofortification breeding targets in rice. JPNSS doi.org/10.1002/jpln.12013

T11 Discovering the hidden power of wild rice: A key to mineral disorders tolerance

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Iron (Fe) toxicity and soil salinity are major mineral disorders that significantly hinder rice growth and yield[1, 2]. Cultivated rice (*Oryza sativa*) is particularly exposed to these stresses. However, the *Oryza* genus is an unexplored reservoir of genetic variation, offering potential solutions. Thanks to the diverse natural growth environments and unique morphological characteristics of these species, they can be leveraged to enhance the tolerance of cultivated rice to mineral disorders [3,4]. Although there is genetic variability for Fe toxicity and salinity tolerance among wild rice relatives, it remains largely unexplored. To better understand the tolerance mechanisms in wild rice and to identify new genomic resources from these wild relatives, we performed a series of experiments. These involved experiments with wild rice species and introgression line populations subjected to both Fe toxicity and salinity stress. In our experiments, wild rice species demonstrated moderately higher tolerance to these stresses compared to cultivated rice. Notably, *O. meridionalis* showed higher tolerance to Fe toxicity, while *O. rufipogon* and *O. rhizomatis* exhibited improved tolerance to salinity. Additionally, wild species displayed a distinct ionomic profile compared to *O. sativa*, constitutively accumulating higher levels of ions in seeds and leaves without any toxicity symptoms. Moreover, transcriptomic analysis allowed the identification of key genes involved in the tolerance mechanism and the molecular crosstalk among these two stresses in *O. rhizomatis* species. These findings emphasize the critical importance of harnessing the vast genetic reservoir of wild species. This approach could pave the way for either introgression of traits or *de novo* domestication of wild rice, aiming to develop genotypes with enhanced stress tolerance and superior grain quality, particularly in terms of essential nutrient content.

[1] Becker, M. and Asch, F. (2005) Iron toxicity in rice - Conditions and management concepts. J. Plant Nutr. Soil Sci., 168, 558–573.
[2] Raza, A., Zaman, Q.U., Shabala, S., Tester, M., Munns, R., Hu, Z., and Varshney, R.K. (2025) Genomics-assisted breeding for designing salinity-smart future crops. Plant Biotechnol. J.
[3] Atwell, B.J., Wang, H., and Scafaro, A.P. (2014) Could abiotic stress tolerance in wild relatives of rice be used to improve *Oryza sativa*? Plant Sci., 215–216, 48–58.
[4] Fornasiero, A., Feng, T., Al-Bader, N., Alsantely, A., Mussurova, S., Hoang, N. V., et al. (2025) *Oryza* genome evolution through a tetraploid lens. Nat. Genet.

T12

Wheat as an early indicator for the shortage of phosphorus in soil

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Under field conditions the grain yield of wheat often reacts rather tolerant to reduced contents of available phosphorus (P) in soils. Previous results however suggest, that whole shoot P contents more sensitively reflect low soil P contents. Insufficient plant P availability is a result of either low soil P reserves due to reduced or no P fertilizer input or caused by an inadequate soil pH value. Low pH values significantly increase the adsorption of P to surfaces of Fe- and Al-oxides and -hydroxides.
In a 46-year long-term field experiment with each three levels of liming and P fertilizer application wheat whole shoot P analysis reflected a shortage of P in soil although the grain yield was still unaffected by P. The calculation of the Phosphorus Nutrition Index (PNI) and its comparison to data from literature was a valuable tool for interpretation. Omitted P application combined with no liming had the strongest effect and decreased PNI down to 0.6 but PNI on no-lime plots was also about 0.8 if P had been added, demonstrating the crucial role of soil pH on P availability.
In addition, root fungal colonization was investigated. The presence of "dark septate endophytes" during wheat growth was negatively correlated to grain yield.
It is concluded, that the analysis of total P in whole shoots of cereals is a valuable tool to predict a beginning shortage of P availability in soils and helps to interpret the sometimes confusing relations between CAL extractable P and grain yield.

T13

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

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Access to boron (B) throughout the entire plant life cycle is essential for development, yet its soil mobility often limits availability. To elucidate the genetic basis of B efficiency in Brassicaceae, we leveraged a doubled-haploid (DH) population of *Brassica napus* derived from B-efficient and B-inefficient parents and 185 natural accessions of *Arabidopsis thaliana*. Both populations were grown under B-sufficient and B-deficient conditions in an automated phenotyping system, capturing >50 shoot traits daily for up to 20 days. Additionally, the *A. thaliana* population was cultivated on Phytagel to assess root responses.

Biomass in the *B. napus* DH population decreased by at least 60% under B limitation, albeit with a 25-fold range in tolerance between accessions. Genetic mapping associated loci on three *B. napus* chromosomes with variation in multiple developmental and ionomic traits. Most *A. thaliana* accessions showed severe growth inhibition, but seven maintained >80% biomass accumulation and were defined as B efficient. We identified a high confidence, pleiotropic QTL for resilience of shoot and root traits to B limitation in *A. thaliana*. This suggests either a single adaptation contributes to both shoot and root resilience to B limitation, or that developing a root system that facilitates continuous B access is critical for maintaining a vigorous shoot system.

To conclude, B-efficient genotypes appear to maintain growth under B limitation through increased B-use efficiency and by maintaining B access, rather than increasing B accumulation. Ongoing fine mapping and candidate gene validation aim to further resolve the genetic mechanisms underlying B efficiency in Brassicaceae.

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T14

NUDIX-Type Hydrolases in *Arabidopsis thaliana* Target Specific Inositol Pyrophosphates and modulate nutrient signaling

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Intracellular phosphate sensing, systemic phosphate signaling, and the perception of various phytohormones relies on a small group of messengers called inositol pyrophosphates (PP-InsPs) [1-4]. Despite their importance in stress responses, the biosynthetic and hydrolytic pathways of PP-InsPs in plants remain largely enigmatic [5]. This is especially true for various PP-InsPs of unknown biological function that were recently discovered thanks to analytical advances [3,6] . Taking advantage of a non-hydrolysable PP-InsP analog and affinity pull-down assays, several NUDIX hydrolases (NUDTs) from *Arabidopsis thaliana* were identified as potential interactors with PP-InsPs. This study explores a potential role of NUDTs in PP-InsP turnover. We will present findings obtained through heterologous expression in various yeast mutants, *in vitro* studies using recombinant proteins, analyses of higher order plant mutants as well as localization studies that suggest specialized PP-InsP substrate specificities for members of different NUDTs subclades. The relevance of our findings with respect to the regulation of phosphate starvation responses and environmental adaptation by PP-InsPs will be discussed.

References:

[1] D. Laha *et al.*, VIH2 Regulates the Synthesis of Inositol Pyrophosphate $InsP_8$ and Jasmonate-Dependent Defenses in Arabidopsis. *Plant Cell* **27**, 1082-1097 (2015).

[2] J. Zhu *et al.*, Two bifunctional inositol pyrophosphate kinases/phosphatases control plant phosphate homeostasis. *Elife* **8**, (2019).

[3] E. Riemer *et al.*, ITPK1 is an InsP6/ADP phosphotransferase that controls phosphate signaling in Arabidopsis. *Mol Plant* **14**, 1864-1880 (2021).

[4] N. P. Laha *et al.*, INOSITOL (1,3,4) TRIPHOSPHATE 5/6 KINASE1-Dependent Inositol Polyphosphates Regulate Auxin Responses in Arabidopsis. *Plant Physiol* **28**, 2722-2738

[5] P. Gaugler *et al.*, Arabidopsis PFA-DSP-Type Phosphohydrolases Target Specific Inositol Pyrophosphate Messengers. *Biochemistry* **61**, 1213-1227 (2022).

[6] D. Y. Qiu *et al.*, Analysis of inositol phosphate metabolism by capillary electrophoresis electrospray ionization mass spectrometry. *Nature communications* **11**, (2020).

T15 Defining plant nutrient elements from the plant's perspective

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Identification of plant nutrient elements has always been a focus of plant nutrition research. A widely accepted definition required an essential nutrient element to (1) be necessary for the completion of the plant's life cycle, (2) cause a specific deficiency that cannot be overcome by other elements, and (3) participate in plant metabolism [1], although criterion 1 was often considered more important than the others (e.g. B, Ni). Arnon and Stout (1939) already pointed out that further minerals can be growth-promoting, nowadays referred to as 'beneficial elements' (e.g. Si, Na, Co, Se).
To allow agriculture to benefit from our improved understanding of plant nutrition under various conditions, Brown et al. (2022) proposed expanding the concept of plant nutrients to include both the classically essential and the beneficial elements [2]. Their proposal also explicitly covers nutrients improving crop quality attributes. However, including quality, understood as 'the totality of features that bear on the products' ability to satisfy given needs', in the proposed definition leads to uncertainty as to what a plant nutrient represents. For example, enriching crops with Cd and Cr, considered ultra-trace nutrients in human nutrition, using contaminated fertilisers could be considered biofortification.
Putting the plant's perspective centre stage, the following revision is proposed: *A plant nutrient element is an element* (1) *that significantly improves growth or development of a given plant species when grown in natural or cultivated environments*, (2) *whose deficiency cannot be overcome by other elements*, and (3) *whose function in plant biology has been established*.

References:
[1] Arnon DI and Stout PR (1939). The essentiality of certain elements in minute quantity for plants with special reference to copper. Plant Physiol 14, 371–375.
[2] Brown PH et al. (2022) What is a plant nutrient? Changing definitions to advance science and innovation in plant nutrition. Plant Soil 476, 11–23.

K5

From soil to root: the role of mucilage in facilitating nutrient and water uptake

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Plants modify the biophysical and chemical properties of their surrounding soil, called the rhizosphere. These modifications, driven by root exudates, are adaptive strategies to mitigate resource limitations. While it is hypothesized that plants regulate rhizosphere hydraulics in response to soil texture and moisture variations, empirical evidence remains limited. The key research questions are: How do plants modify rhizosphere hydraulics through mucilage exudation? How do these modifications vary with soil texture and moisture?
To address these questions, we used a simplified rhizosphere model, mixing three soil textures (sandy, sandy loam, and loam) with varying mucilage content from maize seedlings. We measured hydraulic properties and nutrient diffusion to assess mucilage's role in modifying water transport.
Our results showed mucilage's effect on water retention and transport is texture-dependent. In coarse-textured soils, higher mucilage content was needed to improve water-holding capacity, as indicated by soil water retention curves. In contrast, lower mucilage content was sufficient to enhance water retention in fine-textured soils. Diffusion measurements using ^{45}Ca and phosphorus imaging showed that mucilage reduced diffusion in coarse-textured soils due to increased viscosity. In fine-textured soils, mucilage maintained or enhanced diffusion, suggesting improved liquid connectivity.
To explore mucilage's role in water dynamics, we used neutron radiography to monitor soil water redistribution around 8-week-old plant roots. The rhizospheric soil was wetter than the bulk soil in both coarse and fine textures, with significantly higher water content in sandy soils compared to loamy soils. This supports the hypothesis that plants in sandy soils exude more mucilage to improve rhizosphere water retention.
In a complementary experiment, we measured residual carbon in the rhizosphere of 2-week-old seedlings grown in sandy and loamy soils under optimal and stress conditions. Results showed lower residual carbon in sandy soils, suggesting that wetter rhizospheres in these soils are likely due to mucilage exudation, enhancing the soil's hydraulic properties.
In conclusion, our study provides evidence that mucilage plays a critical role in regulating rhizosphere hydraulics, with effects modulated by soil texture. These findings advance our understanding of plant-soil interactions, with implications for improving soil water retention and nutrient availability.

Prof. Dr. Mohsen Zare is Head of the Professorship for Soil Biophysics and Environmental Systems at the Technical University of Munich. His research focuses on mechanistic understanding of root and rhizosphere traits that enhance plant resilience to drought and nutrient limitations. With a background in soil physics and plant hydrology, Prof. Zare explores how biophysical interactions at the soil-root interface, especially involving root mucilage and rhizosphere processes, affect water and nutrient fluxes under stress. His interdisciplinary work integrates advanced imaging techniques, experimental analysis, and modeling to unravel how plant and microbial strategies influence soil structure and function. Prof. Zare is committed to advancing sustainable agriculture by linking fundamental research to practical solutions in soil and plant health.

T16

Root Exudate Responses to Combined Phosphorus Deficiency and Microplastic Stress

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Plants are increasingly exposed to multiple abiotic stresses, including well-known factors such as phosphorus (P) deficiency and emerging threats like microplastics (MP). While P deficiency is a recognized stress factor affecting root function, the impact of MP remains poorly understood—particularly in relation to root exudation, a key plant response to abiotic challenges at the root-soil interface.
This study examined how combined P deficiency and MPs affect root exudation in tomato plants (*Solanum lycopersicum* L.). Plants were hydroponically grown and treated with either 50 mg L^{-1} polyethylene microspheres (790–4999 µm), lignin (positive control), or no additives (negative control), under both full nutrient (+P) and P-deficient (-P) conditions. After 45 days (24 days under nutrient deficiency and 14 days of MP treatment), morpho-physiological data were collected and root exudates were analysed for organic acids, flavonoids, phenols, proteins, and total organic carbon.
Plant growth and ionomics confirmed severe P deficiency effects. While P starvation had the strongest impact on exudation, MPs also significantly altered the exudate profile. Notably, MP increased citric acid exudation under +P conditions but reduced it under -P, suggesting MP exposure may exacerbate the plant's perception of stress. Lignin had no such effect, indicating that MP act at physiological level in the plant.
The interaction between MP stress and P deficiency appeared synergistic, intensifying plant stress and possibly reducing P uptake. These findings emphasize the complex and potentially intensifying effects of emerging pollutants like MPs on plant nutrient responses.

T17

Characterization of polyacrylamide ZrOH hydrogels for sampling root-exuded carboxylates from soil-grown plants

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Root-released carboxylates play a crucial role in the mobilization and acquisition of nutrients. However, sampling root exudates from undisturbed soil-grown plant roots remains challenging. This study aimed to characterize ZrOH hydrogels as a non-destructive method for sampling root-exuded aconitate, citrate, fumarate, lactate, malate, oxalate, and succinate from soil-grown root systems on a 2D surface (i.e. rhizoboxes, root-windows). Carboxylate uptake kinetics and competition, capacity, stability, and elution parameters of the hydrogels were determined. Carboxylates were measured with ion chromatography coupled to a quadrupole mass spectrometer.
We found that the ZrOH hydrogels could completely uptake all the loaded amount (0.116 - 0.198 µmol) of carboxylates within 5 hours. Furthermore, no competition for uptake was evident between the carboxylates within the supply range of 0.154 to 0.275 µmol. Elution is performed with NaOH, for which the concentration and volume were dependent on the carboxylate. The most efficient elution for eluting all the carboxylates was either 1 or 5 mL with 0.5 mol L^{-1}, except for oxalate, which needed only 0.25 mol L^{-1} NaOH. Elution efficiency was lowest at 80.6 ± 5.1% for malate and highest at 106 ± 3.1% for lactate. The capacity of the hydrogels varied between 0.55 ± 0.13 µmol cm^{-2} for malate and 1.81 ± 0.20 µmol cm^{-2} for succinate, exceeding concentrations present in the rhizosphere by several fold.
Initial results indicate that ZrOH hydrogels can be used as a non-destructive method for sampling carboxylates released by rhizobox-grown roots. The research is ongoing, with additional validation tests currently underway.

