IAPN
INSTITUTE OF
APPLIED PLANT NUTRITION

ANNUAL REPORT 2020

RESEARCH ON SUSTAINABLE PLANT NUTRITION

Imprint

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IAPN – Institute of Applied Plant Nutrition

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Preface

Dear readers,

2020 was a year full of surprises and challenges. 2020, the year we will all remember as the Corona year. New hygiene and distance regulations also affected research and teaching at IAPN and the University of Göttingen. Scientific exchange, conferences and university teaching took place online almost without exception, so we learned to use other ways of communication and exchange. With regard to the organization of our research projects, many things had to be organized differently. But, the experimental plants grew well and, in various forms of home office and shift work, the team was able to complete almost all planned analyses successfully. However, we did have a notable loss in the area of visits by our guest scientists. While Lílian Angélica Moreira was able to reach IAPN before the lockdown and to complete a successful research stay together with the IPAN team, two other planned stays of visiting scientists had to be canceled.

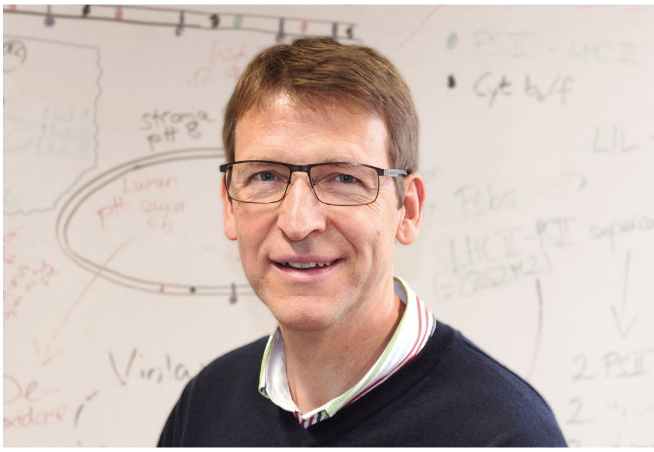
The scientific activities at IAPN focused on stress physiology and stress prevention through improved mineral nutrition. In a cooperation with the team of Professor Dr. Peter Jahns from the Heinrich Heine University in Düsseldorf, Setareh Jamali Jaghdani and Professor Dr. Merle Tränkner were able to show that it is not the process of direct light conversion of the plants but rather the processes of carbon dioxide (CO_2) assimilation, which are not directly light-dependent, that are reduced when plants are not sufficiently supplied with magnesium (Mg). The consequence for the plants is that more of the previously obtained light energy has to be dissipated via other metabolic processes when Mg is short. With this research work, our knowledge of the physiological functions of Mg has been considerably advanced.

In global agricultural practice, salt stress, i.e., the growth of plants in saline soils, is a serious limitation to land use. It is well known that plants in these soils have problems in acquiring sufficient potassium (K) and Mg. Recent IAPN studies have shown how adapted K supply affects not only the performance and metabolism but also the water-use efficiency of plants, even in salt-tolerant plants such as quinoa. These findings provide a further contribution to achieving improved yields and resource-use efficiency under saline conditions in the future.

Finally, there was a whole series of smaller research projects at IAPN in 2020, with very different shares of basic research and applied plant nutrition. These studies provided opportunities for students to gain further qualifications through conducting experiments and analyses for Bachelor's and Master's theses.

I hope you will find insightful information in our current annual report. Please do not hesitate to contact us if you are interested in further information.

Professor Dr. Klaus Dittert
Scientific director of IAPN



As an Associated Institute, IAPN is closely linked to the University of Göttingen's Department of Crop Sciences at the Faculty of Agricultural Sciences. IAPN's scientific director Professor Dr. Klaus Dittert (left) is heading the Department's Division of Plant Nutrition and Crop Physiology. Professor Dr. Merle Tränkner (right), who is head of IAPN's junior research group, is leading the Department's Division of Applied Plant Nutrition. (Photo: K+S)

IAPN at a Glance

Structure and development of the Institute of Applied Plant Nutrition – public-private partnership at the University of Göttingen

The Institute of Applied Plant Nutrition (IAPN) was initiated by Georg-August-Universität Göttingen and K+S Minerals and Agriculture GmbH following both institutions' impetus to strengthen the exchange in academic research and formation activities between the public academic institution and the private company sector. There is much common interest in questions related to sustainable nutrition of plants as well as in environmentally sound strategies for advancing agricultural systems of 21st century. Both partners have vital interest in promoting the formation of young scientists who, based on broad and solid knowledge, are capable of initiating, critically reflecting and developing new ideas and new research methods. IAPN is an Associated Institute according to Lower Saxony's tertiary education legislation. Consequently, it is closely linked to the University of Göttingen and contributes to the University's core responsibilities, academic teaching and research. For both, the University and the Associated Institutes, the common rules of good scientific practice apply.

IAPN became active in 2012. Since, IAPN's scientific and technical personnel were built up and a large number of methods and techniques were established. Researchers work on their projects together with Bachelor's and Master's students, who thereby get closely involved in IAPN's research activities. Moreover, many links to divisions of the Department of Crop Sciences and other University institutes have been established.

IAPN's objectives

Increasing demands for agricultural production and global changes necessitate progress in optimized crop nutrition, which can only be achieved with targeted research efforts. IAPN is committed to research and teaching on the role of resource-efficient use of nutrients in the plants' physiology. As an interface between research, teaching and practice we are involved in interdisciplinary knowledge exchange in a global network.

Our activities complement each other and mainly include:

- **Research**
  Focal point of our research is to improve our understanding of how the plant nutrients Mg, K, and nitrogen (N) affect the self-protective mechanisms and performance of plants in situations of stress and deficiency. IAPN's research projects concentrate on water-use efficiency (WUE), photoprotection, photosynthesis, drought-stress tolerance and salt tolerance. Additionally, we explore remote sensing methods for early detection of nutrient deficiencies in plants as well as interactions of plant nutrients and environment.

- **Teaching**
  The IAPN team is very active in offering classical lectures to students, as well as laboratory and greenhouse courses and insights into practical research. The institute also offers opportunities for students to do their Bachelor's, Master's or PhD thesis or internship.

- **Knowledge exchange**
  IAPN cooperates with experts and research institutions in various countries. On a worldwide basis, we strive to maintain a fruitful interdisciplinary knowledge exchange during conferences and on research visits of IAPN scientists in foreign countries. Also, visiting scientists and students as well as agricultural advisors and extensionists from abroad spend time at IAPN regularly. This way, we are creating synergies for successful research and practical implementation of research results.

The IAPN team

In 2020, the team of IAPN consisted of up to nine members in scientific staff, administration, and technical as well as laboratory assistance. The institute's scientific director is Professor Dr. Klaus Dittert. Professor Dr. Merle Tränkner holds the junior professorship. All administrative matters are managed by Martina Renneberg. The technical and laboratory assistance is provided by Wael Alyoussef, Kirsten Fladung, and Ulrike Kierbaum.

Dr. Paulo Cabrita continued his research on the application of digital and sensing methods in plant nutrition as well as in other projects that focus on the WUE and nutrient status of crop plants.

Dr. Ariel Turcios worked at IAPN until September 2020. During his time at the institute, he supported the teaching in the field of applied plant nutrition. On the research side, he focused especially on investigating the importance of K in quinoa cultivated under saline conditions. The results are planned to be published in the beginning of 2021.

Setareh Jamali Jaghdani, in the third year of her PhD studies, conducted experiments on barley plants. She investigated photosynthetic efficiency, CO_2 assimilation, and reactive oxygen species (ROS) scavenging enzymes gene expression. The research results were published in the article "Mg deficiency induces photo-oxidative stress primarily by limiting CO_2 assimilation and not by limiting photosynthetic light utilization" (*Plant Science*).

In November 2020, we have been welcoming Tingting Liu as a new doctoral student at IAPN. Within her PhD project, she will investigate the physiological and metabolic responses of wheat to different Mg fertilization levels and drought stress. Her research will focus on analyzing the WUE by applying different approaches to measure the assimilation capacity and transpiration of the plant.

Throughout the year, the IAPN team was intensively supported by many graduate and undergraduate student assistants who helped in plant cultivation, measurements and preparations of numerous plant, soil, gas, biochemical and molecular samples. Their contribution is greatly acknowledged.

The IAPN team: Martina Renneberg, Wael Alyoussef, Setareh Jamali Jaghdani MSc., Dr. Paulo Cabrita, Dr. Ariel Turcios, Kirsten Fladung, Ulrike Kierbaum, Professor Dr. Klaus Dittert, and Junior Professor Dr. Merle Tränkner (from left). Missing: Tingting Liu MSc. (Photo: Urstadt)

Roots in aerated nutrient solution. The experiment is part of the IAPN project "Iron and oxygen requirements of maize". (Photo: Tränkner)

Research

Focusing on plant nutrition and plant physiology

The growing world population, changing dietary habits and climate change place great demands on agricultural research. Increasingly, the focus in agriculture and agricultural sciences is on questions pertaining to the efficient use of arable land, pasture, water and plant nutrients. IAPN addresses these issues.

Our research projects concentrate on understanding the connection between plant physiology, plant nutrients and climatic as well as environmental impacts on plant production. Since the founding of IAPN, the institute's scientists contribute to the international advancements of research especially on the plant nutrients Mg, K and N and their relation to WUE, drought stress tolerance, photosynthesis, photoprotection and salt stress tolerance. For early detection of nutrient deficiencies in plants, we are also exploring remote sensing methods.

IAPN scientists focus on a range of concrete problems and their solutions:

- Relevance of nutrients for stress tolerance in plants under changing climate conditions.
- Connection between mineral nutrition, fertilizers and WUE in the soil/plant system.
- Understanding alterations in the plants' physiology in response to fertilization.
- New strategies for improving fertilizer recommendations and management.

In 2020, IAPN's research activities were restricted by the Corona pandemic. Still, our scientists achieved significant progress in their research. Some of the major results were published in 2020 or publication is planned for early 2021. The following pages will introduce you to IAPN's research topics and projects.

Capacity and efficiency of photosynthesis and photoprotective mechanisms under Mg deficiency in crop plants

PhD research project of Setareh Jamali Jaghdani
Supervisor: Merle Tränkner
Related research topics: photosynthesis, photoprotection

Setareh Jamali Jaghdani started her PhD in January 2018. The title of her project is "Capacity and efficiency of photosynthesis and photoprotective mechanisms under magnesium deficiency in crop plants – linking plant physiology with plant genomic and proteomic reactions", hence her studies within this project focus on Mg nutrition. It is funded by K+S Minerals and Agriculture GmbH.

Being neglected in most areas of the world, Mg is called "the forgotten element". It plays various vital roles in plant physiology and biology. It is needed for the activation of the most important enzyme involved in photosynthesis; ribulose-1,5-bisphosphate carboxylase/oxygenase (Rubisco). Since Mg is an important element in the photosynthetic apparatus, its deficiency affects photosynthetic efficiency, CO_2 assimilation and stomatal conductance.

Under different stress conditions such as Mg deficiency, the absorbed light by the photosynthetic machinery is excessive and beyond the utilization capacity of the system. Excessive light absorption leads to the production of reactive oxygen species (ROS). ROS are toxic and cause cell damage and might lead to cell death. Plants have evolved mechanisms to either overcome or to cope with excessive light absorption which are called "photoprotection". Degradation of the ROS compounds by ROS scavenging enzymes is one of the photoprotective mechanisms. Another mechanism is the activation of the xanthophyll cycle. The excessive energy absorbed is dissipated as the heat which is known as the non-photochemical quenching (NPQ) where xanthophyll pigments are involved in.

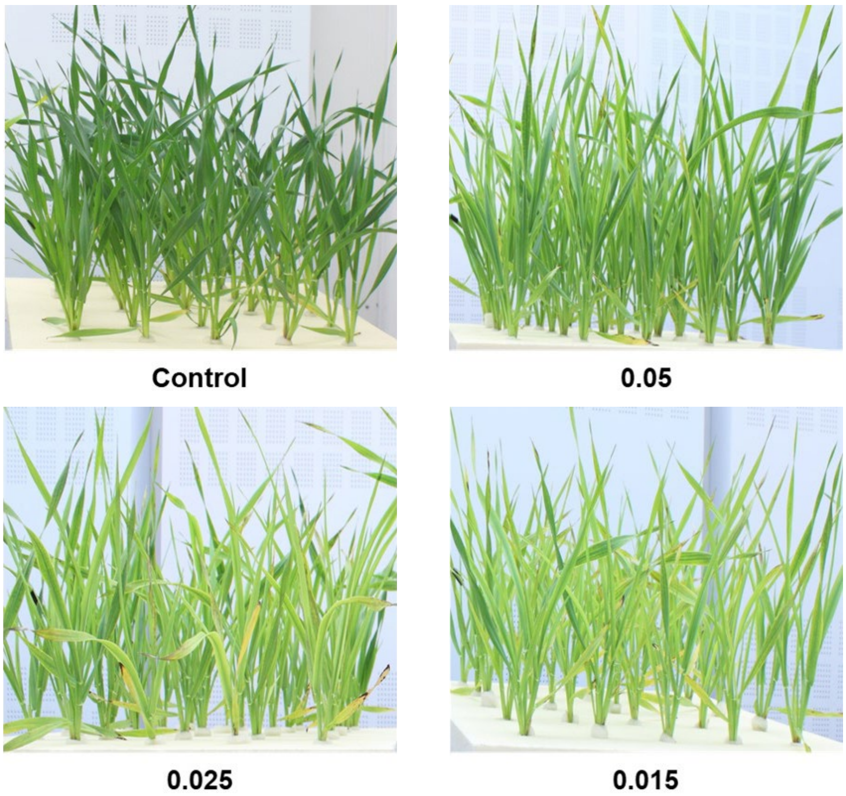


Figure 1: Barley plants *(Hordeum vulgare)* under different Mg treatments. From left to the right, from top to bottom, control (1 mM), 0.05, 0.025, and 0.015 mM Mg treatments are shown. (Source: Jamali Jaghdani)