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T18

Understanding waterlogging tolerance: Mitigation strategies to cope with excess water

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Advancing knowledge of crop resilience to waterlogging is crucial for developing agricultural systems that can withstand prolonged phases of soil water saturation, a growing concern under climate change. Hypoxic/anoxic soil conditions, induced by waterlogging, impede root respiration and nutrient uptake, which in turn leads to reduced crop yields and compromised food security. However, the extent of yield loss depends on crop species, their physiological adaptability, and the timing and duration of water exposure.
High-yielding crops such as wheat and rapeseed are particularly susceptible: Wheat yields decline >60% after late waterlogging (BBCH 51), with adverse effects on grain protein composition and thus baking quality [1]. Similarly, rapeseed exhibits an approximate yield loss of 25% when exposed to early waterlogging (BBCH 31). This phenomenon can be partially attributed to sulfur deficiency, which is triggered in soils that are deficient in oxygen [2]. In contrast, oat displays greater tolerance to waterlogging [3], likely due to yet-to-be-fully-understood physiological, biochemical or morphological traits.
Recent studies emphasize the importance of both genetic and agronomic strategies to improve resilience. Approaches include, besides breeding for waterlogging-tolerant varieties or adjusting sowing times, targeted nutrient management. For example, stress-adapted (pre/post) nitrogen and sulfur fertilization [2,3], as well as the application of melatonin [4], humic acids [5] or silicon, can help maintain nutrient balances, preserve root architecture and leaf integrity and support antioxidant capacity, thus improving crop performance under stress.
Therefore, the integration of tolerant crop varieties with targeted agronomic practices constitutes a robust approach to sustaining agricultural productivity under conditions of increasing waterlogging stress, while also enhancing agricultural resilience.

References:

[1] Wollmer A et al. (2018). Grain storage protein concentration and composition of winter wheat (*Triticum aestivum* L.) as affected by waterlogging events during stem elongation or ear emergence. J Cereal Sci, 83, 9–15.
[2] Hussain Md A et al. (2023). High sulfur (s) supplementation imparts waterlogging tolerance to oilseed rape (*Brassica napus* L.) through upregulating S metabolism and antioxidant pathways. J Plant Growth Regul, 42(1), 7591–7605.
[3] Pitann B, Mühling KH (2024). Oat—an alternative crop under waterlogging stress? Front Plant Sci, 15, 1386039.
[4] Hussain M A et al. (2025). Combined effect of melatonin and sulfur on alleviating waterlogging stress in rapeseed. Plant Environ Interaction, 6(2), e70050.
[5] Pitann B et al. (2024). Does humic acid foliar application affect growth and nutrient status of water-stressed maize? Plant Environ Interaction, 5(3), e10156.

T19

Positive interactions between plant-beneficial inoculants and members of the resident soil microbiome improve plant performance under stress

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Inoculants containing plant-beneficial microorganisms (BMs) can help plant performance by assisting the BM recruitment from the soil microbiome. In a long term field trial investigated whether BMs are particularly beneficial under abiotic stress. We performed field inoculation experiments with a BM consortium, including two bacterial (*Bacillus atrophaeus* ABi03, *Pseudomonas* RU47) and one fungal strain (*Trichoderma harzianium* OMG16). We drench-inoculated maize grown at neighboring sites with tilling practice or reduced soil management; furthermore, fertilizers were supplied at different levels. Plant were harvested and analyzed for their physiological status and the rhizosphere and root-associated soil was collected and analyzed with sequencing methods. Inoculation increased plant biomass and iron uptake in 2020, during severe early drought, but not in 2021, with average precipitation. The consortium-dependent modulation of the resident rhizosphere microbiome depended on the year as well as on the agricultural practice. *Comamonadaceae* spp. significantly increased in the rhizosphere due to BMc inoculation in 2020, but not in 2021, and were predictive for iron uptake and nutritional status of the plants. This suggests that plant-BMs improved plant growth only during stress exposure due to the recruitment of soil resident BMs. Whether isolates from the same field were helping plant growth under drought was addressed mechanistically in the greenhouse. Our study indicates that positive interactions between inoculants and the resident microbiome is crucial for plant performance.

K6 Integration of nutrient signals in plants: Mechanisms, genotypic differences and modeling

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Plants have developed mechanisms to respond to imbalances of multiple nutrients through the regulation of gene expression. Previously, co-authors and I showed that the NIGT1 transcription factor family serves as a hub for integrating nitrogen and phosphorus signals in Arabidopsis [1,2]. Such studies have highlighted the importance of gene networks in coordinating responses to changing nutrient conditions. However, the advantage that these networks provide to plants has remained unclear. In addition, it has not been well understood to what extent genotypic differences exist in the response patterns of plants to multiple nutrients.

To understand the physiological implications of the network involving NIGT1, the nitrate-inducible temporal expression pattern of *NRT2.1*, a major nitrate transporter, was monitored under various conditions using a luciferase reporter protein, and a mathematical model was constructed. Simulations based on the model and validation experiments showed that the amplitude of *NRT2.1* induction is relatively constant in the presence of NIGT1 proteins, while it is highly variable in the absence of NIGT1 proteins when variable amounts of nitrate were provided [3]. Additionally, the conservation of NIGT1-binding sequences in the *NRT2.1* promoter in both Arabidopsis and rice accessions further supports the importance of this gene network, suggesting its contribution to plant survival under fluctuating soil nutrient conditions.

Genotypic differences in nutrient response patterns were explored in rice. Low phosphorus conditions affected nitrogen use patterns differently in the nutrient-efficient landrace DJ123 and the popular variety IR64. Compared to IR64, DJ123 more strongly down-regulated the expression of *AMT1*, which encodes an ammonium transporter under phosphorus deficiency, leading to a different uptake ratio of ammonium and nitrate [4]. Responses of crown root growth also differed substantially in these accessions, suggesting differences in nutrient response networks. To understand the integration mechanisms of multiple nutrient signals, RNA-seq was performed using root tips obtained from plants grown under different combinations of nitrate, ammonium, phosphorus, and iron. Co-expression analysis suggested groups of genes whose expression levels correlate with root length, potentially harboring key genes that distinguish the responses in these accessions. These findings suggest the presence of natural variation in the response strategy to multiple nutrient signals.

References

[1] Ueda Y et al. (2020). Nitrate-inducible NIGT1 proteins modulate phosphate uptake and starvation signalling via transcriptional regulation of *SPX* genes. Plant J, 102, 448–466.
[2] Ueda Y et al. (2020) NIGT1 family proteins exhibit dual mode DNA recognition to regulate nutrient response-associated genes in Arabidopsis. Plos Genet, 16, e1009197.
[3] Ueda Y and Yanagisawa S (2023) Transcription factor module NLP-NIGT1 fine-tunes *NITRATE TRANSPORTER2.1* expression. Plant Physiol, 193, 2865–2879.
[4] Ueda Y and Wissuwa M (2022) Physiological evidence that nitrate use positively correlates with internal phosphorus utilization efficiency and phosphorus uptake efficiency in rice (*Oryza sativa* L.). Plant Soil 481, 547–561.

Dr. Yoshiaki Ueda obtained his PhD degree from the University of Bonn in 2015, focusing on oxidative stress tolerance in rice. Following that, he worked as a postdoctoral researcher at the Japan International Research Center for Agricultural Sciences (JIRCAS) and the University of Tokyo, where he started plant nutrition research in rice and Arabidopsis. Dr. Ueda joined JIRCAS in 2020 and is currently working as a senior researcher. His primary research interests lie in understanding the mechanisms that control the plants' responses to multiple nutrient signals, particularly nitrogen, phosphorus and iron. Additionally, he also conducts field-based rice genomics studies to identify key genes and QTLs essential for addressing nutrient disorders common in Africa, such as iron toxicity.

T20 **Conducting stress signalling: Impact of organellar calcium dynamics on salt tolerance**

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In plants, calcium (Ca^{2+}) functions as second messenger on organismic level and in the single cell. Characteristic transient 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, meristematic cells, and the guard cells of stomata [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]. We demonstrated that *eca3* knockout mutants show a severe hypersensitivity to salinity (sodium chloride) stress as compared to the wild type. Supported by the expression of *ECA3* in the vasculature [1,2], ECA3 is also assumed to be involved in systemic responses to high salt conditions. Our experiments suggest that *eca3* mutants display a delayed and reduced translocation of sodium to the shoot upon elevated salt uptake via the root. Intriguingly, *eca3* mutants respond differently to salt treatment on a local tissue level in the root tip. ECA3 pumps Ca^{2+} ions into the Golgi and thereby seems to maintain or reconstitute the basal Ca^{2+} status in the cytosol and to affect Ca^{2+}-dependent reactions in the secretory pathway. Additionally, our preliminary data suggest an altered Ca^{2+} signal in the Golgi of *eca3* mutants upon salt treatment, which underlines the hypothesis of a crucial role of the Golgi in the plant´s systemic salt stress response.

References:
[1] Mills RF et al. (2008). ECA3, a Golgi-localized P_{2A}-type ATPase, plays a crucial role in manganese nutrition in Arabidopsis. Plant Physiol, 146, 116-128.
[2] Li X et al. (2008). A distinct endosomal Ca^{2+}/Mn^{2+} pump affects root growth through the secretory process. Plant Physiol, 147, 1675-1689.

T21 **Detection of Nutrient Deficiencies in Barley from RGB images, hyper-spectral images and hyperspectral point sensor data**

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Climate change and the sensitivity of ecosystems worldwide demand a reduction in the environmental impact of fertilizers while the need for food security requires the maintenance of high crop yields.
Sensor-controlled precision fertilization is a promising approach to reduce fertilizer application rates while at the same time meeting the nutritional requirements of crops.

In this study, spring barley was grown under various single-nutrient deficient conditions in four different experimental set ups: i) a hydroponic system in greenhouse, ii) a pot experiment in soil in greenhouse, iii) a Mini-Plot experiment under field-like conditions, and iv) a long-term fertilizer field trial. RGB image data sets were generated from all trials using a mobile camera (Huawei P20), and deep learning methods applied to predict nutrient deficiencies from these data sets. Plants of the Mini-Plot experiment were additionally phenotyped by hyperspectral images (Specim IQ handheld camera) and hyperspectral point sensor data (PolyPen RP 410). Machine learning approaches were applied to predict the respective nutrient deficiencies from hyperspectral data.

Prediction results will be presented for each nutrient treatment: i) across all experiments using RGB data, and ii) of the Mini-Plot experiment using RGB data, hyperspectral images, and hyperspectral point sensor data.

T22

Profitability of Digestate Application Strategies – Results from Parcel and Field Trials

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In an interdisciplinary research project, strategies for using digestate and mineral fertilizer on selected crops at various locations across Germany from 2022 to 2024 were investigated. In total, seven trials were carried out, with three parcel trials located in the Braunschweig region and four whole field trials in Northern Hessen and Schleswig-Holstein. For all trials, various variants were selected, ranging from different levels of sole digestate to sole mineral fertilizer and a combination of both. To evaluate the trials with respect to profitability, DAKFL [1] (revenues minus variable costs and fixed costs of machines) were calculated. For this, five scenarios were developed, considering different transportation distances from farms to fields and application costs. Taking digestate application and transportation distance costs (3 km) as the base scenario, the results showed that in most trials digestate performed economically better than the mineral fertilizer. In some parcels, the outperformance of the DAKFL value under digestate ranged from 8 to 146 €/ha, with one field trial reaching up to 317 €/ha. However, when the transportation distance was increased to 15 km, digestate became economically less attractive compared to mineral fertilizer. Results indicate that an assumed utilization rate of about 70 % of the total nitrogen in digestate leads most likely to an economically optimal fertilization level. Overall, digestate fertilization makes economic sense when it can be provided for free and the transportation distance does not exceed the single-digit kilometer range.

References:

[1] SCHROERS, J. O.; SAUER, N., 2011: Die Leistungs-Kostenrechnung in der landwirtschaftlichen Betriebsplanung. Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL) (KTBL-Schrift, 486).

P1 **Long-term effects of crop rotation and nitrogen management on N_2O emissions in long-term crop production trials (N_2O-DV)**

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Nitrous oxide (N_2O) is a potent greenhouse gas. Nitrogen fertilization in crop production is one of the most important sources of nitrous oxide emissions. Emission levels depend on a variety of management factors, particularly organic and mineral nitrogen fertilization and crop rotation.

This project aims to measure nitrous oxide fluxes in two long-term field experiments (Speyer and Rauschholzhausen) on crop production, in which continuous field management was followed for at least three decades. The test factors for these comprehensive experiments are crop rotation (legumes versus cereals), the type of fertilization (with or without organic fertilization), and various levels of mineral nitrogen fertilization (0-50-100-150-200 kg/ha). Nitrous oxide emissions are measured over a complete crop rotation (3 years) in all experiments. At the same time, important factors influencing nitrous oxide emissions will be recorded, such as total nitrogen and Nmin content in the soil, soil moisture, organic carbon, and microbial activity. This project promises comprehensive insights into the practical and long-term effects of crop rotation and fertilizer management on nitrous oxide emissions.

References:
Machado, P. V. F., Farrell, R. E., Deen, W., Voroney, R. P., Congreves, K. A., & Wagner-Riddle, C. (2021). Contribution of crop residue, soil, and fertilizer nitrogen to nitrous oxide emissions varies with long-term crop rotation and tillage. *Science of The Total Environment*, *767*, 145107. https://doi.org/10.1016/J.SCITOTENV.2021.145107
Wang, C., Amon, B., Schulz, K., & Mehdi, B. (2021). *Factors That Influence Nitrous Oxide Emissions from Agricultural Soils as Well as Their Representation in Simulation Models: A Review*. https://doi.org/10.3390/agronomy11040770
Drinkwater, L. E., Wagoner, P., & Sarrantonio, M. (1998). Legume-based cropping systems have reduced carbon and nitrogen losses. *Nature*, *396*(6708), 262–265. https://doi.org/10.1038/24376

F1

Effects of Crop Rotation and Nitrogen Management on N_2O Emissions in Long-Term Field Experiments in Hesse, Germany

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Nitrous oxide (N_2O) is a potent greenhouse gas primarily emitted from agricultural soils due to nitrogen (N) fertilization and the decomposition of organic matter. To develop effective mitigation strategies, there is a pressing need to understand how long-term crop management practices influence N_2O emissions conditions. This study investigates the long-term effects of crop rotation and nitrogen fertilization (both organic and mineral) on N_2O emissions in arable systems in the Hesse region of Germany. The research utilizes two long-term field experiments at the Weilburger Grenze experimental station of the University of Giessen: The Biologische Stickstoffgewinnung (BSG) experiment, established in 1982, and the Erschöpfungsversuch (EV), established in 1954. These trials present unique historical datasets and consistent cropping systems that include rotations of winter wheat, winter rye, winter and/or spring barley, and sugar beet, combined with varying pre-crops (legumes and cereals) and fertilization levels. N_2O fluxes were measured using the LI-COR trace gas analyzer (LI-7820) from November 2023 to April 2025 in the BSG experiment, and from May 2024 to April 2025 in the EV experiment. Measurements were supported by detailed recordings of soil properties (organic matter, total nitrogen and carbon, mineral nitrogen), as well as parameters including soil moisture, temperature, and weather conditions. Initial observations suggested that legume-based pre-crops and full mineral NPK treatments are associated with elevated N_2O emissions, particularly during moist and warm conditions, while cereal-based rotations and reduced fertilizer inputs contribute to lower emissions. The addition of farmyard manure in the EV experiment may result in delayed but prolonged N_2O release due to ongoing mineralization processes. This study is expected to reveal statistically significant relationships between N management, crop rotation, and environmental factors influencing N_2O fluxes. By providing empirical evidence from decades-long trials, the findings will support site-specific mitigation strategies and contribute to the "Fertilization" action area of the BLE Arable Farming Strategy 2035. Ultimately, the research underscores the importance of integrating sustainable crop rotation and fertilizer management to improve nitrogen efficiency and reduce greenhouse gas emissions in temperate agricultural systems.

Keywords:
Nitrous oxide; crop rotation; long-term field experiments; climate-smart agriculture; N_2O fluxes; sustainable farming

P2 Soil Nitrogen Mineralization in Sandy Soils During Potato Cultivation Under Different Irrigation Conditions

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Sandy soils typically exhibit low cation exchange capacity and organic matter content, resulting in limited nitrogen (N) retention and mineralization. Despite this, high-yielding potato cultivation often relies on such soils, increasing the risk of nitrate leaching due to shallow rooting and low N use efficiency of the crop.

The project PotenzioN (Potentials for increasing nutrient efficiency and reducing nitrogen emissions in starch potato cultivation) investigates the effects of reduced N fertilization in field trials. Surprisingly, field data from unfertilized plots in the Uelzen region, characterized by sandy soil (Ss), a low soil quality index (28), and only 19 kg N_{min} ha^{-1} in spring, showed tuber yields and plant N uptake exceeding expectations. This cannot be explained by atmospheric deposition or irrigation water alone.