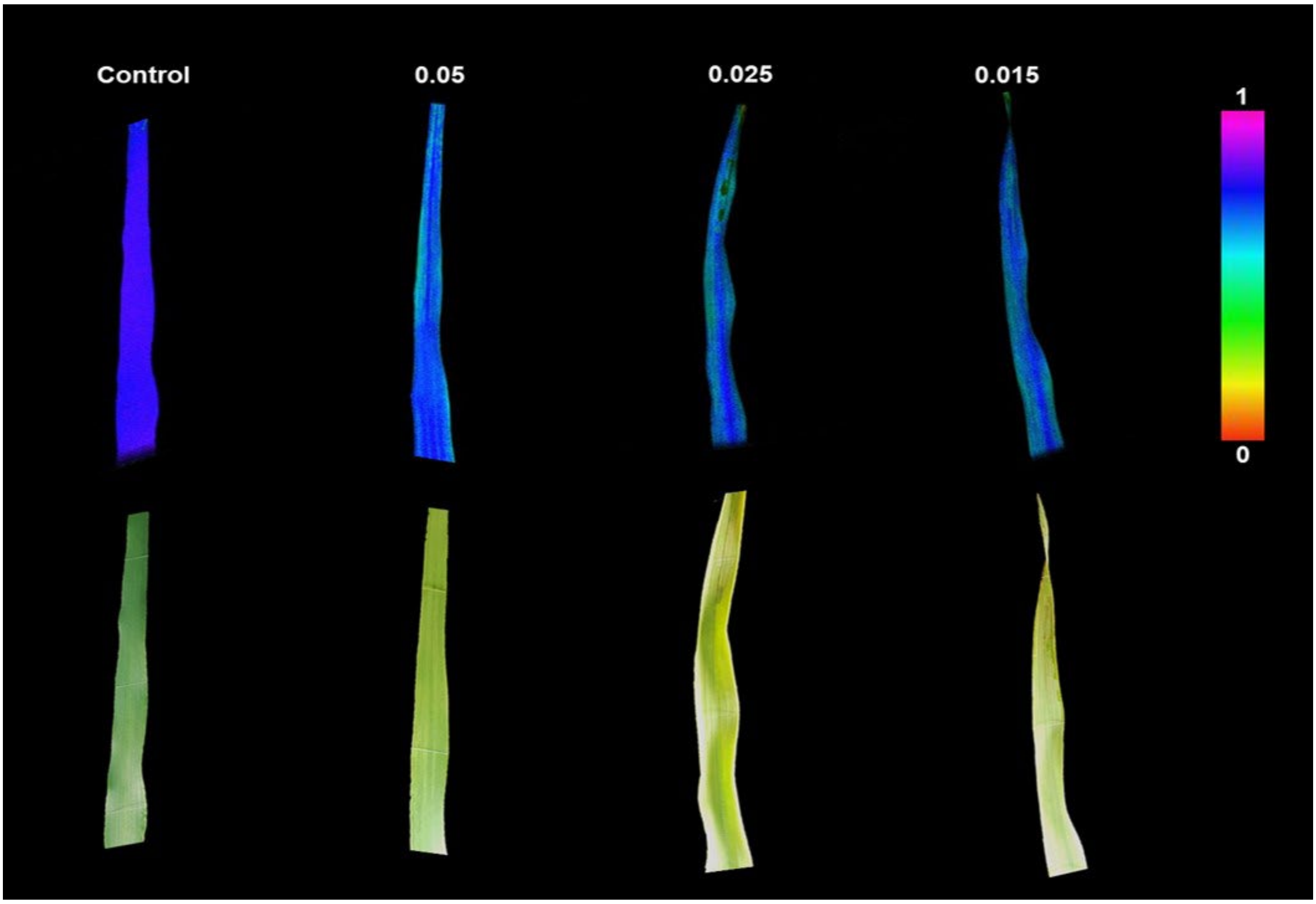


Figure 2: Maximum quantum efficiency (F_v/F_m) of barley plant (*Hordeum vulgare*) samples taken from 1 (control), 0.05, 0.025, and 0.015 mM Mg treatments. The pictures on the top represent false color images of chlorophyll fluorescence measurements which were done after 17 days under deficiency. Pictures at the bottom were taken from the measured plants with a RGB camera. Zero (lowest efficiency) to one (highest efficiency) as scale for F_v/F_m. The optimal value can vary among different species under different environmental conditions in unstressed plants. Here, in control plants, F_v/F_m was 0.79. (Source: Jamali Jaghdani)

The impact of Mg nutrition on the functioning of NPQ is not yet fully understood and studied. Thus, the PhD project of Setareh Jamali Jaghdani aims at understanding the changes in photoprotection and photosynthetic processes under various Mg supplies. She continued her work in the year 2020 with experiments on barley plants. She applied four different Mg treatments to barley (Figure 1) and investigated photosynthetic efficiency (Figure 2), CO_2 assimilation, and ROS scavenging enzymes gene expression including glutathione reductase (GR), superoxide dismutase (SOD), ascorbate peroxidase (APX) and catalase (CAT). In a last step she quantified the concentration of pigments involved in the xanthophyll cycle. The article reporting on this project was published in the journal *Plant Science* in November 2020. It is entitled "Mg deficiency induces photo-oxidative stress primarily by limiting CO_2 assimilation and not by limiting photosynthetic light utilization". In the last year of her PhD project, Setareh Jamali Jaghdani will continue her research on Mg nutrition and expand her focus on the photoprotective mechanism NPQ by analyzing gene expression of xanthophyll cycle pigments, CO_2 assimilation and flux capacity. The results are planned to be published in 2021.

Research topic

Photosynthesis

Photosynthesis is a highly coordinated process in plants which provides the plant with metabolic energy and carbon molecules and generates oxygen as a byproduct.

Photosynthesis takes place in the chloroplast. Chloroplasts consist of an internal system of interconnected membranes, the thylakoids. On and in these thylakoid membranes, light harvesting complexes which are composed of pigments such as chlorophyll, and proteins of the photosystem I and II are bound. The pigments absorb the incident light, whose energy drives an electron transport through the photosystems which induces the synthesis of the energy-rich molecules ATP and NADPH. Part of the energy is used for the fixation of CO_2 by the enzyme Rubisco which takes place in the stroma and generates sugar.

The processes of photosynthesis are influenced by numerous environmental factors such as nutrient and water availability. Under insufficient or excess nutrient and water supply, the CO_2 assimilation rate decreases and the photosynthetic capacity is limited.

Understanding the responses in the photosynthetic capacity to environmental stress factors, to mainly Mg and K deficiency and drought, is a major research focus at IAPN. In order to assess the photosynthetic capacity, measurements of leaf gas exchange and chlorophyll fluorescence are used. The latter is a measure of re-emitted light from photosystem II as the absorbed light energy in the chlorophyll molecules does not only drive photosynthetic processes but is partly re-emitted as fluorescence. Hence, measurements of chlorophyll fluorescence give valuable information about the efficiency of photochemistry and thereby about the plants' productivity.

Leaf gas exchange measurements assess the CO_2 influx from the atmosphere into the leaf by infra-red gas analyzers. Both techniques, chlorophyll fluorescence and leaf gas exchange are non-invasive, hence allowing *in-vivo* observations in plants which are useful in monitoring the photosynthetic alterations under ongoing stress conditions.