To explore the source of this N, a 57-day greenhouse pot experiment was conducted using trial-site soil to assess nitrogen mineralization potential under four irrigation regimes (no irrigation, natural rainfall, 35 % and 50 % of field capacity) and with or without potato plants (cv. Eurotonda).

The results show that the soil can mineralize considerable amounts of N within 57 days, particularly in the presence of plants. While N_{min} levels remained largely unchanged in unplanted pots, planted pots showed a rapid depletion of soil mineral N, reaching nearly zero after ~30 days. However, total plant N uptake exceeded 240 mg N kg^{-1} soil more than twice the initial N_{min} content, regardless of irrigation treatment, indicating a strong mobilization of organic N reserves.

Plants grown under 50 % field capacity produced higher biomass (>10 %), showed faster development and higher evaporation rates (~25 %), and had a wider C/N ratio (20; 18), although plants under natural rainfall eventually exceeded them in height (25 cm) due to episodic precipitation events. Unirrigated plants experienced early drought stress, leading to stunted growth, elevated chlorophyll concentration (57 g cm^2; 32 g cm^2 irrigated), due to reduced leaf area expansion, and poor N uptake and mineralization stimulation.

These findings suggest that even low-humus sandy soils contain substantial total nitrogen reserves, which, under favourable temperature and moisture conditions and in the presence of active root systems, can mineralize significant amounts of N over a short time period. This has important implications for site-specific N management strategies in potato cultivation.

P3

Maize inoculation with microbial consortia: contrasting effects on rhizosphere activities, N acquisition, and plant growth under different N supply

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The benefit of plant growth-promoting microorganisms (PGPMs) as plant inoculants and its interaction with different N supply is influenced by a range of environmental factors. Therefore, microbial consortia products (MCPs) based on multiple PGPM strains have been proposed as superior for improved plant growth and nutrient use efficiency in disturbed soil environments. The performance of a MCP was investigated in greenhouse maize experiments with maize with different N supply (nitrate and ammonium), contrasting pH, organic matter content and microbial activity. Interestingly, the MCP inoculant stimulated plant growth and improved acquisition of macronutrients only on a freshly collected field soil with high organic matter content and high background microbial activity, exclusively in combination with stabilized ammonium fertilization. This was associated with transiently increased expression of AuxIAA5 in the root tissue, a gene responsive to exogenous auxin supply, suggesting root growth promotion by microbial auxin production as a major mode of action of the MCP inoculant. High microbial activity was indicated by intense expression of soil enzyme activities involved in C, N and P cycling in the rhizosphere (cellulase, leucine peptidase, alkaline and acid phosphatases) without detectable effects induced by MCP inoculation. The results demonstrate that the MCP strategy, combining large numbers of PGPM strains with complementary properties, not necessarily translates into plant benefits under challenging environmental conditions. Soil properties, such as organic matter content, pH buffering and the form of N may crucially influence the plant-microbial interactions, plant-protection metabolism and thus contribute to an improved nitrogen use efficiency accordingly [3].

[1] Bradacova et al., 2019. Microbial consortia vs. single strains inoculants: an advantage in PGPM-assisted tomato production? Agronomy. 9:105.
[2] Bradacova et al., 2019. Maize inoculation with microbial consortia: contrasting effects on rhizosphere activities, nutrient acquisition and early growth in different soils. Microorganisms. 7:329.
[3] Maywald, N., Francioli, D., Mang, M., & Ludewig, U. (2023): Role of Mineral Nitrogen Nutrition in Fungal Plant Diseases of Cereal Crops. Critical Reviews in Plant Sciences, 42:3, 93-123, 10.1080/07352689.2023.2196100

F2 Wheat-Rapeseed Intercropping for Drought-Resilient Agriculture

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Crop production systems are increasingly challenged by climate change, particularly through prolonged droughts and extreme weather events. Intercropping offers a promising approach to enhance yield stability under variable environmental conditions. This project investigates a novel intercropping system combining wheat (*Triticum aestivum*) and rapeseed (*Brassica napus*), two staple crops critically important for German food security. Although widely practiced in tropical and organic systems, intercropping remains underutilized in conventional agriculture for this crop combination.
The central hypothesis is that rapeseed, through its deep taproot system, can access deeper soil water and redistribute it via hydraulic lift, facilitating water availability for shallow-rooted wheat during drought conditions. We hypothesize that such complementary root interactions improve water-use efficiency and enhance drought resilience compared to sole cropping.
The project aims to (1) develop a practical wheat–rapeseed intercropping system, and (2) understand physiological interactions under water-limited conditions. A two-year field trial at three locations evaluates agronomic performance and drought resilience. Complementary greenhouse trials focus on physiological measurements and transcriptomic analyses.
Preliminary trials demonstrate this approach's potential. In the dry year 2023, the intercropping system achieved a Land Equivalent Ratio (LER) of 1.39, indicating enhanced productivity. In 2024, the LER was 1.0, showing no reduced productivity in rainfall-abundant years. Stomatal conductance measurements reveal wheat plants in intercropping exhibit significantly higher values (0.113 mol m^{-2} s^{-1}) compared to sole-cropped wheat (0.092 mol m^{-2} s^{-1}). These findings suggest the wheat-rapeseed intercropping system enhances water-use efficiency through facilitative interactions, particularly benefiting wheat plants.

F3

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

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Due to climate change, rising temperatures combined with water deficits are expected to intensify in the future representing an increasing challenge to crop production [1]. For wheat (*Triticum aestivum* L.), a heat-sensitive crop with an optimal shoot growth at around 20°C [2; 3], previous studies have shown that combined heat and drought stress leads to reduced photosynthetic activity and biomass accumulation [4]. Furthermore, sink capacity reduced under continuous heat stress, though no source limitation occurred [5]. We hypothesize that wheat grain yield is primarily sink-limited under stress conditions rather than source-limited.

A pot experiment was conducted in a climate chamber with two spring wheat cultivars (Winx and Akvitan). Heat (30°C/25°C day/night), drought (35% WHC) or combined stress during vegetative growth was investigated compared to optimal conditions (22°C/16°C day/night, 60% WHC).

Stomatal conductance and photosynthetic activity were monitored using a LI-COR 600 before and during stress application. Source strength is assessed by analyzing sugar and fructan concentrations in leaves and stems. Sink-related parameters are determined by quantifying ears per plant and kernel number per ear (sink capacity), as well as by measuring the enzymatic activity of acid invertase and by characterization of plasma membrane H^+-ATPase in the kernels (sink activity).

Thus far, it can be concluded that heat had a stronger negative impact on plant development and shoot growth than water deficiency during vegetative growth in both varieties. The results can help to understand crop responses to stress conditions in order to improve stress resilience and ensure stable yields under future climate scenarios.

References:

[1] Senapati, N.; Halford, N.G.; Semenov, M.A. (2021): Vulnerability of European wheat to extreme heat and drought around flowering under future climate. Environmental Research Letters 16, 024052. https://doi.org/10.1088/1748-9326/abdcf3.

[2] Wang, X.; Dinler, B.S.; Vignjevic, M.; Jacobsen, S.; Wollenweber, B. (2015): Physiological and proteome studies of responses to heat stress during grain filling in contrasting wheat cultivars. Plant Science 230, 33–50. https://doi.org/10.1016/j.plantsci.2014.10.009

[3] Abdelrahman, M.; Burritt, D.J.; Gupta, A.; Tsujimoto, H.; Tran, L.-S.P. (2020): Heat stress effects on source-sink relationships and metabolome dynamics in wheat. Journal of Experimental Botany 71, 543-554. https://doi.org/10.1093/jxb/erz296

[4] Habti, A.E.; Fleury, D.; Jewell, N.; Garnett, T.; Tricker, P.J. (2020): Tolerance of combined drought and heat stress is associated with transpiration maintenance and water soluble carbohydrates in wheat grains. Frontiers in Plant Science 11, 568693. https://doi.org/10.3389/fpls.2020.568693.

[5] Perdomo, J.A. et al. (2015) Effects of long term individual and combined water and temperature stress on the growth of rice, wheat and maize: relationship with morphological and physiolocal acclimation. Physiologia Plantarum 155, 149-165. https://doi.org/10.1111/ppl.12303

[6] Hütsch, B.W.; Jahn, D.; Schubert, S. (2019) Grain yield of wheat (*Triticum aestivum* L.) under long-term heat stress is sink limited with stronger inhibition of kernel setting than grain filling. Journal of Agronomy and Crop Science 205, 22-32.

P4

First-Year Results of Strip-Cropping Spring Wheat with Aromatic Herbs in Central Germany

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Strip cropping is increasingly explored as a strategy to enhance resource use efficiency and improve cropping system resilience under climate variability. This study evaluated the performance of spring wheat (Triticum aestivum L.), coriander (Coriandrum sativum L.), and caraway (Carum carvi L.) in strip-intercropping systems under rainfed conditions across four contrasting sites in Hesse, Central Germany. In 2024, all sites experienced above-average precipitation. Field trials were conducted in a randomized complete block design comparing pure stands with strip-intercropping configurations. Grain yields were assessed, and land equivalent ratios (LER) calculated to evaluate land use efficiency.

Results showed that the wheat–coriander mixture (WCO) achieved a significantly higher mean LER (1.162 ± 0.323; $p = 0.036$), indicating a 16.2% increase in land use efficiency compared to pure stands. In contrast, the wheat–caraway mixture (WCA) showed no significant advantage (LER = 0.975 ± 0.356; $p = 0.610$). Performance varied strongly across sites, with one site (Darmstadt) showing consistently lower LERs due to heavy weed infestation. Excluding this outlier site reinforced the positive effect of WCO ($p = 0.020$) and revealed a non-significant trend for WCA ($p = 0.108$). Row-wise yield analysis indicated a slight spatial gradient, with rows further from the mixing zone yielding more. No significant treatment effects were found for leaf reflectance indices, stomatal conductance, or Photosystem II efficiency.

These first-year results suggest that strip-intercropping—particularly with coriander—can improve land use efficiency under adequate moisture conditions without yield penalties. The trial will continue for two additional seasons, including drought simulation, to assess the long-term performance and physiological responses under increased climate stress.

P5

ANAPLANT – Three-year project results for updating the target ranges for plant analysis in Saxony-Anhalt

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The plant analysis, which has been further developed since the 1960s, compares nutrient concentrations in the crops with target ranges at an early vegetation stage. Following, nutrient deficits can be balanced by late soil or foliar fertilization. Target ranges were validated/updated due to changed framework conditions - e.g. climate change, reduction of emissions, new varieties. Based on a total of 1.200 data sets sampled on field and trial sites in three growing seasons (2022-2024) from the arable crops oilseed rape, barley, rye, wheat, maize, sugar beet, potatoes and grain peas, target ranges for individual development stages were determined using envelope curves [2, 3, 4]. Data obtained on-farm were comparable with those from trial sites. Depending on the sample size (per crop and development stage), conclusive results were obtained (example in Fig. 1).

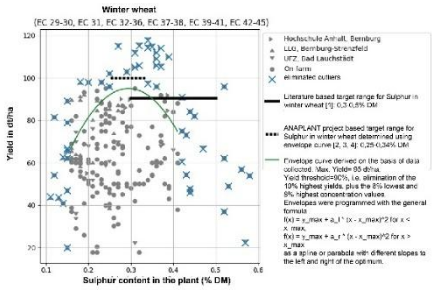

Fig. 1: Target range for sulphur concentrations in winter wheat determined by means of an envelope curve and currently used (over several EC stages as common so far).

Literature target ranges were confirmed for the majority of the elements. The results of the project led to the following suggestions for adaptions:
- Sulphur and N/S ratios: Reduction or splitting of the target ranges, especially for cereals and maize;
- Magnesium: Reduction of the target range for maize;
- Boron: Reduction of the target range for potatoes;
- Molybdenum: reduction of the target range for all crops.

Further studies are required for organic farming. We are very interested in continuing and expanding the project. For more information, please visit www.anaplant.de. The project was funded by the European Union (EIP AGRI).

[1] Bergmann, W. (1983): Ernährungsstörungen bei Kulturpflanzen. Gustav Fischer-Verlag, Jena.
[2] Heym, J., Schnug, E. (1995): A mathematical procedure for the development of boundary lines form XY scattered data. Aspects of applied biology, 43, 317-142.
[3] Klages, S., Erb-Brinkmann, M. Haberkern, W., Bennett, D., Siegmund, S., Bannach, W. (2024): ANAPLANT – Erste Ergebnisse der Zielwertaktualisierung für die Pflanzenanalyse in Sachsen-Anhalt. VDLUFA-Schriftenreihe Bd 81, 241-248, Kongressband 2024 Karlsruhe, VDLUFA-Verlag, Darmstadt
[4] Klages, S., 2012: Evaluation of the mineral status of organically grown cotton in Egypt. Dissertation. Technischen Universität Carolo-Wilhelmina zu Braunschweig, Fa-kultät für Lebenswissenschaften (http://www.digibib.tu-bs.de/?docid=00042509).Vielemeyer, H.-P., Hundt, I. (1991): Written communication. Institute for plant nutrition and eco-toxicology, Jena.
[5] Walworth, J.L., Sumner, M.E. (1987): The diagnosis and recommendation integrated system (DRIS): Soil Sci., 6, 149-188.

P6

THE EFFECTS OF NO-TILL FARMING ON CARBON SEQUESTRATION AND SOIL RESPIRATION

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Tillage in agriculture has a significant impact on the global carbon balance. Farmers that use no-till cultivation rely on the assumption that it is more environmentally benign than other methods owing to the build-up of humus [1]. However, this premise is seriously challenged [2].
The *JLU-Institute of Agronomy and Crop Physiology,* as a partner of the EU-funded EIP project *„InDiA",* aims to quantify and compare the specific *CO_2 fluxes* and *carbon sequestration* in different cultivation methods including direct, mulch, and plow sowing. Transportable infrared gas analyzers are used in farmer's fields in order to understand the mechanics of soil respiration. Substrate-induced respiration will be used in future research to investigate microbial activity.
The initial results demonstrate disparities between the cultivation methods. The plow sowing method showed the greatest CO_2 flux values, with an average fo 6.7 µmol m^{-2} s^{-1}, but the direct and mulch sowing versions have more moderate values, with average values of 4.1 µmol m^{-2} s^{-1}. Thus the CO_2 flux of the plow variant was 63.4% higher. The increased soil respiration of the plow sowing variant indicates a faster mineralization of soil organic matter. In contrast, the minimum tillage strategy indicates more stable carbon sequestration in the soil. The preliminary results of this exploratory study contribute to the advancement of knowledge about the climatic impact of various agricultural techniques and provide valuable information for the development of sustainable agriculture systems. Additional long-term studies are required to confirm the observed trends.

Keywords: No-till, climate adaptation, greenhouse gas emissions

References

[1] Luo Z. et al. 2010: Can no-tillage stimulate carbon sequestration in agricultural soils? A meta-analysis of paired experiments. Agric. Ecosys. Environ. Vol. 139, 224-231
[2] John M. et al. 2007: Tillage and soil carbon sequestration - What do we really know? Agric. Ecosys. & Environ. Vol. 118, 1-5

P7

Targeted application of mineral fertilizers and biostimulants for plant protection without chemical-synthetic pesticides in winter wheat under field conditions

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The project - LaNdwirtschaft 4.0 Ohne chemisch-synthetischen PflanzenSchutz (NOcsPS), investigates and develops arable farming systems using optimal organic and mineral fertilization but without chemical-synthetic plant protection.
Increased plant growth and pathogen defense with a combination of stabilized ammonium fertilizer and microbial biostimulants as well as micronutrients and non-microbial preparations (seaweed extracts) has already been observed in several studies [1][2][3][4][5].
Our aim is to develop fertilization strategies in combination with biostimulants to optimize crop tolerance against biotic stress.
Winter wheat was investigated under natural infestation and with inoculation of the pathogen *Zymoseptoria tritici*.
As fertilizer treatments, different forms of nitrogen were used with a focus on stabilized ammonium as well as the application of micronutrients and silicon. Furthermore, different microbial and non-microbial biostimulants were applied.
The key findings from the trial years 2021 and 2022 in winter wheat are as follows:
In 2021, the nitrate treatments showed the significantly lowest *Zymoseptoria* infestation due to the faster nutrient absorption of the mineral nitrate fertilizer than the ammonium sulphate solution (ASL) applied using the CULTAN method, while in 2022 the stabilized ammonium treatment in combination with microorganisms, micronutrients, seaweed extracts and chitosan showed the significantly lowest *Zymoseptoria* infestation due to increased metabolic activities (increased H_2O_2 concentration and ascorbate peroxidase activity) in ammonium treatments as protection against oxidative burst.

References:
[1] Göbel, M. et al. (2024). Protective potential of selected microbial and non-microbial biostimulants against Zymoseptoria tritici leaf blotch in winter wheat as affected by the form of N supply. Front. Plant Sci. 15, doi: 10.3389/fpls.2024.1407585.
[2] Bradáčová, K. et al. (2019a). Microbial Consortia versus Single-Strain Inoculants: An Advantage in PGPM-Assisted Tomato Production. Agronomy, 9, 1–23, doi:10.3390/agronomy9020105.
[3] Bradáčová, K. et al. (2019b). Maize inoculation with microbial consortia: contrasting effects on rhizosphere activities, nutrient acquisition and early growth in different soils. Microorganisms, 7, 329, doi:10.3390/microorganisms7090329.
[4] Mpanga, I.K. et al. (2019). The role of N form supply for PGPM-host plant interactions in maize. J. Plant Nutr. Soil Sci.,
[5] Bradáčová, K. et al. (2016). Micronutrients (Zn/ Mn), seaweed extracts, and plant growth - promoting bacteria as cold - stress protectants in maize. Chem. Biol. Technol. Agric., 1–10, doi:10.1186/s40538-016-0069-1.

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P8

Applying urea foliarly to increase grape must yeast assimilable nitrogen 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.

P9

Root trait variation in winter wheat conferring nitrogen use efficiency under field conditions

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Wheat is one of the major crops globally, providing approximately 20% of the calories and proteins consumed by humans. Yields are highly depending on nitrogen (N) fertilization which comes with high energy consumption, environmental and financial costs. As roots pose a major organ of N uptake, they could potentially provide means for improving N use efficiency (NUE) in crops through breeding. However, due to laborious phenotyping, root traits are not commonly used in breeding programs. Molecular markers can help to overcome this limitation in the selection for root traits. In previous works, GWAS has been applied in a diverse wheat population under contrasting N levels and drought conditions. This led to the discovery of several major loci being linked to root traits and NUE [1,2].

Currently, 54 genotypes showing contrasting features in root traits and putative differences in N-stress tolerance are grown at two locations under various levels of N applications for two growing seasons under field conditions. The aim of the study is to link root traits with higher nitrogen use efficiency and to validate previously found QTLs under field conditions. Based on haplotype analysis and underlying allelic variation in QTLs, KASP-markers will be developed. Crossing populations based on contrasting parental lines in NUE and root traits will be screened with the markers for validation of co-segregation with the chosen traits.

References:

[1] Koua, A. P., Siddiqui, M. N., Heß, K., Klag, N., Kambona, C. M., Duarte-Delgado, D., Oyiga, B. C., Léon, J., & Ballvora, A. (2024). Genome-wide dissection and haplotype analysis identified candidate loci for nitrogen use efficiency under drought conditions in winter wheat. The Plant Genome, 17(1), e20394.

[2] Siddiqui, M. N., Pandey, K., Bhadhury, S. K., Sadeqi, B., Schneider, M., Sanchez-Garcia, M., Stich, B., Schaaf, G., Léon, J., & Ballvora, A. (2023). Convergently selected NPF2. 12 coordinates root growth and nitrogen use efficiency in wheat and barley. New Phytologist, 238(5), 2175–2193.

F4 Can intercropping of cowpea and amaranth improve crop performance under drought conditions in Kenya?

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Drought stress is one of the major factors affecting global food security, especially in semi-arid and arid regions, and is expected to intensify due to climate change. Farmers need to adapt their cropping strategies and practices to improve resilience and resource efficiency. This study investigated effects of different cropping systems and harvesting intervals on dual-purpose cowpea (*Vigna unguiculata*) and vegetable amaranth (*Amaranthus* spp.) yields, to better understand whether diversification of small-holder agriculture improves farmers´ resilience in drought prone areas.

The field experiment was conducted at the Kenya Agricultural and Livestock Research Organization (KALRO) Kiboko research station in the drylands of Makueni County (AEZ = LM 5–9), Kenya. A two-factorial randomized complete block design with two water-regimes (irrigated vs. less irrigated) and four replications was established, including two cropping systems (sole crops of cowpea or amaranth, and strip-intercropping of both species). Each plot (N = 48, 3 × 3 m, spaced 1 m apart) was subdivided into three subplots for (i) non-destructive physiological measurements, (ii) short and (iii) long harvest intervals. Pest control and common agronomic practices were carried out according to local practice.

While cowpea leaf and grain yields showed no significant differences between cropping systems, both in well-watered as well as drought conditions, amaranth intercrop leaf yield was significantly lower under reduced irrigation compared to sole crop yield. However, LER (land equivalent ratio) values >1 in both water-regimes indicated improved land-use efficiency through intercropping of cowpea and amaranth. The diversification of the system through intercropping of dual-purpose cowpea and vegetable amaranth does not come at the expense of land use efficiency. Our findings suggest that cowpea may be successfully integrated into intercropping systems without reducing productivity, while vegetable amaranth leaf yield performance in this intercrop needs further improvement. Overall, intercropping of cowpea and amaranth showed potential for diversifying smallholder cropping systems in water-limited environments, particularly as green leafy vegetables and legumes contribute to a healthy diet and strengthen the resilience of farming systems.

P10

Functional analysis of salt stress-specific membrane transporters from halophytic barley relatives

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Salinity and drought pose major challenges to global agriculture by reducing crop productivity. Over 1,125 million hectares of arable land—about 20% of irrigated areas—are salt-affected [1]. Among wild crop relatives, the Triticeae tribe stands out for its halophytic traits and close anatomical, physiological, and genomic resemblance to major cereals [2, 3]. *Hordeum marinum*, native to coastal and salt marsh regions, thrives at salinity levels above 1.8% and serves as a key source of salt tolerance for wheat and related crops [4]. Another wild barley, *H. intercedens*, is a rare annual found in Californian saline and alkaline soils. We analyzed transcript profiles of both species under salinity stress. In *H. marinum*, we observed elevated expression of genes encoding channels and transporters, including SLAH Cl^-/NO_3^- channels, NRT1/PTR NO_3^- transporters, SKOR K^+ channels, BOR4 borate transporters, and CHX cation exchangers [5]. In contrast, *H. intercedens* showed a distinct expression profile, indicating independent evolutionary acquisition of salt tolerance. Its upregulated genes included ALMT transporters, PM-ATPase, a GLR channel, and CCX transporters. We cloned *HmCHX20* and *HiCCX1* for functional analysis. Yeast mutants (*axt3*) expressing these genes regained growth under high salinity (250–300 mM NaCl) and showed reduced Na^+ accumulation after 2 hours in 300 mM Na^+ medium. Transient expression of mCherry-tagged proteins in barley protoplasts suggested ER localization.
We are currently developing Arabidopsis and *H. vulgare* lines expressing these genes, along with CRISPR-Cas9-generated *HvCHX20* knockouts, to further explore their roles in salt tolerance.

References:
[1] FAO (2016). The State of Food and Agriculture: Climate Change, Agriculture and Food Security; FAO: Roma, Italy, p. 173
[2] Garthwaite AJ et al. (2005). Salt tolerance in wild Hordeum species is associated with restricted entry of Na^+ and Cl^- into the shoots. J. Exp. Bot. 56, 2365–2378
[3] Isayenkov S (2023). Wild Barley Relatives - Potential Donors of Salinity Tolerance for Cereal Crops
Multiple Abiotic Stress Tolerances in Higher Plants: Addressing the Growing Challenges, 2023, pp. 75–90
[4] Islam S et al. (2007). Salt tolerance in a *Hordeum marinum-Triticum aestivum* amphiploid, and its parents. J. Exp. Bot. 58, 1219-1229
[5] Isayenkov S et al. (2020). Adaptation strategies of halophytic barley *Hordeum marinum* ssp. *marinum* to high salinity and osmotic stress. Int. J. Mol. Sci. 21, 9019

F5

Validation of a novel, diffusive gradients in thin films (DGT) based carboxylate exudate sampling method using artificial roots and numerical simulation

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Plant roots continuously exude various compounds into the rhizosphere. Root exudates composition depends on the plant species, age, and nutritional status [1]. Rapid mineralization and root inaccessibility pose challenges to collect exudates. Recently, Tiziani et al. [2] presented a carboxylate (citrate) sampling method using ZrOH hydrogels based on diffusive gradients in thin films (DGT) technique, which offers the advantage of (1) sampling carboxylates from roots growing in soil, (2) concomitantly protecting the sampled compounds from mineralization, (3) allowing for localized sampling and imaging. This method is further developed and applied in the DGT Exudates project, which aims also at studying the impact of carboxylate (aconitate, citrate, fumarate, lactate, malate, oxalate, and succinate) exudation on Durum wheat phosphorus (P) acquisition. In this work we estimate the carboxylate recovery from roots by this novel sampling approach to better understand the method's performance.
We employ microdialysis (MD) as an artificial root, allowing to experimentally simulate carboxylate exudation by a root-like structure. The recovery of carboxylates will be assessed in sterilized, non-sterilized, and rhizosphere soil. Perfusate, dialysate, and gel eluates will be collected and analyzed using ion chromatography. In addition, numerical simulation using Comsol Multiphysics will be used to parameterise the soil processes involved in DGT carboxylate recovery. Carboxylates exudation, binding on the ZrOH gel, and carboxylate diffusion, sorption, and mineralization in the soil will be implemented in the model.
This study will provide insights into MD carboxylate release and DGT recovery rates, and will demonstrate, through both experimental and simulation data, the expected DGT carboxylate recovery for applying the method to real plant roots.

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References
[1] Jones, D.L. (1998). Organic acids in the rhizosphere – a critical review. Plant Soil. 205, 25–44.
[2] Tiziani, R., et al. (2021). Millimetre-resolution mapping of citrate exuded from soil-grown roots using a novel, low-invasive sampling technique. J. Exp. Bot. 72, 3513–3525.

P11

How does strip intercropping with coriander under reduced irrigation affect growth, physiology, and water use efficiency of spring wheat?

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With climate change, prolonged droughts are expected in many regions of Germany, requiring agronomic strategies to ensure stable wheat yields. Intercropping presents a promising approach. While most studies focus on wheat-legume systems, the taprooted coriander (*Coriandrum sativum*) could be a valuable intercrop partner for wheat, particularly under water-limited conditions. The differing root architectures of wheat and coriander may reduce competition for water by accessing different soil layers. Additionally, coriander could function as a “living mulch,” lowering soil evaporation and conserving moisture for wheat.
This study examined the effects of intercropping spring wheat (*Triticum aestivum*) with coriander on plant growth, water use efficiency, and crude protein content in wheat. The experiment was conducted in 120-liter containers filled with sandy loam, placed in an open-air cage. Two irrigation regimes, well-watered (ww; 60% of the maximum water holding capacity [WHC_{Max}]) and reduced watering (dw; 40% WHC_{Max}), were applied to pure spring wheat stands (WHE) and strip intercropping with coriander (WCO).
Results showed that wheat grain yield of the intercropping variant did not decrease significantly compared to pure wheat stands with reduced irrigation, even though the latter contained twice as many wheat plants per container. The intercrop wheat variant had a higher water use efficiency than pure spring wheat, with an increase of around 70% in both irrigation regimes. The crude protein content of the wheat grains tended to be higher in the intercrop variant under both irrigation treatments.
Intercropping wheat with coriander helps stabilise yield under drought by improving water use efficiency and enhancing grain quality, despite lower wheat planting density.

F6

Silicon fertilization in Hesse – Can drought stress be mediated through Si supplementation?

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Drought stress is a major problem in plant production due to its strong effects on crop yield [1]. Its abundance increases [2] and we need to adapt our farming practices to ensure a sustainable crop production. The supplementation of Silicon (Si) could enhance the plants' ability to generate yield under drought conditions. Through apoplastic Si precipitates, plants are hypothesized to enhance their barrier to the environment [3]. To test this, we carry out a comprehensive trial program in Hesse from 2024 to 2026.
Three potential products to supply Si were tested in 2024. Unfortunately, natural drought stress was absent. Our field trials with *Triticum aestivum* cv. SU Jonte, *Zea mays L.* cv. P8317 showed no effects of the Si application. In our trial with permanent grassland only an elevated Si concentration for some products could be observed (some analyses still pending). Another pot trial was conducted with *Zea mays L.* cv. P8317, artificial drought stress resulted in a reduction of biomass. In this trial we found that the Si concentration of the aboveground biomass was very low (<0.5%), this could indicate that the chosen cultivar might be not respondent to Si as there are some genotypical differences [4]. Also, we observed an increase in root dry mass in the absence of drought stress. In future trials we will screen for genotypical differences and new materials to supply Si as well as check additional application rates (and methods) to deepen our understanding of the observed effects.
This project is co-funded by the European Union (EIP-agri) and the state of Hesse. It is implemented by Justus Liebig University Giessen in collaboration with the Hesse Department of Agricultural Affairs (LLH), several partners in the agribusiness sector, and innovative farmers.

References:
[1] N. Mi, F. Cai, Y. Zhang, R. Ji, S. Zhang, and Y. Wang, "Differential responses of maize yield to drought at vegetative and reproductive stages," *Plant Soil Environ.*, vol. 64, no. 6, pp. 260–267, Jun. 2018, doi: 10.17221/141/2018-PSE.
[2] O. Rakovec *et al.*, "The 2018–2020 Multi-Year Drought Sets a New Benchmark in Europe," *Earth's Future*, vol. 10, no. 3, p. e2021EF002394, Mar. 2022, doi: 10.1029/2021EF002394.
[3] D. Coskun *et al.*, "The controversies of silicon's role in plant biology," *New Phytologist*, vol. 221, no. 1, pp. 67–85, Jan. 2019, doi: 10.1111/nph.15343.
[4] V. Vasudevan and C. Thiyagarajan, "Screening Maize Hybrids for Silicon Efficiency to Improve the Growth and Yield on Silicon Deficient Soils," *Silicon*, vol. 14, no. 15, pp. 9711–9720, Oct. 2022, doi: 10.1007/s12633-022-01700-z.

P12 **Effect of bio-acidification and leonardite addition to slurry on ammonia and GHG emissions in soil-plant systems**

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Agricultural ecosystems emit reactive trace gases like ammonia and nitric oxide, and greenhouse gases (GHGs) such as carbon dioxide, methane, and nitrous oxide. These emissions contribute to global warming, air pollution, and ecosystem eutrophication. Conventional mitigation measures, such as sulfuric acid slurry acidification, effectively reduce ammonia and methane emissions but are costly, pose safety risks, and are restricted in organic farming. This study investigates alternative slurry amendments derived from organic waste: cheese whey (a dairy byproduct), sauerkraut juice (a fermentation byproduct), and leonardite (a humic-rich natural material), assessing their emission mitigation potential.
A controlled soil-plant mesocosm system was used to simulate field-like conditions in the laboratory. Ammonia, methane, nitrous oxide, nitric oxide, and carbon dioxide fluxes were continuously monitored over nine days using a dynamic chamber method at 18 °C and 50% water-filled pore space. Treatments included untreated slurry, slurry amended with cheese whey, sauerkraut juice, or leonardite, and an unfertilized control.
Cheese whey and sauerkraut juice significantly reduced ammonia emissions by up to 91%, with cheese whey also lowering combined GHG emissions. Sauerkraut juice reduced methane emissions but increased nitrous oxide fluxes, likely due to elevated ammonium levels. Leonardite did not mitigate ammonia emissions but contributed to overall GHG reduction.
These findings highlight cheese whey and sauerkraut juice as promising amendments for ammonia mitigation, while leonardite shows potential for GHG mitigation. However, nitrous oxide trade-offs underscore the need for further optimization. The study supports sustainable nutrient management by repurposing agricultural byproducts within a circular economy.