Assessing the photosynthesis of wheat by the measurement of leaf gas exchange in an IAPN experiment. (Photo: K+S)

Measuring chlorophyll fluorescence on a leaf of a soybean grown in nutrient solution in an IAPN study. (Photo: K+S)

Research topic

Photoprotection

Unfavorable environmental conditions such as nutrient deficiency, lead to restrictions in the photosynthetic capacity. Under such conditions, the absorption of light in the light harvesting complexes of the photosystems is excessive, i.e., the available energy cannot be consumed by the photosynthetic processes. Therefore, the excessive energy might react with ground state molecular oxygen which leads to production of reactive oxygen species (ROS) inside the photosynthetic machinery. ROS, mainly singlet oxygen, superoxide and hydrogen peroxide, mediate photooxidative damage to the photosystems. When excess energy conditions persist over a prolonged period of time, the photosynthetic apparatus is destroyed. This might lead to photoinhibition which is a sustained reduction of the photosynthetic capacity.

To prevent photoinhibition, photoprotective mechanisms have evolved in plants. These mechanisms comprise movement of leaves and chloroplasts, photorespiration, cyclic electron flow around photosystem I, screening of photoradiation, thermal energy dissipation of absorbed light energy, and detoxification of ROS. The latter two mechanisms are in focus of the research at IAPN.

Dissipation of absorbed light energy as heat energy is induced by the molecular mechanism of non-photochemical quenching (NPQ) and can be determined from measurements of chlorophyll fluorescence. NPQ is considered a photoprotective mechanism because it helps to release the excitation energy absorbed in the light-harvesting complexes of photosystem II as heat, thus protecting the photosynthetic system from an excessive amount of excitation energy. In this process, numerous complex processes take place in the chloroplast, including the xanthophyll cycle, which involves the conversion of violaxanthin to zeaxanthin by the enzyme violaxanthin de-epoxidase (VDE) and the protonation of the photosystem II protein subunit PsbS.

Detoxification of ROS, the production of which is accelerated under conditions of excess light, takes place not only in chloroplasts, but also in peroxisomes and mitochondria of plant cells. The ROS are converted to non- or less-toxic molecules by enzymes such as superoxide dismutase, ascorbate peroxidase, glutathione reductase and catalase. Evaluation of the scavenging capacity in plants is achieved by *in vitro* analysis of the enzyme activities by photospectrometry, and transcript abundance of the respective gene by molecular methods.

Assessing leaf turgor pressure and water status in sunflower at IAPN using a LPCP probe. (Photo: D. Jákli)

Non-invasive and continuous monitoring of plant-water relations and hydraulic mechanisms in response to drought stress

Research project conducted by Paulo Cabrita
Related research topics: water-use efficiency, drought and salt stress

Non-invasive methods that allow the continuous monitoring of plants *in vivo* have clear advantages over the more traditional destructive methods used in plant physiology, especially when long term measurements are required. In this respect, the leaf patch clamp pressure probe (LPCP) is typically used to investigate the hydraulic mechanisms involved in the dynamics of plant water relations, particularly plant responses to drought stress. Upon application of two small magnets on a leaf patch, the patch clamp measures pressure P_p that is inversely related to the leaf patch turgor pressure, P_c, which relates to the tissue water content ultimately. Therefore, the ability to observe changes in P_c with time non-invasively allows following the dehydration/rehydration dynamics continuously, i.e., the internal redistribution of water within the plant over diel scales in response to treatments or changes in the surrounding environment.

However, to best and fully interpret the data obtained and to see how P_p changes with time under given environmental conditions, it is necessary to know the leaf structure completely and how its components relate spatially. Turgor pressure-dependent components (e. g., protoplasts volume) and turgor pressure-independent components (e. g., intercellular air spaces, cell walls) all contribute to the observed changes of P_p with time.

Plants of different species, grown in soil and hydroponically, were submitted to varying water supply regimes under greenhouse and outdoors conditions; in which temperature, relative humidity, and air pressure were also recorded continuously. On plants grown hydroponically, drought stress was simulated by using varying concentrations of polyethylene glycol 6000 (PEG) in the treatment nutrient solution. Under varying water supply regimes plants redistributed water within their bodies, prioritizing different water needs between older and younger tissues.

Hysteretic relationships are then possible to establish between P_p and environmental factors, such as temperature and relative humidity or physiological parameters, e. g., transpiration rate, photosynthetic rate. As the day progresses, P_p increases up to a maximum reflecting the decrease in turgor pressure due to transpiration and concomitant photosynthesis. As temperature decreases and the relative humidity increases after noon transpiration decreases, causing P_p to decrease and resuming to levels like those observed previously at dawn. The rate at which P_p changes with time, especially after stomata open and close, triggered by changes in light, seems to reflect not only the hydraulic conductivity of the leaf tissue, but also its dependence on the plants nutrient content. The continuous monitoring of the patch clamp pressure output, P_p, proves to be an efficient way of assessing plant water status as well as assisting on irrigation and water management in agriculture.

Research topic

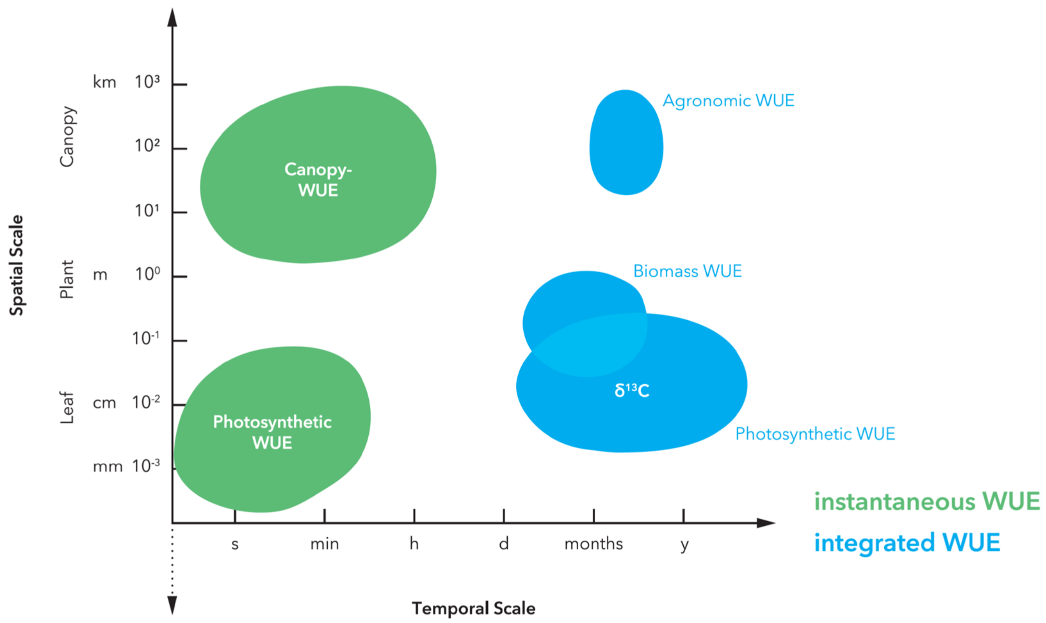
Water-use efficiency

Agricultural production is highly vulnerable to increased incidences of drought, and water availability is one of the most frequently limiting abiotic factors in crop production. Improving water-use efficiency (WUE) of crops and cropping systems is therefore an important goal to meet the current challenges of global climate change.

WUE can be considered a measure for the efficiency in optimizing carbon (C) assimilation while minimizing the water use and is generally described by the ratio of assimilated C or biomass per unit of water loss via transpiration. Stomata play a crucial role in regulating the WUE as they determine the rate of water loss by transpiration and CO_2 uptake for photosynthesis and thus, plant productivity. Since both photosynthesis and transpirational processes react to environmental and plant internal responses, WUE is rather highly dynamic than static.

Research at IAPN focuses on the evaluation of WUE on a leaf and plant scale by measurements of biomass production, whole plant transpiration, and photosynthetic leaf gas exchange, hence assessing the C and water fluxes in the air-leaf-interphase. In order to understand WUE, IAPN's research on photosynthesis is complemented with intensive research on plant water relations and transpirational processes.

The water relations at the whole plant and canopy levels and the way plants respond to water stress by distributing water, and consequently nutrients, between its different organs at specific times of plant development is not fully understood. In this respect, the non-destructive and continuous monitoring of water relations in different plant parts can complement measurements of transpiration and provide insight into how plants respond to their environment and WUE is affected. The research conducted at IAPN on this field aims to investigate the hydraulic mechanisms used in complex spatial and temporal dynamics of plant water relations, in particular plant responses to drought stress, across multiple scales from within-leaf to canopy level using the leaf patch clamp pressure probe (LPCP).



WUE can be assessed on different temporal and spatial scales, i.e., from seconds to years and from small leaf areas on a single plant to whole ecosystems. (Source: B. Jákli, IAPN)

Effects of Mg status on photosynthetic efficiency and WUE in wheat suffering from drought

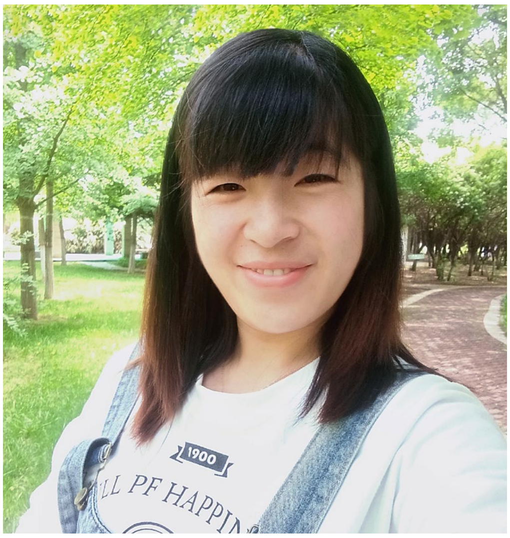
PhD research project of Tingting Liu
Supervisor: Merle Tränkner
Related research topics: water-use efficiency, drought and salt stress

Tingting Liu started her PhD in November 2020. The title of her research project is "Effects of magnesium status on photosynthetic efficiency and water-use efficiency in wheat suffering from drought". The physiological and metabolic responses of wheat suffering from drought stress to different Mg concentration supply will be investigated. The PhD project is planned for a period of three years and is funded by the Chinese Scholarship Council and K+S Minerals and Agriculture GmbH.

Drought stress is a major constraint on crop productivity. To achieve stable crop yields under limited water conditions, improving WUE can make very effective contributions. Intrinsic WUE is defined as the ratio of CO_2 assimilation to water use by transpiration at the leaf level. Hence, higher WUE indicates a higher ratio of productivity to water consumption and is thus desirable under present and future cropping situations where drought stress is expected to play an important role. In addition to plant breeding, nutrient management is a key factor for WUE and, different levels of nutrient supply to the plant can affect WUE by impacting plant physiology and productivity.

Due to the numerous functions of Mg in photosynthesis, improved Mg management under drought stress may enhance WUE and plant performance. Although Mg is called "the forgotten element" because Mg is often neglected in plant nutrition, its deficiency leads to severe impairment of plant performance and yield formation. Mg deficiency directly decreases chlorophyll synthesis, reduces photosynthesis rates and influences photoassimilate transport within the plant, which further reduces the size of the root system and the root-to-shoot ratio. A reduced root system in turn inhibits nutrient uptake and the use of water resources in greater soil depths, which becomes a vicious cycle. However, the interactions between Mg supply and drought stress and their responses on WUE are not yet fully understood and require more detailed research on carbon and water fluxes, source-sink relationships and WUE measurements at different levels.

As initial activities in her research, Tingting Liu prepared the plan for her first experiment. She established measurements of the osmolality of nutrient solutions by an osmometer, which is a new method at IAPN. Furthermore, she was engaged in the measurement of the osmotic potential in leaves by using the Scholander bomb. These measurements are crucial with regard to inducing drought stress in hydroponic systems and quantifying the response to drought stress in plants. Plant cultivation experiments will start in early 2021.



Tingting Liu, PhD student at IAPN since November 2020. (Photo: Liu)

Research topic

Drought and salt stress

It is estimated that today about 15 % of the total land area of the world has been degraded by soil erosion and physical and chemical degradation, including soil salinization. Salt-affected soils can be found in all continents and under almost all climatic conditions. Worldwide, the major factor in the development of saline soils is the lack of precipitation. Most salt-affected soils are found in the arid and semiarid regions and the share of saline soils is increasing. At the same time, periods of drought are observed more frequently in agriculture. Drought and salt stress are therefore some of the most important abiotic constraints that affect crop growth and productivity in large regions of the world.

The accumulation of excessive concentrations of salts in the soil first results in the stagnation of plant growth, called phase I in salinity research and, eventually, even higher concentrations can lead to necroses and plant death, called phase II. In phase I, the availability of water for plants decreases due to negative water potential in the rhizosphere inhibiting plant growth. In phase II, ion toxicity increases and the plants' capabilities for ion exclusion and internal compartmentalization are exceeded. As a consequence of such nutritional disorders, these abiotic stresses also lead to oxidative stress, reduction of cell division and expansion, alteration of metabolic processes and synthesis of photosynthetic pigments.

Strategies to mitigate losses in agricultural productivity by salinity and drought focus on new cultivation techniques, the use of alternative potential crops to exploit areas that are not suitable for growing traditional crops, and the development of new fertilizer management schemes. At IAPN, we initiated research on the importance of K^+ and Mg^{2+} in such situations of abiotic stress. K^+ and Mg^{2+} bear significant potentials since they compete with sodium ions (Na^+), the latter being highly dominant in most saline soils. Since Na^+ interferes with K^+ homeostasis, particularly given its involvement in numerous metabolic processes, maintenance of a balanced cytosolic Na^+/K^+ ratio has become a key subject in salinity tolerance research.

A sunflower with symptoms of salt stress. These are identifiable by rolling-up of leaves, chloroses and necrosis. Sunflower leaves are serrated; this characteristic will be less pronounced in case of salt stress, and leaf edges appear smoother. (Photo: IAPN)

Can optimized K fertilization enhance the salt stress tolerance of crops?