P13

Crop residue burning: loss of mineral nutrients in different sugarcane (*Saccharum officinarum*) cultivars

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Crop biomass management and soil fertility pose significant challenges on a global scale and has become one of a major concern. Crop residue (CR) burning is a global issue due to its high greenhouse gas and particulate pollution emissions, specifically CH_4, N_2O and particulate matter (PM2.5). CR burning in the field is one of the widely practiced crop waste management approach which increases the soil surface temperature, negatively impact soil microflora, and deplete plant nutrients and organic matter. Moreover, CR burning results to the loss of total carbon and major mineral nutrient elements (N, P, K, S). Specifically, burning sugarcane residue has a detrimental impact on soil health, human health, and moisture loss from harvested sugarcane. However, genotypic variation on mineral nutrients loss by burning sugarcane biomass among commercial cultivars and between the production systems (organic vs commercial farming) are still underexplored. Therefore, we aimed to explore how burning sugarcane residue affect soil fertility while minimizing aerosol pollution at farm level.

The sugarcane burning experiments were carried out in controlled field environment in Kamphaeng Phet province, Thailand. This area has the highest sugarcane planting in northern Thailand. One kilogram of sugarcane dry residue at harvest was collected, each from five commercial cultivars. These cultivars were cultivated either in commercial or in organic farming. A part of dry residue and Ash samples were taken to the lab at the University of Bonn, Germany for mineral analysis. Since data analysis are still continuing, the in-depth results will be presented in the poster.

P14

Influence of different fertilizing systems on soil organic matter quality and glomalin-related soil protein content in cambisol

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The long-term effects of mineral and organic fertilisers on soil organic matter (SOM) content and quality were studied over 27 years in field trials on Cambisol soil under a crop rotation of potatoes, winter wheat, and spring barley. All treatments received equal nitrogen input and included: an unfertilised control (Cont), sewage sludge at standard and triple doses (SS1, SS3), farmyard manure at full and half doses with mineral N (F1, F1/2 + N1/2), straw with mineral N (N + St), and mineral N alone (N) [1]. Key indicators of SOM quality included total and easily extractable glomalin-related soil proteins (T-GRSP and EE-GRSP) [2] and water-stable aggregates (WSA) [3]. These were compared with humic substance fractions—carbon in humic substances (CHS), humic acids (CHA), and fulvic acids (CFA) [4]. The control treatment showed the lowest SOM content and quality, while the F1 treatment exhibited the highest, marked by elevated GRSP levels and degree of humic acid polymerisation. Organic matter from sewage sludge was less effective in stabilising SOM than straw. Significant correlations were found between GRSP (both T-GRSP and EE-GRSP) and CHS, CHA, and HA, but not with CFA. Although fertilisation influenced GRSP levels, no clear relationship was observed between WSA and SOM quality or GRSP content.

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References:

[1] Balík J et al. (2025). Soil organic matter quality and glomalin-related soil protein content in cambisol. Agronomy, 15, 1-16.
[2] Wright SF, Upadhyaya A (1998). A survey of soils for aggregate stability and glomalin, a glycoprotein produced by hyphae of arbuscular mycorrhizal fungi. Plant Soil, 198, 97-107
[3] Nimmo JR, Perkins KS (2002) Aggregate stability and size distribution. Methods of soil analysis: Part 4 Physical methods, SSSA. 317-327
[4] Kononova MM. (1966) Soil Organic Matter: Nature, Properties and Methods of Study. Pergamon Press Ltd.: Oxford, England. 531 p.

P15 Physiological effects of foliar-applied magnesium salts on stomatal regulation in magnesium deficient faba beans

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Foliar fertilization is an effective strategy for improving crop nutrition, particularly when root nutrient supply is restricted due to poor soil conditions, high nutrient losses, or limited translocation to critical plant organs [1]. Although nutrient absorption occurs through the leaf cuticle, stomatal pores are also considered important pathways for foliar nutrient uptake [2]. However, further research is needed to understand how foliar-applied salts affect stomatal regulation and whether changes in stomatal aperture affect the absorption of ions into the leaf. Foliar application of magnesium (Mg) salts is commonly used to alleviate emerging Mg deficiency. Different Mg salts vary in their companion anion, such as chloride, sulfate, or nitrate. We hypothesize that these anions affect the stomatal aperture differentially, influencing the overall effectiveness of foliar nutrient uptake, particularly through the stomatal pathway. To investigate these effects, we examined the impact of foliar-applied Mg salts on stomatal aperture in *Vicia faba* using in vivo light microscopy. Concurrently, the pH in the mesophyll apoplast is monitored to track changes in plasma membrane H^+-ATPase activity associated with ion uptake into the cytosol. To quantify ion translocation into the leaf apoplast, we extracted apoplastic wash solution following foliar salt application. Additionally, we assessed the physiological responses in Mg-deficient plants by measuring photosynthesis and chlorophyll content to evaluate nutrient uptake efficiency. Combining the physiological responses provides deeper insights into how stomata respond to different companion anions in foliar fertilizers, ultimately influencing nutrient absorption efficacy. This improves our understanding of effective and sustainable foliar fertilization.

References:

[1] Eichert T and Burkhardt J (2001). Quantification of stomatal uptake of ionic solutes using a model system. J. Exp. Bot., 52, 771-781.
[2] Fernández, V & Sotiropoulos, T & Brown, P (2013): Foliar Fertilization: Scientific Principles and Field Pratices. Paris, France: International Fertilizer Industry Association (IFA).

P16

P availability of conventional and wastewater-derived P fertilizers as determined by vegetation and microdialysis experiments

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Mineral rock phosphate (RP)-based fertilizers are essential for agricultural production. Due to uneven global distribution of RP [1], European countries rely on imports and classify RP and phosphorus (P) as 'critical raw materials' [2]. Since wastewater contains a considerable amount of P, attempts are being made to recover P via sewage sludge ash or precipitation products for use as fertilizer. However, the physico-chemical properties of conventional and recycled fertilizers lead to different P release characteristics over time, resulting in different plant availability and fertilization effectiveness. We investigated the course of P release of different wastewater-derived fertilizers (untreated sewage sludge ash, thermochemically treated sewage sludge ash and struvite) in comparison to conventional fertilizers (RP and triple superphosphate), using vegetation and laboratory experiments. The fertilizers were mixed into a sandy soil using a fixed fertilizer P dose. The course of P release or plant availability from the fertilizers was determined by the P uptake in several successive harvests of perennial ryegrass (*Lolium perenne* L.). Microdialysis, a minimally invasive, continuous sampling method based on diffusion of solutes into a semi-permeable membrane of a probe, was used as a complementary method, to investigate the course of P release from the fertilizers. Microdialysis sampling was carried out on duplicates of the soil-fertilizer mixture containing the same soil P concentrations as in the plant experiment. We will present first results of this study, which are part of the ongoing research to investigate the agronomic performance of P recycling fertilizers.

References:

[1] U.S. Geological Survey (2023). Mineral commodity summaries 2023: U.S. Geological Survey. https://doi.org/10.3133/mcs2023
[2] EU (2024). Regulation (EU) 2024/1252 of the European Parliament and of the Council of 11 April 2024 establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1724 and (EU) 2019/1020

P17

Can magnesium mitigate the effect of drought on wheat biomass production?

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Proper mineral-nutrient status in crops can help improve water use efficiency, improving crop growth under drought [1,2,3]. Roles of magnesium (Mg) for production of crops such as wheat are often overlooked as focus has been on other nutrients. As Mg is known to play a crucial role in photosynthesis, sugar transport, and root development, affecting crop yield [4,5,6], we hypothesise that its deficiency may exacerbate drought effects and additional Mg improves crop production and could mitigate the effects of drought on biomass production. We investigated the effect of Mg and water supply on biomass production in wheat under controlled conditions. Three Mg levels (0, 4, and 8 mM Mg), and two water levels (well-watered and water-deficient) were tested. We did not find significant effects of Mg on leaf photosynthetic parameters at either water level. However, under water-deficient conditions, plants grown in medium and high Mg levels increased shoot biomass by 21.9% and 22.4%, respectively, compared to plants grown in low Mg supply. In contrast, no significant differences in shoot biomass were observed among the three Mg levels under well-watered conditions. Root biomass did not differ significantly among Mg levels under water-deficient conditions. However, under well-watered conditions, root biomass increased by 25.8% and 7.4% in medium and high Mg levels, respectively, relative to the low Mg level. This study highlights the potential of Mg to mitigate the consequences of drought on wheat biomass production and calls for further research on optimal Mg fertilization practices under different environments.

References:
[1] Carlsson M et al. (2017). Drought stress resistance and resilience of permanent grasslands are shaped by functional group composition and N fertilization. Agric. Ecosyst. Environ., 236, 52–60.
[2] Hofer D et al. (2017). Nitrogen status of functionally different forage species explains resistance to severe drought and post-drought overcompensation. Agric. Ecosyst. Environ., 236, 312–322.
[3] Waraich EA et al. (2011). Improving agricultural water use efficiency by nutrient management in crop plants. Acta Agric. Scand. Sect. B - Soil Plant Sci., 61(4), 291–304.
[4] Jaghdani SJ et al (2021). The impact of magnesium deficiency on photosynthesis and photoprotection in Spinacia oleracea. Plant Stress, 2, 1-11.
[5] Cakmak I et al. (2008). Role of magnesium in carbon partitioning and alleviating photooxidative damage. Physiol. Plant., 133(4), 692–704.
[6] Wang Z et al. (2020). Magnesium fertilization improves crop yield in most production systems: a meta-analysis. Front. Plant Sci., 10, 1-10.

P18 Zeolite-Amended Biogas Digestate in Nitrogen Loss Mitigation: Insights from a Greenhouse Trial

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Recycling agricultural waste and optimizing fertilizer management are vital for sustainable agriculture. Zeolite amendments have been reported to mitigate greenhouse gas emissions and influence nitrogen (N) dynamics in soil. This study, part of the FNR-funded ZeoMin project, investigates how different zeolite amendments applied during anaerobic digestion at two ammonium (NH_4^+) concentrations influence N losses during subsequent fertilizer application.
A 42-day pot trial with perennial ryegrass was conducted using digestates obtained from anaerobic digestion of cattle slurry at two NH_4^+ levels. Treatments included control (CT), urea fertilization (U), digestates with low (BD_LN) and high (BD_HN) NH_4^+ content, and four zeolite/mineral amendments (BD_L/HN_x), each replicated four times. Emissions of ammonia (NH_3), nitrous oxide (N_2O), methane (CH_4), and carbon dioxide (CO_2) were measured, alongside plant biomass yield, soil mineral N, plant carbon (C) and N contents, and abundance of soil microbial domains, N-cycling related genes.
Zeolite-treated digestates reduced NH_3 emissions by 24-55% (low-N) and 58-68% (high-N) compared to digestates without amendment. However, the mitigation on N_2O emissions and the benefit on plant yield were not observed. These findings highlight that both zeolite amendments and substrate NH_4^+ content interact to influence NH_3 and N_2O gas emissions. In conclusion, zeolite amendments effectively reduce NH_3 emissions, particularly when digestates have higher NH_4^+ content. Our findings suggest that the NH_4^+ content of substrate is a key factor in determining the effectiveness of zeolite amendments in nitrogen loss mitigation. These results provide insights for improving fertilizer strategies and reducing nitrogen losses in agricultural systems.

References:

[1] He, Z.L., et al. 2002. Clinoptilolite zeolite and cellulose amendments to reduce ammonia volatilization in a calcareous sandy soil. Plant soil. 247, 253-260.
[2] Javaid, A., et al. 2024. The role of natural and synthetic zeolites as soil amendments for mitigating the negative impacts of abiotic stresses to improve agricultural resilience. Plant Stress. 14, 100627.
[3] Liu, R., et al. 2024. Green manuring combined with zeolite reduced nitrous oxide emissions in maize field by targeting microbial nitrogen transformations. Sci. Total Environ. 950, 175382.
[4] Schwalb, S.A., et al. 2023. Long-term differences in fertilization type change the bacteria :archaea :fungi ratios and reveal a heterogeneous response of the soil microbial ionome in a Haplic Luvisol. Soil Biol. Biochem. 177, 108892.
[5] Tzanakakis, V.A., et al. 2021. Effects of clinoptilolite zeolite and vermiculite on nitrification and nitrogen and phophorus acquiring enzymes in a nitrogen applied agricultural soil. J. Soil Sci. Plant Nutr. 21(4), 2791-2802.
[6] Wang, H., et al. 2021. The potential of ryegrass as cover crop to reduce soil N2O emissions and increase the population size of denitrifying bacteria. Eur. J. Soil Sci. 72, 1447-1461.

P19 Effects of long-term conservation tillage on soil nitrogen turnover in a Haplic Luvisol

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Conservation tillage is promoted for enhancing soil health, yet its effects on nitrogen (N) turnover and greenhouse gas (GHG) emissions remain uncertain. Soil was collected in October 2024 from a long-term experimental site near Göttingen, Germany, where conventional tillage (CT) and reduced tillage (RT) have been implemented since 1970. A 28-day incubation experiment examined the effects of tillage systems (CT vs. RT), soil depths (0-10 cm vs. 10-30 cm), and N fertilization (100 mg N kg^{-1} soil as $^{15}NH_4{}^{15}NO_3$). GHG fluxes (N_2O, CH_4, CO_2) were monitored alongside soil physicochemical properties and gross N mineralization (GNM). RT significantly increased N_2O emissions in the 10-30 cm layer after fertilization, associated with higher dissolved organic carbon (DOC), elevated pH, and increased labile C availability. In contrast, CH_4 and CO_2 fluxes were unaffected by tillage or fertilization. Soil moisture was highest in the RT0-10 cm layer but lowest in RT10-30 cm, suggesting altered water distribution under RT. This moisture gradient likely influenced microbial activity and GHG dynamics. The RT10-30 cm layer exhibited the highest DOC content but the lowest microbial biomass carbon (MBC), indicating RT promotes DOC accumulation at depth. Enhanced GNM in the 10-30 cm layer under RT suggests enhanced N mineralization due to increased availability of labile C and favorable microbial conditions. Overall, a greater availability of labile C below the tilling layer of RT (i.e., 10-30 cm) compared to CT triggers denitrification and N_2O emissions after N addition.

References:

[1] Lago-Olveira S et al. (2025). Quantifying spatially explicit LCA midpoint characterization factors to assess the impact of specific farming practices on ecosystem services. Ecosyst. Serv, 71, 101686.
[2] Lv L et al. (2023). Impact of conservation tillage on the distribution of soil nutrients with depth. Soil Till. Res, 225, 105527.
[3] Yue K et al. (2023). No tillage decreases GHG emissions with no crop yield tradeoff at the global scale. Soil Till. Res, 228, 105643

P20

SMT1: A Senescence-Induced Transporter Linking Metal Homeostasis and Senescence in Arabidopsis

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At the end of their life cycle plants undergo senescence, a highly regulated developmental process ultimately resulting in programmed cell death. This transition is initiated by an increased production of reactive oxygen species (ROS), which affect the transcriptional induction of senescence-associated genes (SAGs) [1]. In addition to age-dependent cues, nitrogen (N) deprivation also initiates senescence-associated processes such as N redistribution [2]. Here, we identify a novel transporter, Senescence-associated Metal Transporter 1 (SMT1), that links cellular metal homeostasis and senescence. *SMT1* expression is markedly up-regulated during natural senescence and also under N deprivation. Localization studies reveal that SMT1 predominantly resides in endomembranes but dynamically translocates to peroxisomes in response to elevated ROS levels. This shift points to a functional involvement in ROS detoxification processes, tightly linked to peroxisomal function, and a key aspect of senescence. Functional analysis of *smt1* mutants revealed pronounced growth defects under limited N supply, accompanied by elevated ROS levels and differentially expressed *SAG*s, leading to premature onset of senescence compared to the wild type. The reallocation of SMT1, combined with the mutant's susceptibility to ROS, supports the hypothesis that SMT1 contributes to metal-dependent antioxidant mechanisms during senescence. These findings and, above all, the role of SMT1 in response to insufficient N supply, advance our understanding of how plants coordinate metal homeostasis with developmental and environmental signals, and they may open new avenues for improving nitrogen use efficiency through targeted manipulation of metal transport pathways.