Research project conducted by Merle Tränkner
Related research topic: drought and salt stress

Salt (NaCl) affects more than 20% of the world's irrigated land and causes huge economic losses by limiting agricultural production due to increased salinization. Soil salinization is a significant global problem that affects plant development through ion toxicity and nutrient imbalance. In plants, salt stress triggers two sequential responses. First, there is a rapid osmotic shock that reduces relative water content, leaf water potential, stomatal conductance, and turgor potential. After this first phase, a phase of ion homeostasis is induced, triggering salt toxicity and accelerating senescence of mature leaves.

osmoregulation, stomatal movement, phloem transport, anion-cation balance, and stress resistance. K^+ is particularly important as an inorganic osmotic element in plant cells, and therefore adequate K^+ supply is critical for the regulation of turgor-controlled processes such as stomatal movement and cell elongation.

The interaction between Na^+ and K^+ can have negative effects on K^+ uptake, which is regulated by passive and active transport systems. K^+ is transported from roots to shoots by transpiration-driven water flux in the xylem, which is im-

Measurement of leaf gas exchange in a quinoa plant. Clearly visible are the salt bladders on the leaf surface in which the plant stores the salt it has absorbed and thus makes it harmless for its metabolism. (Photo: IAPN)

Salt stress is induced by high concentrations of Na^+ and chloride (Cl^-) in the soil. Excess Na^+ and Cl^- ions compete with other nutrient elements and can lead to reduced nutrient uptake and translocation, and thus to imbalances in nutrient status. However, Na^+ is not essential for plants. K^+ in particular is susceptible to this competition because of its similar chemical properties to Na^+, for example, in ionic radius and hydration energy. K^+ is an essential plant nutrient and is required for enzyme activity, energy transfer, protein synthesis,

paired during salt stress. Disruption of K^+ homeostasis occurs, which is crucial for salt stress tolerance. For optimal plant growth, Na^+ uptake must be reduced and K^+ uptake increased, as a higher K^+/Na^+ ratio favors salt stress tolerance in plants.

The goal of this project is to gain insight into the importance of K^+ in mitigating salt stress and to investigate the response of plants to salinity using different K^+ supplies.

Importance of K in *Chenopodium quinoa* cultivated under saline stress

Research project conducted by Ariel Turcios
Supervisor: Merle Tränkner
Related research topic: drought and salt stress

Quinoa is considered a very valuable crop as it has highly beneficial nutritious properties, which makes it favorable for both human consumption and animal nutrition. Being a halophyte, quinoa (*Chenopodium quinoa* Willd.) has another important property, which is its salt stress tolerance. Hence, quinoa can be grown on salt affected land and thereby maintain a certain productivity on degraded soils.

In order to study the importance of K in mitigating salt stress in quinoa, an experiment with different K supply levels and different salt concentrations was carried out. Different physiological parameters were assessed during the growth of quinoa plants. The key outcomes were:

- Under salt stress, K uptake was increased when being supplied in enhanced concentration.
- An adequate supply of K under salinity conditions benefited the plant growth.
- High salt concentrations reduced the stomatal density, most likely as a strategy to control transpiration.
- Enhanced K supply under saline conditions resulted in higher biomass WUE.

The study showed that the tolerance to salt stress increases with increasing K doses in the culture medium. By enhanced uptake of K under saline growth conditions favorable K/Na ratios are maintained which serves as a mechanism to avoid salt stress. Therefore, K is important to reduce salinity caused damage while enhanced supply has the potential to increase or at least to maintain crop productivity. Consequently, adequate doses of K are highly recommended in quinoa cultivation under saline conditions. Our results can serve as a basis for further studies, considering mineral nutrition as an important key for salt tolerance and thus optimizing crop productivity under saline conditions.

The results will be published in an article entitled "Potassium, an important element to improve water use efficiency and growth parameters in quinoa *(Chenopodium quinoa)* under saline conditions" in the *Journal of Agronomy and Crop Science* at the beginning of 2021. The study was authored by Ariel Turcios, Merle Tränkner, and Professor Dr. Jutta Papenbrock of the Institute of Botany at Leibniz University Hannover.

***Chenopodium quinoa* cultivated under saline conditions. (Photo: Turcios)**

IAPN's field trial in which remote sensing is used to continuously monitor crop stands during their development. (Photo: Hanebut, K+S)

Research topic

Remote sensing of nutrient supply status

In agriculture, remote sensing technologies have gained much importance in recent years. Mostly, they involve detection of changes in the optical properties of crop stands or plant leaves. The optical properties are based on interactions between light and the various components in plant tissues, for example pigments, water, cellulose, proteins. Part of the incident light spectrum is absorbed by the leaf tissue, while the remaining spectrum is reflected. By detecting and quantifying the absorbed and reflected wavelengths, various physiological and anatomical parameters can be assed. Hence today, numerous properties such as the developmental status of plants and their responses to nutrient deficiencies, diseases, drought and water stress or environmental changes can be evaluated with remote sensing methods.

In research, remote sensing methods such as field spectrometry or the analysis of satellite images, are used and calibrated with data collected in the field and laboratory. Apart from being non-invasive, which allows *in vivo* observations of plants, this methodology is particularly useful as it allows continuous monitoring of plant development over time with high spatial resolution. Therefore, it is possible to fully follow the entire life cycle of crop plants.

Early detection of nutrient deficiencies is one of the main focuses of research at IAPN and particular attention is given to the role of Mg in plant nutrition. Being an essential plant macronutrient, Mg participates in many physiological processes by being a cofactor of many enzymes involved in respiration, membrane transport, photosynthesis, and the synthesis of DNA and RNA, a structural stabilizer of several nucleotides, and part of the ring structure of the chlorophyll molecule. Its deficiency in crops can affect plant biomass and yield formation severely.

When plants display visible symptoms or even before they appear, plant growth and development may already be compromised, leading to considerable yield decreases. Therefore, the presymptomatic and non-invasive detection of Mg deficiencies in plants is crucial for crop monitoring and for alleviating stress at early stages of plant development.

Mg-induced N uptake in spelt (*Triticum spelta* L.)

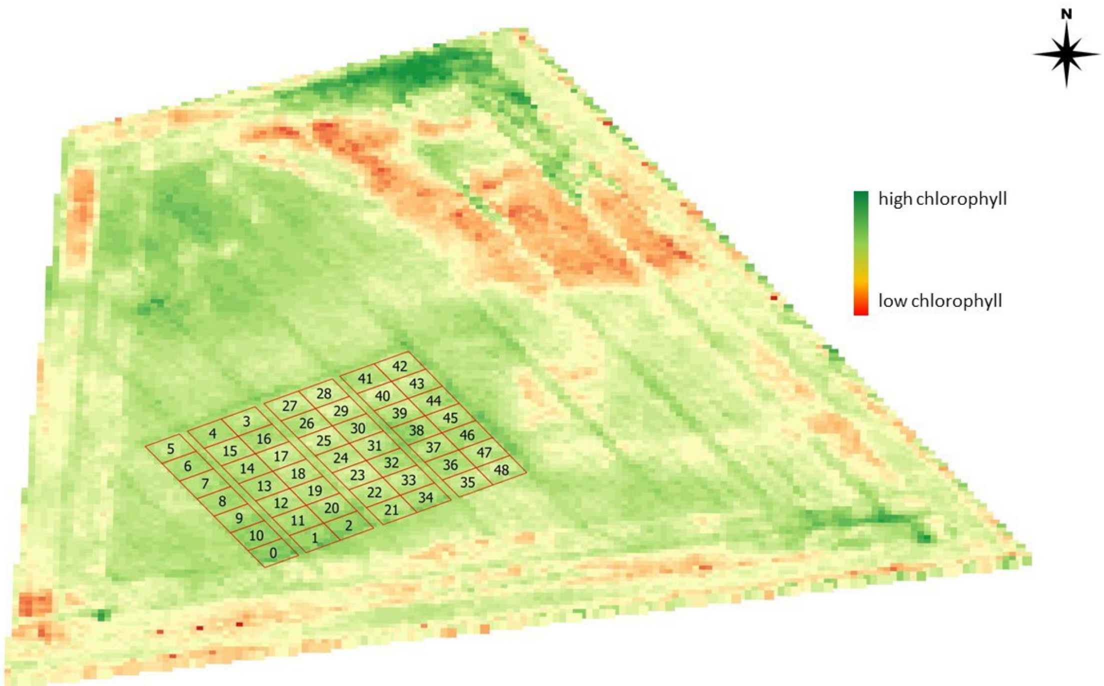
Research project conducted by Paulo Cabrita
Supervisor: Merle Tränkner
Related research topic: remote sensing of nutrient supply status

Within the scope of the project "Quantification of the plant response to Mg fertilization using remote sensing" initiated in 2018, a field trial was set up in Ahlten, near Hannover, on a field located in an area with soils classified as being deficient in Mg. The main goal of this trial was to understand the effect of Mg fertilization on the plant's N uptake, namely on plant growth and development, using remote sensing methodology combined with field measurements. A plot trial with different Mg and N fertilization rates was additionally designed in which the development of spelt (*Triticum spelta* L.) was monitored and surveyed at specific times until harvest.

Field sampling and satellite imagery (WorldView-3 Satellite) were scheduled at specific dates, complemented with local weather and phenological data collection for the whole growing season. Field work involved leaf optical measurements of pigments and plant sample collection at specific dates, according to the plant growth and development, for subsequent analysis on biomass accumulation and nutrient content. About 900 different samples were collected and prepared for laboratory analysis.

Preliminary results from satellite imagery suggest various responses to the different combined Mg and N regimes applied (Figure). The increase in the amount of photosynthetic pigments, namely chlorophyll, observed after Mg fertilization, relates to the increase in biomass and, consequently, leaf area index. This response, observed when plants had more available N in the soil, for example, resulting from fertilization, agrees with what is called as Mg-induced N uptake. It suggests that the consequent increase in biomass, due to previous N availability in the soil, accompanied by an increase of photosynthetic pigments, favored by Mg availability, further promotes N uptake to sustain high levels of plant growth.

Field sampling, and associated laboratory work, combined with high-resolution satellite imagery analysis turned out as particularly useful methodology to follow and quantify not only plant development, but also physiological and morphological responses of plants to fertilization and treatments, which can be used in precision farming.



The distribution of the chlorophyll index, ChlRed, on May 8th 2020, obtained from satellite imagery (WorldView-3 Satellite) analysis, on the IAPN field trial. (Source: Cabrita)

Digital assessment of crop nutrient status

Research project conducted by Paulo Cabrita
Supervisor: Klaus Dittert, Merle Tränkner
Related research topic: remote sensing of nutrient supply status

The project funded by K+S Minerals and Agriculture GmbH and Spacenus GmbH, a start-up company based in Darmstadt, was continued. In this project, IAPN conducted plant nutrition studies aiming at developing the digital Agricultural Nutrient Assistant (ANA) that will support farmers in precision farming. IAPN's focus was on phenotypes of specific variations in plant nutrient supply using spring wheat and spring rapeseed as model plants.

In 2020, the first part of a trial initiated in 2019 using spring wheat (*Triticum aestivum* L.) as plant model was finished. For that purpose, three of the most common spring wheat varieties in the market in Germany were submitted to different nutrient deficiencies to collect data to train and test artificial intelligence (AI) models. The second part of the trial using spring rapeseed (*Brassica napus* L.), also submitted to specific nutrient deficiencies, was initiated in the summer.

Spring rapeseed in an IAPN trial for the project "Digital assessment of crop nutrient status" which aims at developing the digital product Agricultural Nutrient Assistant (ANA). (Photo: Cabrita)

How do fertilizers affect pollination services? IAPN scientists conducted an experiment on this question with strawberries in cooperation with the Division of Agroecology at the University of Göttingen. (Photo: Tränkner)

Research topic

Interactions of plant nutrients and environment

Plant nutrients are part of a complex system whose dynamics can influence the behavior and availability of nutrients. Thus, a cause-and-effect relationship can arise that involves a wide variety of factors and levels, such as soil and plant, or pH and rhizosphere. In response, numerous adaptations in physiology and anatomy take place in the plant. Therefore, looking at a single nutrient in isolation is often not useful and cannot reflect the complexity that underlies nutrient behavior.

The interactions of nutrients with their biotic and abiotic environments are diverse. For the discipline of plant nutrition, the interaction of nutrients with each other is of particular importance. Nutrients interact with other elements and may exhibit antagonistic or synergistic behavior, or they may not interact at all. In the first case, either the availability, uptake or functions in the metabolism of another nutrient are inhibited (antagonism) or promoted (synergism). Nutrient interactions can occur at the root surface or within the plant, inducing deficiencies or inducing or reducing toxicities.

Maize leaves showing symptoms of iron deficiency. This experiment is part of the IAPN project "Iron and oxygen requirements of maize". (Photo: Tränkner)

The physical, chemical, and biological properties of the soil have a major influence on the strength and nature of the interactions and the conditions in the rhizosphere. Biological properties, such as microbial composition or symbiosis with mycorrhizae, also influence soil nutrient dynamics.

A detailed study of the nutrient dynamics and interactions with the abiotic and biotic environment are of great importance due to the great complexity in order to make plant production efficient.

The run of a quantitative real-time PCR (qPCR) was recorded and a time lapse video was created, so that the students were able to see the full analysis of their samples. (Source: Jamali Jaghdani)