References:

[1] Evans KV et al. (2024). Expression of the Arabidopsis redox-related LEA protein, SAG21 is regulated by ERF, NAC and WRKY transcription factors. Sci. Rep., 14, 7756.
[2] Guo Y et al. (2021). Leaf senescence: progression, regulation, and application. Mol. Hortic., 1, 5.

F7 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, contain high concentrations of silicon. Silicon accumulates mainly in the shoots in the form of silica (SiO_2) bodies, which are also termed phytoliths [1]. The removal of straw and crop yields removes silicon from the fields every year, which can lead to soil depletion over many years [2]. In addition, phosphate and silicic acid (H_4SiO_4) compete for binding sites on mineral soil surfaces, so that an increase in soluble Si in the soil leads to a mobilization of P from soil minerals [3]. The aim of this work is to investigate to what extent straw removal and P fertilization have an influence on Si uptake by plants.
We analyzed two long-term field trials of the Austrian Agency for Health and Food Safety (AGES), in which (a) long-term Si depletion by straw removal and (b) P fertilization (0, 33, 65 and 131 kg P ha^{-1}) in triticale were investigated.
The results show that 38 (location Rottenhaus) and 42 (location Rutzendorf) years of straw removal lead to a depletion of soluble Si in the soil, which in turn is reflected in lower Si concentrations in the plant. Furthermore, P fertilization in combination with the incorporation of straw into the soil increased soluble Si in the soil. Straw incorporation increased the yield at the Rutzendorf site by a maximum of 22%. No significant differences were found in the P concentrations in the grain.
We conclude that long-term incorporation of crop residues counteracts soil Si depletion and that P fertilization has an effect on Si concentration in the plant and soil, respectively.

[1] Guntzer, F., Keller, C., Poulton, P.R. *et al.* Long-term removal of wheat straw decreases soil amorphous silica at Broadbalk, Rothamsted. *Plant Soil* 352, 173–184 (2012). https://doi.org/10.1007/s11104-011-0987-4.
[2] Vandevenne, Floor; Struyf, Eric; Clymans, Wim; Meire, Patrick . (2012). Agricultural silica harvest: have humans created a new loop in the global silica cycle?. *Frontiers in Ecology and the Environment*, 10(5), 243–248. doi:10.1890/110046.
[3] Haynes, R.J.; Zhou, Y.-F. (2018) Competitive and noncompetitive adsorption of silicate and phosphate by two acid Si-deficient soils and their effects on P and Si extractability. *Soil Science and Plant Nutrition*, 64(4), 535-541. doi: 10.1080/00380768.2018.1473008.

P21

Silicon-mediated protection against waterlogging stress in wheat: Tissue-specific accumulation and growth responses

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Waterlogging (WL) severely impacts wheat productivity by disrupting root function and metabolic processes. Our study investigated how silicon supplementation affects wheat's response to waterlogging at critical growth stages, such as BBCH 31 (early WL), BBCH 51 (late WL), as well as combined stress scenarios, analyzing silicon distribution patterns and their relationship to biomass preservation with particular attention to tissue-specific responses in roots, leaves, and stems.
Under waterlogged conditions, silicon showed distinct allocation patterns that differed markedly from unstressed plants. While control plants preferentially accumulated silicon in leaves (250 mg g^{-1} DW), stressed plants redirected silicon to roots (301 mg g^{-1} DW) under early stress) and leaves (286 mg g^{-1} DW), with stems showing intermediate levels (144 mg g^{-1} DW). This reallocation correlated strongly with improved biomass retention - silicon-treated plants maintained 40% higher dry weights under combined stress compared to non-treated counterparts during grain development. Notably, even under prolonged dual-stage stress, roots retained substantial silicon (401 mg g^{-1} DW), suggesting persistent protective mechanisms.
The strong association between Si accumulation and dry weight preservation was consistent across growth stages, with early WL showing the most pronounced effects. Post-stress analysis revealed preserved root architecture and leaf integrity in silicon-treated plants, likely due to enhanced structural reinforcement and oxidative stress mitigation. Our findings demonstrate that silicon's protective role extends beyond simple accumulation, involving strategic tissue prioritization that adapts to both stress timing and intensity.
These results provide actionable insights for optimizing silicon application in flood-prone wheat cultivation. Future work should explore molecular drivers of stress-responsive silicon allocation while validating these patterns under field conditions.

P22

TaNPF2.12-Mediated Root Plasticity and Nitrogen Use Efficiency in Winter Wheat Hybrids under Nitrate Limitation

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Nitrogen (N) is a critical macronutrient influencing plant growth, yet its inefficient use in modern wheat cultivars contributes to environmental degradation and yield losses. The nitrate transporter gene *TaNPF2.12* has been identified as a potential regulator of root system architecture and nitrate uptake efficiency under limiting N conditions. This study investigates the physiological and molecular basis of *TaNPF2.12* function in winter wheat F1 hybrids derived from crosses between low-N tolerant (Oakley) and susceptible genotypes (Basalt), alongside a TILLING-derived *npf2.12* mutant (Kronos4652).
Seedlings were grown hydroponically under contrasting nitrate regimes (0.5mM *vs*. 10 mM KNO_3) for 14 days. Root architectural traits were quantified via WinRHIZO, while anatomical characteristics were assessed using digital microscopy. Temporal gene expression of *TaNPF2.12* and of *NIA1* (which is a key gene in nitric oxide biosynthesis) were evaluated in roots across three timepoints using qRT-PCR.
Under low-N conditions, the F1 hybrids exhibited enhanced root length, root surface area, and root volume, outperforming both parents and showing similar values to the *npf2.12* mutant line. *TaNPF2.12* expression was significantly downregulated in the mutant and hybrid genotypes, coinciding with enhanced root development, confirming that reduced expression of this gene is associated with improved root growth. In contrast, *NIA1* was upregulated in these genotypes, suggesting a signalling mechanism involving nitric oxide pathways.
These results provide mechanistic insight into the regulation of root plasticity and nitrogen use efficiency by *TaNPF2.12* and underscore the utility of hybrid breeding and functional alleles in optimizing root traits for nutrient-efficient wheat cultivars.

Keywords: *Winter wheat*, *NPF2.12*, nitrogen use efficiency, root plasticity, nitrate signalling

P23 Exploring biodynamic preparations and their potential plant growth promoting benefits

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Biodynamic preparations (BDs), BD500 (horn manure) and BD501(horn silica), which are used in biodynamic agriculture have been associated with positive effects on soils and plants such as enhanced soil fertility and plant health.
The BD500 and BD501 are produced by filling cattle horns with cattle manure and powered quartz which are then buried in agricultural soils in a depth of 40-60 cm during autumn and spring, respectively. After incubation in soils specific procedures are used to produce liquid suspensions of the horn fillings. BD500 is sprayed on soils to stimulate soil microbial activity and root growth while BD501 is sprayed over leaves to improve plant immunity, photosynthesis, and fruit ripening.
Although many studies on BDs have focused on plant physiological parameters, some microbial studies indicated the enrichment of potential plant growth promoting bacteria [1]
We hypothesize that both BDs themselves contain PGPBs which can colonize plants after spraying and directly affect plant health, growth, and yield. Using a cultivation dependent study, we investigated the abundance of potential PGPB in both BDs and try to re-culture those bacteria form sprayed plants approximately 8 weeks after spraying.
First data indicated the high abundance of activity growing bacteria in both BDs. Genomic and phenotypic studies of isolated bacterial strain are currently used to prove the abundance of those bacteria on plants and to confirm their plant growth promoting activities.

Reference

1. Felix Milke, Heberto Rodas-Gaitan, Georg Meissner, Vincent Masson, Meike Oltmanns, Morten Möller, Yvette Wohlfahrt, Boris Kulig, Alberto Acedo, Miriam Athmann, Jürgen Fritz (2024). Enrichment of putative plant growth promoting microorganisms in biodynamic compared with organic agriculture soils, *ISME Communications*, Volume 4, Issue 1, January 2024, ycae021, https://doi.org/10.1093/ismeco/ycae021

F8

Optimizing Resource Use Efficiency in Temperate Agroforestry Systems: Integrating Gradient Analysis and Adaptive Management Strategies

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This study investigates the spatiotemporal dynamics of resource use efficiency in temperate agroforestry systems (AFS) by examining natural gradients along tree-crop interfaces and evaluating optimized management strategies to enhance system productivity. Combining precision field measurements with controlled experiments, we employ LI-6800 photosynthesis systems, hyperspectral reflectance indices (NDVI, PRI), and biochemical stress markers (proline, MDA) to quantify how tree proximity influences gradients of radiation interception, water use efficiency, and nutrient uptake [1]. Parallel split-plot experiments test adaptive management approaches, comparing drought-tolerant and sensitive crop varieties under organic and conventional fertilizer regimes to determine optimal resource partitioning strategies [2]. The research builds on preliminary findings demonstrating land equivalent ratio advantages in mixed systems [3] while incorporating novel precision agriculture tools like LiDAR-derived canopy measurements and RTK-GPS yield mapping [4]. By integrating high-resolution physiological data (stomatal conductance, Fv/Fm, Vcmax) with spatial yield analysis across multiple growing seasons, we develop a mechanistic framework for understanding stressor interactions (heat, drought, nutrient limitation) at varying distances from tree rows [5]. The study addresses two core hypotheses of the FORMULA Research Unit: (SP-H1) that crop yields in AFS follow predictable resource use efficiency gradients perpendicular to tree rows, and (SP-H2) that these gradients can be optimized through targeted management. Results will provide both fundamental insights into tree-crop interactions and practical recommendations for designing AFS that balance agricultural productivity with ecosystem services like microclimate regulation and carbon sequestration, ultimately supporting the sustainable intensification of temperate farming systems.

References:
[1] Jacobs SR, Webber H, Nietner W, Grahmann K, Lüttschwager D, Schwartz C, Breuer L, Bellingrath-Kimura SD (2022). Modification of the microclimate and water balance through the integration of trees into temperate cropping systems. Agric. Forest Meteorol. 323, 109065.
[2] Dobermann A (2007). Nutrient use efficiency-measurement and management. Proceedings of the International Fertilizer Industry Association (IFA) Workshop on Fertilizer Best Management Practices, 7-9 March 2007, Brussels, 1-28.
[3] Graves AR, Burgess PJ, Palma J, Keesman KJ, van der Werf W, Dupraz C, van Keulen H, Herzog F, Mayus M (2010). Implementation and calibration of the parameter-sparse Yield-SAFE model to predict production and land equivalent ratio in mixed tree and crop systems under two contrasting production situations in Europe. Ecol. Model. 221(13), 1744-1756.
[4] Donat M, Geistert J, Grahmann K, Bellingrath-Kimura SD (2023). Orientation of tree rows in alley cropping systems matters - The "ShadOT" modelling tool for tree growth and shading effects. MethodsX 11, 102282.
[5] Webber H, Rezaei EE, Ryo M, Ewert F (2022). Framework to guide modeling single and multiple abiotic stresses in arable crops. Agric. Ecosyst. Environ. 340, 108179.

P24 Point of deliquescence and point of efflorescence of different foliar applied salts and their role in nutrient uptake

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Foliar fertilization currently receives increased attention as it is an efficient way to improve plants' nutrient status. After being sprayed to plant leaves, salts mixtures are exposed to strongly changing environmental conditions. Pronounced diurnal changes in humidity lead to alternating crystallization and re-dissolution of the applied fertilizer salts on leaves. The Point of Efflorescence (POE) and Point of Deliquescence (POD) characterize the humidity levels at which different salts dry out or get re-dissolved, hence they play a crucial role in the effectiveness of foliar fertilizers, as they determine moisture retention, nutrient solubility, and crystallization dynamics on leaf surfaces. Understanding these properties is essential for improving foliar fertilizer composition, preventing leaf surface damage, and ensuring efficient nutrient uptake [1]. This project aims to evaluate the POD and POE of different salts and salt mixtures using magnesium (Mg) and the micronutrients zinc (Zn), manganese (Mn), and copper (Cu). The study focuses on how different salt properties influence leaf cuticle permeability, the role of stomata, and nutrient uptake efficiency, providing information for improving the composition of foliar fertilizers. The study was conducted in a controlled-environment hydroponic system using wheat plants. Various magnesium salts were analyzed for their POD and POE under different humidity conditions. Foliar applications were done to evaluate the effects of these physicochemical properties on transpiration as a source of humidity, leaf surface retention, and nutrient uptake efficiency. The results indicate that salts with a lower POD facilitated moisture retention on leaf surfaces, leading to enhanced nutrient uptake.

References:
[1] Bahamonde, H. A., Pimentel, C., Lara, L. A., Bahamonde-Fernández, V., & Fernández, V. (2023). Foliar application of potassium salts to olive, with focus on accompanying anions. Plants, 12(3), 472.

P25 **Magnesium regulates ion homeostasis in faba bean (*Vicia faba* L.) under salinity stress**

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Magnesium is crucial for plant resilience under salt stress, enhancing physiological processes that mitigate the harmful effects of salinity. However, its role in maintaining ion homeostasis, especially in limiting sodium uptake, remains unclear. The interaction among sodium (Na^+), potassium (K^+), and Mg^{2+} under salinity stress is complex. Additionally, the potassium-induced suppression of magnesium uptake in plants has been studied for over a decade, suggesting that high-affinity magnesium un/specific transporters facilitate greater potassium accumulation. Acknowledging that potassium and sodium have the same ionic valence, the present study aims to investigate the effect of Mg^{2+} application at varied K^+ levels on plant growth and ion homeostasis, with the hypothesis that under salt stress, ion homeostasis disrupts more significantly or leads to higher sodium uptake in magnesium-deficient plants compared to potassium-deficient plants. To test this, Vicia faba plants were grown hydroponically and subjected to salinity stress with 50 mm NaCl four weeks after transplanting, under varying levels of Mg^{2+} (sufficient: 0.5 mm; deficient: 0.02 mm) and K^+ (sufficient: 2 mm; deficient: 0.3 mm). Harvesting occurred two weeks post-salinity induction. Results indicate that plants with K^+ and Mg^{2+} deficiencies exhibited reduced growth, with Mg^{2+}-deficient plants experiencing a more significant reduction under salt stress. For the first time, we observed that in examining the ionic ratios of leaves and roots, the Na^+/Mg^{2+} ratio was 73% higher in Mg^{2+}-deficient plants than in potassium−deficient plants (40%), as indicated by the Na^+/K^+ ratio. This highlights the importance of Mg^{2+} in maintaining ion homeostasis rather than K^+ under salinity stress.

P26 Effects of insect frass on soil microbial activity, nutrient availability, and seed germination

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The increasing global food demand calls for a more sustainable agricultural and the valorisation of organic waste. Insect farming offers high-protein feed for animals but also by-products, i.e. frass composed by insect excreta, exuviae, and leftover substrate, that can be of high-value for agriculture.
To better understand frass potential, we conducted a laboratory experiment to investigate its effect on soil properties and early plant development.
A target agricultural soil was amended with mineral N or frass derived from *Hermetia illucens* or *Tenebrio molitor* at the dose of 4% (dw). Sunflower and maize were selected to assess frass effect on germination and early plant growth.
Soil respiration increased rapidly after frass application, likely due to microorganisms present in the frass. Microbial biomass C increased up to 4 times compared to the control, with varying intensities depending on frass type. Frass-amended soils showed a slower N release compared to the mineral-fertilised one, suggesting a modulation of soil nutrient cycling.
Seed germination was generally enhanced by the addition of frass, particularly in maize. Plant dry biomass of maize also increased with frass application, whereas that of sunflower was lower and negatively correlated to soil nutrient content. This suggests possible species-specific thresholds of frass phytotoxicity.
Overall, our results proved that insect frass can improve soil fertility, by enhancing microbial activity and nutrient mobilisation. Moreover, preliminary data on plants suggest the potential role of frass as biostimulant, although its optimal dose should be carefully assessed based on crop species and frass type.

P27

Influence of cow feeding system and slurry type on ammonia emissions from grassland

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Ammonia emissions from slurry-applied grasslands are a major source of nitrogen loss and environmental pollution. This study assessed the influence of cow feeding systems and associated slurry types on ammonia volatilization under field conditions. The experiment was conducted on grassland in Villmar, Hessen, Germany, from February to April in 2023–2025. Two cow-feeding regimes were compared: a high-input diet including corn silage, and a low-input diet with 50% reduced concentrates and no corn silage. Slurry types included raw unseparated slurry and mechanically separated liquid slurry from each diet, resulting in four treatments (Raw Slurry-High, Raw Slurry-Low, Liquid Slurry-High, Liquid Slurry-Low) with four replicates each (16 plots total).

Ammonia emissions were monitored continuously for two weeks post-application using a semi-open chamber acid trap system. Across all treatments and years, 60–70% of total emissions occurred within the first two days. In 2023 and 2024, high-input diets resulted in 3–14% higher cumulative emissions compared to low-input diets. In contrast, in 2025, emissions from low-input diets were higher, primarily due to greater ammonium concentrations in the slurry. Slurry type had a consistent effect, with mechanically separated liquid slurry reducing emissions by up to 65% compared to raw slurry.

Overall, while slurry separation proved highly effective in lowering ammonia losses, cow diet also influenced emissions, although effects were smaller and varied across years. These findings suggest that dietary adjustments—such as reducing concentrates and altering forage composition—may complement slurry management practices to improve nitrogen use efficiency. Further research is recommended to refine feeding strategies for consistent reductions in ammonia emissions under varying conditions.

Key words: Ammonia, feeding regime, slurry, grassland.

P28 Using small molecules to investigate and improve plant growth and nutrient efficiency

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A chemical genetic screen identified a novel small molecule, A1, that promotes plant growth [1]. A1 stimulates shoot and root growth by increasing fresh and dry biomass, an effect observed across a range of plants and crop species, including both monocots and dicots. In Arabidopsis, A1 treatment leads to the degradation of DELLA proteins, known repressors of plant growth, suggesting that A1 acts through a DELLA-dependent mechanism. Consistently, the *della* quintuple mutant showed no response to A1. Similarly, the *ga1-5* mutant, deficient in gibberellin biosynthesis, was unresponsive to A1, indicating that A1 activity also depends on the presence of endogenous gibberellins. This was further supported by the observation that *gid1* double mutants, lacking key gibberellin receptors, were also insensitive to A1, confirming the requirement for functional GA signalling [1]. Transcriptomic analysis of A1-treated plants suggested that the compound may enhance nutrient uptake and utilization. To uncover the direct molecular targets of A1 in plant cells, we are pursuing both genetic and chemical approaches. For the genetic approach, we screened a randomly mutagenised Arabidopsis population for mutants with altered responses to A1. In parallel, we are developing novel affinity-based A1 probes to purify potential direct targets. At the conference, we will present our progress on identifying A1 targets, elucidating its mechanism of action, and understanding its effects on nutrient uptake and use efficiency.

References:
[1] Sukiran NA et al. (2022). Plant growth promotion by the interaction of a novel synthetic small molecule with GA-DELLA function. Plant Direct, 6, e398

P29 Contribution of Sodium to Cationic Charges in Contrasting Crops

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Antagonistic interactions among cationic nutrients during root uptake and transport are well documented. While Na interactions have been extensively studied under salt stress, their roles under non-saline conditions are still poorly understood. To address this gap, a nutrient solution experiment was conducted to assess how varying levels of Na, K, Ca, and Mg affect root uptake, root-to-shoot translocation, and accumulation in crop plants with contrasting responses to Na including maize, rapeseed, soybean, and sugar beet [1]. Particular attention was given to the role of Na in maintaining charge balance.
Treatments did not significantly affect plant growth. However, notable differences were observed in cation translocation, accumulation and Na's role in charge balance. In maize, shoot Na remained very low across all treatments due to highly effective root retention of Na, where Na accounted for 15–37% of the total cationic charge (Σ[K, Na, Ca, Mg]). Soybean showed somewhat less root Na retention, with a maximum Na contribution to cationic charge of 15.5% in roots. In contrast, rapeseed exhibited much higher Na in both roots and shoots, while exhibiting some Na retention by the roots. In the case of sugar beet substantially high amounts of Na are transported and accumulated in the shoots. These results indicate that certain crops (particularly maize) retain most Na in the roots, significantly contributing to root charge balance. This Na-retention mechanism facilitates enhanced translocation of K, Ca, and Mg to shoots, thereby promoting shoot growth and reducing the risk of Na-induced cellular damage in the shoot.

References:

[1] Ma JF et al. (2023) Beneficial elements. In Rengel Z et al. (Eds.), *Marschner's Mineral Nutrition of Plants* (pp. 387-418), 4th Edition, Academic Press.

P30

Effect of Calcium Nanoparticles on growth and calcium biofortification on lettuce (*Lactuca sativa* L. cv) plant

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Nano fertilizer have advantages on plant growth and yield with decrease of chemical fertilizers cause economic burdens, chemical pollution for especially soil [1]. Calcium (Ca) is one of the most important plant nutrition on plant senescence, extension with cell wall stiffness, photosynthesis, cofactor for enzymes [2-3]. This study aimed to determine the effect of nano-calcium (Nano-Ca) and calcium-citrate (Ca-citrate) on lettuce plants (*Lactuca sativa* L. cv. Sementel) growth and Ca concentration grown under soil. The four treatments were; control, Nano-Ca, Ca-citrate and calcium nitrate ($CaNO_3$), respectively. The 200 mg Ca kg^{-1} applied from the different Ca sources. The four different Ca treatment were applied to lettuce leaf by spraying. The experiment was designed using completely randomized design with four replications. Functional and structural properties of nano material was determined by scanning electron microscopy (SEM) and fourier transform infrared spectroscopy (FTIR) before plant experiment. The best growth was from plants grown in Ca-citrate and Nano-Ca followed by $CaNO_3$ and control. The Ca-citrate and Nano-Ca resulted in the highest Ca concentration in lettuce (2.59 and 2.49 g kg^{-1}). The soluble oxalic acid content of nano fertilizers were higher than the $CaNO_3$ treatment. The study results suggest that Nano-Ca and citrate fertilizers as an alternative and in eco-friendly. This will enable us to find its effectiveness in growth and Ca nutrition in different types of soils and plants.

References:

[1] Jakhar, A.M., Aziz, I., Kaleri, A.R., Hasnain, M., Haider, G., Ma, J., Abideen, Z. (2022). Nano-fertilizers: A sustainable technology for improving crop nutrition and food security. NanoImpact, 27, 100411.

[2] White, P. J., Broadley, M. R. (2003). Calcium in plants. Annals of botany, 92(4), 487-511.

[3] Sahin, O., Yagcioglu, K. D., Kadioglu, Y.K. et al. (2024). Evaluating Ecological Nano-Calcium from Eggshells: Effects on Calcium Nutrition and Oxidative Stress in Lettuce Under Saline and Boron Toxicity. Journal of Plant Plant Growth Regulation **43**, 4416–4425.

P31

Drought stress in sugar beet: Alleviation of yield losses through silicon fertilization

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Sugar beet is the most important crop for sugar production in Europe. However, the increasing frequency and intensity of drought lead to yield and quality losses [1]. It was shown that silicon (Si) application increased beet yield under drought conditions in an arid environment [2]. Similar data for temperate climates are missing. Moreover, most studies focused either on foliar application [3,4] or drip irrigation with Si [2].
Thus, the aim of this study was to determine the effect of soil Si application on yield and quality parameters of *Beta vulgaris* in a temperate environment.
In 2024, field trials were conducted at three different sites in Germany and Austria. Different Si fertilization rates were tested (site 1: 0, 37, 78 kg ha^{-1}; site 2+3: 0, 50 kg ha^{-1}). The trial at site 1 was divided into an irrigated control and a non-irrigated drought treatment. At sites 2 and 3 irrigation was not possible. Yield and quality parameters were determined after harvest.
At site 1, drought stress reduced beet yield by 30% without Si application. Under drought conditions, the highest Si fertilization rate led to a significant yield and net sugar yield increase by 17 and 18%, respectively. Quality parameters were only affected by irrigation, not by Si. No natural drought stress occurred at sites 2 and 3.
The results from site 1 indicate that Si fertilization could become a relevant tool for adapting sugar beet cultivation to a changing climate. The mechanisms behind this yield effect are yet to be determined.

References:
[1] Shaw B et al. (2002) Responses of sugar beet (*Beta vulgaris* L.) to drought and nutrient deficiency stress, Plant Growth Regul. 37, 77-83,
[2] Zhou H et al. (2024) Silicon drip fertigation improved sugar beet root and canopy growth and alleviated water deficit stress in arid areas, Eur. J. Agron. 159, 127236
[3] Artyszak A et al. (2016) The effect of calcium and silicon foliar fertilization in sugar beet, Sugar Tech 18, 109-114
[4] Artyszak A et al. (2021) Impact of foliar application of various forms of silicon on the chemical composition of sugar beet plants, Sugar Tech 23, 546-559

P32

Allelic variation of a vacuolar cation channel modulating ion homeostasis and calcium signalling in plants

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TWO PORE CHANNEL 1 (TPC1) is a non-selective cation channel localized to the vacuolar membrane of plants. It plays a major role in the maintenance of the cellular ion homeostasis, and it is also involved in the propagation of systemic calcium signals [1]. Extensive natural variability in its sequence has been found both among and within species. Although some TPC1 proteoforms differ only at the level of a few amino acids, they can exhibit large differences in their functional properties, with a considerable impact on the plant phenotype. For instance, in *Arabidopsis arenosa*, a single substitution in the pore region of TPC1 is associated with the plants' ability to grow on extreme serpentine soils, presumably by altered ion selectivity [2]. In the model species *A. thaliana*, the analysis of *TPC1* sequences from 1135 accessions has revealed the presence of a wealth of non-synonymous single nucleotide polymorphism at this locus. However, the physiological relevance of these substitutions is as yet unknown. In this work, we are investigating the functional variability among TPC1 proteoforms in *A. thaliana* at the protein, cellular and organismic levels. To this purpose, we are employing a combination of cell biological, physiological, electrophysiological and computational approaches. A special focus is placed on a TPC1 proteoform with a substitution at the same site as in TPC1 from *A. arenosa* populations thriving on serpentine soils. The obtained data will provide insights into the mechanistic properties of TPC1, as well as into its role in shaping the plant phenotype.

References:

[1] Peiter E (2011). The plant vacuole: Emitter and receiver of calcium signals. *Cell Calcium*, 50, 120-128.
[2] Konečná V et al. (2021). Parallel adaptation in autopolyploid *Arabidopsis arenosa* is dominated by repeated recruitment of shared alleles. *Nat. Commun.*, 12, 4979.

P33 # Nitrate:Chloride Ratio Influences Growth, Stomatal Traits, and Transpiration in Barley depending on soil water availability

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Drought stress limits crop productivity. Chloride (Cl^-), when reaching concentrations typical for a macronutrient, may improve water use template efficiency under drought [1]. However, Cl^- competes with nitrate (NO_3^-) for uptake due to shared transport pathways and the need for electroneutrality [2,3]. In other words, increasing Cl^- concentration could influences nitrogen nutrition and processes that require NO_3^- in the plant. Given the limited understanding of NO_3^-:Cl^- interactions under varying soil water availability, this study examined their combined influence on ion-specific plant responses to drought.
We examined how four NO_3^-:Cl^- ratios (in mmol kg^{-1} substrate: 4.84:0.35, 2.42:2.11, 1.21:4.23, 0.21:5.63) and three soil water contents (WC) (30%, 50%, 70%) affect morphology and physiology in *Hordeum vulgare*, assessing biomass, leaf and stomatal features and transpiration. Five barley plants were grown per 1L pot containing 500g N-depleted substrate (soil:sand:perlite 6:3:1). Each pot represented one biological replicate, with five replicates per ratio × WC combination. Plants were cultivated under controlled greenhouse conditions and pots were irrigated to target WC using gravimetric method.
Plants grew better and had more leaf area when they received more NO_3^- than Cl^- and had more water. In contrast, high Cl^- and low NO_3^- reduced growth, likely due to nitrogen shortage, Cl^- stress, or both. Cl^--rich plants had thinner leaves with higher specific leaf area (SLA), while NO_3^--rich plants had thicker, denser leaves with lower SLA, possibly improving photosynthesis. Stomatal density stayed mostly stable, except under drought with high NO_3^-, where it dropped, likely to reduce water loss. At high water levels, low NO_3^-:Cl^- ratios led to wider stomatal openings but smaller complexes, showing that ion balance affects stomatal traits. Transpiration decreased with lower NO_3^- at moderate to high water levels, suggesting reduced water use efficiency. Under drought, extreme ion ratios lowered transpiration most, while intermediate ratios allowed more, possibly due to less precise stomatal control. NO_3^--rich plants had the highest transpiration at high water, matching their stronger growth.

Barley growth and stomatal traits were influenced by the NO_3^-:Cl^- ratio depending on soil water availability. Under well-watered conditions, NO_3^--rich conditions promoted shoot biomass, while high Cl^- reduced growth and led to thinner leaves. Under drought, high Cl^- was associated with reduced stomatal aperture and transpiration, suggesting a role in limiting water loss. These results point to a trade-off between growth and transpiration control shaped by NO_3^-:Cl^- balance.

References:
[1] Geilfus CM (2018). Chloride: from nutrient to toxicant. Plant and Cell Physiology, *59*(5), 877-886.
[2] Cubero-Font P et al. (2016). Silent S-type anion channel subunit SLAH1 gates SLAH3 open for chloride root-to-shoot translocation. Current Biology, *26*(16), 2213-2220.
[3] Carillo P et al. (2022). Nitrate Uptake and Use Efficiency: Pros and Cons of Chloride Interference in the Vegetable Crops. Front. Plant Sci. 13:899522.

P34

Promoting tree vitality by improving plant nutritional status - a concept for urban climate trees in Hamburg

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Urban trees are exposed to many interacting environmental stress factors, e.g. poor soil conditions, limited rooting space, drought stress due to poor water availability and radiation intensity [1]. The natural self-protection function of the trees decreases, and their susceptibility to diseases and pests increases. Climate change even exacerbates the severity of such factors. Plant nutritional status is one factor that reflects tree vitality and thus disease resistance. As an example, systemic resistance of trees against several pathogens may be improved by moderate nitrogen and sufficient sulfur supply [2].

Within a project on urban healthy climate trees in the city of Hamburg (funded by Ministry of Economy and Innovation, Head of Plant Protection Service) a concept model for sustainable urban planning measures to maintain tree health is elaborated. Fertilizing strategies for urban trees are not well established and in many European cities there is little knowledge on plant nutritional status of different tree species [3; 4]. We will contribute to fill a part of this gap for selected tree species and pathosystems. Knowledge will be gathered on the range of the nutritional status of individual trees under different growth conditions. These data will be related to tree vitality and the presence of diseases. Based on previous project results [2] we will conduct accompanying fertilizing experiments and monitor the development of tree health. This "nutrient-approach" is part of an integrated concept for increasing tree vitality in Hamburg.

References:

[1] Büttner C et al. (2023). Virus diseases of forest and urban trees. In: Forest Microbiology, Volume 3, Fred Asiegbu and Andriy Kovalchuk (eds), Elsevier Verlag, 61-97. https://doi.org/10.1016/B978-0-443-18694-3.00011-0
[2] Soethe et al. (2024). Liebig review: The role of mineral nutrients in the development of *Pseudomonas syringae diseases*—Lessons learned and implications for disease control in woody plants. *J Plant Nutr Soil Sc*, *187*(3), 301-320.
[3] Schönfeld et al. (2013). Düngung von Straßenbäumen - Substrate, Nährstoffe, Düngung im Projekt „Stadtgrün 2021" Editor: Bayerische Landesanstalt für Weinbau und Gartenbau Abteilung Landespflege, 9 pages.
[4] Kleiber T et al. (2019) How does the content of nutrients in soil affect the health status of trees in city parks? PLoS ONE 14(9): e0221514.

P35

Agroecology in Practice: Soil Responses to Oxen Grazing in Alpine Vineyards

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Mixed crop-livestock farming was once widespread, but with the advent of mechanization and chemical fertilizers, its practice declined. Reintroducing livestock into crop fields offers a promising agroecological strategy to improve soil health, biodiversity, sustainability, and land-use efficiency. Thus, the present study investigates the effects of oxen grazing on soil properties in South Tyrol vineyards.
Soil samples were collected from two neighbouring vineyards—one with seven years of oxen grazing and one without. Fifteen composite topsoil samples from each site were analysed for physico-chemical (texture, pH, bulk density, total and dissolved carbon and nitrogen, elemental composition, aggregate stability) as well as biological parameters (microbial biomass, fungal and bacterial abundance and mycorrhizal community composition). The two sites showed similar parent material and weathering status highlighted by the similar texture, elemental composition and pH. Contrary to what was hypothesised, no soil compaction was observed in the oxen grazed site, likely due to the low animal density, higher soil organic matter (SOM) and improved micro-aggregate stability in the grazed vineyard. While pH and microbial biomass did not differ between sites, bacterial abundance increased in the grazed area. In addition, even though fungal population was unaffected, the community composition of mycorrhiza was significantly altered.
Oxen grazing positively influenced key soil health indicators. With appropriate management, integrating livestock into vineyards represents a viable agroecological practice that enhances soil fertility, supports biological diversity and improves land use efficiency. This approach offers a scalable and nature-based solution for transitioning toward more resilient and sustainable agricultural systems.

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P36 Arbuscular Mycorrhizal Fungi as a sustainable approach to improve grapevine fitness in a changing climate

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Increasing pressures from biotic and abiotic stresses threaten grapevine health and vineyard productivity worldwide. Arbuscular mycorrhizal fungi (AMF) inoculants offer a promising bio-based solution to mitigate these stresses by enhancing nutrient uptake, water relations, and plant defense mechanisms [1]. The efficacy of this plant-fungal interaction depends on the compatibility between AMF strains and grapevine rootstocks, particularly under challenging environmental conditions [2].

In controlled greenhouse trials, three widely used grapevine rootstocks (Borner, SO , Vinto) were inoculated with commercial AMF inoculants and subjected to well-watered and drought conditions. Key parameters measured included root colonization rate, chlorophyll content (Dualex index), and flavonoid and anthocyanin content. The findings demonstrate that colonization rates varied significantly among rootstock–AMF combinations, underscoring that effective colonization depends on the specific rootstock-AMF combination. For instance, Vinto rootstocks inoculated with AMF attained 98.8 ± 1.4% root colonization under drought conditions, compared to 93.8 ± 3.2% in non-inoculated controls. Under identical conditions, SO4 rootstocks with AMF inoculation demonstrated a significant increase in flavonoid content, from 2.64 ± 1.60 (non-inoculated) to 5.71 ± 1.29 units (inoculated), indicating an enhancement in antioxidant capacity exceeding 100%.

These results highlight the importance of selecting compatible AMF–rootstock partnerships to enhance grapevine resilience to biotic and abiotic stresses. Identifying the most effective combinations will guide subsequent field validation and mechanistic studies, facilitating the integration of AMF into sustainable viticulture strategies.

1. Valenzuela-Aragon B, Cardinale M, Rolli E, Rustioni L, Francioli D. The role of arbuscular mycorrhizal fungi in abiotic stress management in viticulture under climatic shifts. Plant Stress. 2025;16:100863.
2. Francioli D, Strack T, Dries L, Voss-Fels KP, Geilfus C-M. Roots of resilience: Optimizing microbe-rootstock interactions to enhance vineyard productivity. PLANTS PEOPLE PLANET. 2025;7:524–35.

P37 Chloride-Induced Nitrate Transport Enhancement Is Modulated by Cation Type

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Chloride (Cl^-) and nitrate (NO_3^-) are traditionally believed to have an antagonistic relationship due to their similar physical and electrical properties[1]. Although Cl^- is typically regarded as detrimental to NO_3^- accumulation, moderate levels of Cl^- have been reported to enhance nitrate utilization[2]. Our study investigated whether foliar application of 60 mM calcium chloride ($CaCl_2$) to young leaves of faba bean (*Vicia faba* L.) trigger the translocation of NO_3^- from mature to developing leaves. Results indicated that under low NO_3^- conditions (0.8 mM), foliar Cl^- enhanced photosynthesis and facilitated NO_3^- translocation while driving Cl^- translocation into roots. Building on these findings, we further examined whether this promotive effect of chlorine on NO_3^- transport is influenced by the type of cation associated with NO_3^-. Three sources of NO_3^-, calcium nitrate ($Ca(NO_3)_2$), potassium nitrate (KNO_3), and ammonium nitrate (NH_4NO_3) were used, maintaining the same NO_3^- level (0.8 mM) by depleting it, followed by brushing the young leaves with $CaCl_2$ (60 mM). The results indicated that the phenomenon of Cl^- improving NO_3^- accumulation was cation-dependent. Distinctly with $Ca(NO_3)_2$ and NH_4NO_3, NO_3^- concentration accumulated in young leaves was decreased in the group of KNO_3 under foliar Cl^- treatment. Nevertheless, in the Ca(NO3)2 group, there was a significantly negative effect on photosynthesis with Cl^- treatment , although it did not ultimately influence biomass. Foliar Cl- application has the potential to enhance nitrate use efficiency while the NO_3^- fertilizer type, as well as the dosage and timing of chloride application need to be considered.

References:
[1] Zhang, X., Franzisky, B.L., Eigner, L. et al. (2021). Antagonism of chloride and nitrate inhibits nitrate reductase activity in chloride-stressed maize. Plant Growth Regulation, 93, 279–289.
[2] Rosales, M. A., Franco-Navarro, J. D., Peinado-Torrubia, P., et al. (2020). Chloride improves nitrate utilization and NUE in plants. Frontiers in Plant Science, 11, 442.

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P38

Analysis of ECA3, a Golgi-Localized P_{2A}-Type Calcium-Transporting ATPase involved in Salt Stress Response, in the Crop Species *Hordeum vulgare* and *Brassica rapa*

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As sessile organisms, plants require a highly sensitive way of reacting and adapting to external stimuli and environmental changes. Cytosolic calcium (Ca^{2+}) homeostasis and transient changes of free Ca^{2+} in organellar compartments have been identified as the primary culprit in responses to biotic and abiotic stressors [1,2]. In these processes, Ca^{2+} acts as second messenger and [Ca^{2+}] transients as electro-chemical messages, which are modulated and decoded by a wide variety of Ca^{2+} responders, to induce physiological and transcriptional stress adaptations [3]. ECA3, an ER-type Ca^{2+}-transporting ATPase is involved in active Ca^{2+} transport into the Golgi apparatus [4,5]. Under saline conditions, *Arabidopsis thaliana eca3* mutant lines exhibit characteristic Ca^{2+} transients ($[Ca^{2+}]_{cyt/Golgi}$) as well as a distinct growth impairment and disturbed Na^+ distribution to the shoot, implicating a central role of AtECA3 in organellar and systemic salt stress responses in plants [Daamen, un-published].

In silico comparative gene analysis revealed, that *Brassica rapa (e.g. turnip)*, another member of the Brassicaceae, contains two isoforms of ECA3, while *Hordeum vulgar*e (barley), a salt-tolerant agricultural crop with distinct Ca^{2+} signaling patterns [6], contains a single ortholog.

In this study, *eca3* mutant lines of *B. rapa* and *H. vulgare* will be generated by CRISPR/Cas-mediated genome editing. Mutant lines and respective reporter lines will be subjugated to saline conditions and growth phenotype, subcellular localization and [Ca^{2+}] transients will be analyzed, to further characterize the role of ECA3 in salt tolerance and Ca^{2+} homeostasis as well as to further elucidate the role of the Golgi in stress-related physiological processes.

[1] Clapham, DE (2007). Calcium Signaling. Cell, 131, 1047–58.

[2] Kudla, J et al. (2018). Advances and current challenges in calcium signaling. New Phytologist, 218, 414–31.

[3] Alves, HLS et al. (2021). Carbon/nitrogen metabolism and stress response networks – calcium-dependent protein kinases as the missing link? Journal of Experimental Botany, 72, 4190–201.

[4] Wu, Z et al. (2002). An Endoplasmic Reticulum-Bound Ca2+/Mn2+Pump, ECA1, Supports Plant Growth and Confers Tolerance to Mn2+ Stress. Plant Physiology, 130, 128–37.

[5] Mills, RF et al. (2008). ECA3, a Golgi-Localized P2A-Type ATPase, Plays a Crucial Role in Manganese Nutrition in Arabidopsis. Plant Physiology, 146, 116–28.

[6] Giridhar, M et al. (2022). Comparative analysis of stress-induced calcium signals in the crop species barley and the model plant Arabidopsis thaliana. BMC Plant Biol, 22, 447.

P39 Ascorbate redox regulation for abiotic stress tolerance in rice

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Iron (Fe) is a critical micronutrient for rice plants, yet it can become toxic in excess. Rice plants must carefully maintain Fe homeostasis to prevent both deficiency and toxicity. Lowland rice fields, characterized by anaerobic conditions, promote the conversion of ferric iron (Fe^{3+}) to ferrous iron (Fe^{2+}). This often leads to Fe toxicity, which significantly impairs lowland rice production [1].

Our previous research has uncovered a surprising prooxidant function of ascorbate (AsA), which, unexpectedly, negatively correlates with Fe toxicity tolerance. We've pinpointed the essential role of AsA redox-regulating enzymes, specifically dehydroascorbate reductase (DHAR) and ascorbate oxidase (AO), in maintaining a lower redox state (reduced/total) of AsA for enhanced Fe toxicity tolerance [2]. Transcriptional and sequencing analyses of candidate genes for DHAR and AO activities have highlighted the *OsAAO2* gene as a key player in this tolerance [3].

Furthermore, a field-based genome-wide association study (GWAS) on drought tolerance in a diverse rice panel revealed significant correlations between yield production and DHAR/AO activity [4]. Subsequent studies identified *OsAAO2* as the candidate gene for improved yield under drought conditions. These findings suggest that modulating the redox state of the ascorbate pool could be a promising strategy for fine-tuning stress tolerance in rice.

Understanding the specific and multifaceted contributions of AsA redox regulation illuminates the intricate networks governing plant stress resilience. This knowledge is crucial for developing innovative breeding strategies aimed at producing more robust rice varieties better equipped to handle environmental challenges.

References:
[1] Wu L-B et al. (2019). Potassium Ion Channel Gene OsAKT1 Affects Iron Translocation in Rice Plants Exposed to Iron Toxicity. Front. Plant Sci., 10, 579.
[2] Wu L-B et al. (2017). Shoot tolerance mechanisms to iron toxicity in rice (Oryza sativa L.). Plant Cell Environ. 40. 570-584
[3] Wairich A et al. (2024). The role of ascorbate redox turnover in iron toxicity tolerance. Plant Physiol. Biochem., 215, 109045.
[4] Milandri G et al. (2020). Biomarkers for grain yield stability in rice under drought stress. J. Exp. Bot., 71, 669-683.

P40 Impact of Magnesium deficiency on guard cell photosynthesis and stomatal aperture at dawn

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Stomata are pores in the epidermis regulating gas exchange. Opening of these pores at dawn is an energy consuming process triggered by light. Since much of the leaf's energy reserves deplete overnight [1], we hypothesized first that stomata opening at dawn is at least in part fueld by guard cell-autonomous photosynthesis and, second, that energy provision is hampered under Mg-deficiency, since Mg plays an essential role in photosynthesis [2-4]. We therefore cultivated *Vicia faba* plants hydroponically under Magnesium (Mg)-deficiency or sufficient supply of Mg. We compared the photosynthetic responses at dawn of different tissues under red light (RL) illumination as it activates photosynthesis. Reduced transpiration and stomatal conductance in magnesium-deficient leaves indicated a disturbance in stomatal opening. Next, by using a Microscopy-PAM, we measured the photosynthetic activity in a single pair of guard cells and a single mesophyll cell under low and high RL intensities (6 and 55 μ mol m^{-2} s^{-1}) in dependency to Mg-nutrition. Under weak RL that mimics very early dawn conditions, Photosystem II quantum yield dropped markedly in guard cells while the mesophyll remains stable when Mg was limited. Under stronger RL (55 mol m^{-2} s^{-1}), guard cell yield stayed high, but mesophyll yield dropped. The data support the working hypothesis that at early dawn, opening is at least in part energized by guard cell photosynthesis that requires Mg to be functional. Adequate Mg is therefore likely to favour timely stomatal opening for gas exchange.

[1] Graf, A. et al. (2011) Starch and the clock: the dark side of plant productivity. Trend in Plant Science, Volume 16, Pages 169-175
[2] Milne, B. F. .et al. (2015). Unraveling the intrinsic color of chlorophyll. Angewandte Chemie International Edition, Volume 54, Pages 2170-2173.
[3] Portis, A. R. et al. (1976) Light-dependent changes of the M2+ concentration in the stroma in relation to the Mg2+ dependency of CO2 fixation in intact chloroplasts. Biochimica at Biophysica Acta (BBA) – Bioenergetics, Volume 449, Pages 434-446
[4] Hermans, C. et al. (2004). Physiological characterisation of Mg^{2+} deficiency in sugar beet: acclimation to low magnesium differentially affects photosystems I and II. Planta, Volume 220, Pages 344-355.

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The Role of Inositol Pyrophosphates in Phosphate Homeostasis and Immunity in *Eragrostis tef*

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Eragrostis tef (tef) is a small-seeded, gluten-free cereal millet native to Ethiopia. Yield losses in tef are common due to various factors, including insect pests such as shoot flies (*Atherigona hyalinipennis*). There is limited information about phosphate use efficiency in tef, despite phosphate being one of the most limiting plant nutrients in Ethiopian soils.

Inositol pyrophosphates (PP-InsPs) are signaling molecules involved in various aspects of plant metabolism, including responses to nutrient deficiencies such as phosphate starvation, regulation of plant growth, and defense mechanisms.

In this study, the role of inositol pyrophosphates (PP-InsPs) in phosphate homeostasis and jasmonate-mediated defense will be assessed through the identification and functional characterization of inositol pyrophosphate synthases and hydrolases in tef, based on *Arabidopsis* homologs. These genes will be expressed in bacterial and yeast systems to verify enzymatic activity. CRISPR/Cas9-mediated genome editing will be applied to activate or deactivate target genes in tef.

A tef transformation protocol will be developed to support genome editing and ectopic gene expression. The resulting plants will be tested under normal and phosphate-deficient conditions for phenotypic, biochemical, and transcriptomic traits.

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Gas Exchange and Ionome Profiling Across Multiple Tissues and Cell Types Under Salt Stress: Distinct Tolerance Strategies in Faba Bean (Vicia faba) and Maize (Zea mays)

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Faba bean (C_3) and maize (C_4) exhibit contrasting salt-tolerance strategies due to differences in stomatal complex composition and morphology. To dissect these mechanisms, two genotypes per species—faba bean (sensitive Fuego, tolerant Scoop) and maize (sensitive LG30222, tolerant ES-Metronom)—were grown under controlled conditions and exposed to six treatments: control, 50 mM NaCl, 100 mM NaCl, 50 mM Na_2SO_4, 50 mM $CaCl_2$, and PEG6000-induced osmotic stress. Gas exchange parameters were measured in fully expanded leaves, and ionome profiling was conducted on leaves, peeled epidermis (faba bean), or whole leaves (maize) using ICP-OES/MS and Cryo-SEM-EDX.

PCA showed species- and genotype-specific responses. In faba bean, Fuego exhibited weak NaCl responses but heightened sensitivity to $CaCl_2$ and PEG, with increased K^+ and Mg^{2+} accumulation across leaves, epidermis, and stomatal complexes as a transient osmotic adjustment. Scoop maintained active ion homeostasis, explaining its tolerance. In maize, LG30222 showed increased gas exchange under NaCl but declines under PEG, while ES-Metronom sustained photosynthesis under high NaCl by regulating stomatal conductance and transpiration. PEG increased stomatal Ca^{2+} and leaf K^+/Mg^{2+} in ES-Metronom, indicating osmotic adjustment. ES-Metronom also sequestered Na^+/Cl^- in subsidiary cells, preserving gas exchange, a strategy absent in LG30222.

Faba bean tolerance relies on early ion homeostasis, while maize depends on ion compartmentalization and gas exchange moderation. Fuego's transient ion accumulation and gas exchange instability confirm its sensitivity, contrasting with Scoop's proactive regulation. These findings highlight distinct salt-adaptation strategies between C_3 legumes and C_4 cereals, informing stress-resilient crop breeding.

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