Teaching

Teaching at the University of Göttingen

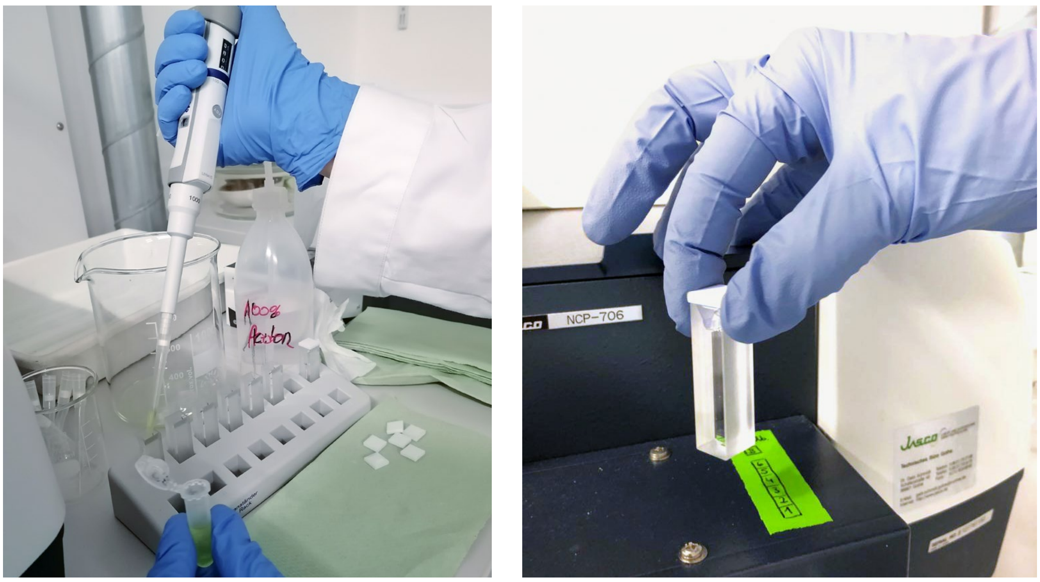
An important objective of IAPN is to provide students with knowledge on nutrition and physiology of plants. For this, alongside traditional lectures, practical parts and lab training units are included in the teaching activities. So, students get insight into the importance of plant nutrition and the different functions of single plant nutrients. Of course, students have options of doing a thesis at IAPN, at undergraduate, Master's and PhD level.

Teaching during the pandemic

The Corona pandemic also had its impact on teaching at IAPN. Fortunately, the hands-on laboratory course "Modern Plant Nutrition – Application of Molecular Methods in Plant Nutrition Research" could take place under a hygiene concept required by the University.

This year, the participants were divided into groups, carrying out their tasks in the laboratory in a day-shifted manner. In addition, the participant groups were divided into subgroups, which were spatially separated so that contact among the small groups was minimized. The scope of the teaching program was shortened this year, but the basic methods for DNA, RNA and protein extraction as well as polymerase chain reaction (PCR) and gel electrophoresis were retained. Some analytical steps were left out in the practical course, as the hygiene concept could not be adhered to. These work steps were documented by the IAPN team by means of photographs or video recordings and made available to the students online. After the daily tasks in the laboratory were completed, the lectures corresponding to the tasks and pre- and post-discussions of the laboratory work took place online via Big Blue Button web conferencing system in afternoon sessions.

The three-week course was conducted by Merle Tränkner together with Ariel Turcios and Setareh Jamali Jaghdani. In the lab, the two technical assistants Kirsten Fladung and Ulrike Kierbaum as well as student research assistant Ben Hoßbach assisted with preparation, follow-up and group supervision.



One methodology that complemented the molecular methods was the extraction of chlorophyll a and b. Chlorophyll was extracted by acetone and the extract was transferred from reaction tubes to cuvettes to be measured with a spectrophotometer. (Photos: Tränkner)

Completed theses supervised by IAPN scientists in 2020

Pascal Berg, MSc Thesis (2020):
Verteilung von Magnesium und Chlorophyll in *Chenopodium quinoa* unter verschiedenen Magnesiumkonzentrationen und salzigen Bedingungen

Constantin Dröge, BSc Thesis (2020):
Einfluss von Nähr- und Wirkstoffbeizen auf die Ertragsbildung und Wurzelentwicklung von Winterweizen

Marcel Heinrich, BSc Thesis (2020):
Eignung von Pflanzenparametern und Vegetationsindizes zur Abschätzung des Stickstoff-Düngebedarfs von Mais – Auswertung am Versuchsstandort Wehen der Landwirtschaftskammer Niedersachsen

Daniel Herrmann, BSc Thesis (2020):
Blatteigenschaften und Frosttoleranz bei Zuckerrübe unter dem Einfluss einer Kalium- und Saccharose-Frostschutz-Düngung

Lea Krug, BSc Thesis (2020):
Beeinflusst die Kationenaustauschkapazität im Boden die Leistung von NZONE Max bei der Reduzierung von NH_3-, N_2O- und CO_2-Emissionen?

Lukas Oertelt, BSc Thesis (2020):
Potentiale eines Magnesiumsulfat-Borax-Zeolith-Zusatzes zur Minderung der NH_3- und N_2O-Emissionen nach Harnstoffdüngung

Dina Erika Marianne Schärfe, BSc Thesis (2020):
Auswirkungen verschiedener Beregnungsintensitäten sowie Kaliumdüngestufen auf den Ertrag und ausgewählte Qualitätsparameter in Kartoffeln

Carina Schulz, MSc Thesis (2020):
Yield and quality traits of spring barley in response to nitrogen fertilization and irrigation in Northern Germany

Anna-Maria Trappe, BSc Thesis (2020):
Bedeutung der im Kulturmedium zur Verfügung stehenden Kaliummenge, um Salzstress in der Quinoa-Kultur zu vermeiden

Knowledge Exchange

Interdisciplinary discourse with scientists and practitioners

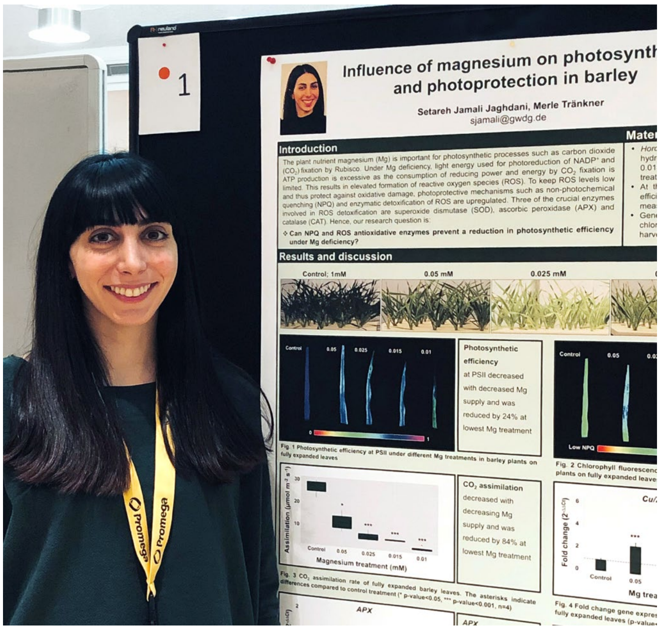
IAPN strives to expand its international and national cooperation with professionally complementary institutions and researchers. In addition, IAPN consciously turns to practice-oriented research. The institute aims to transfer the already available scientific knowledge into practice more intensively, but also to formulate open research questions jointly with national and local practitioners and scientists.

The annual conference of Molecular Biology of Plants

From February 11th to 14th 2020, the 33rd Conference Molecular Biology of Plants (MBP) took place at Maria in der Aue, Dabringhausen, Germany. Setareh Jamali Jaghdani and Merle Tränkner attended the conference, presenting a poster of Setareh Jamali Jaghdani's PhD project with the title "Influence of magnesium on photosynthesis and photoprotection in barley". The results of her project revealed that under Mg deficiency, CO_2 assimilation was influenced significantly although photosynthetic efficiency was not affected equally. The gene expression of reactive oxygen species (ROS) scavenging enzymes was upregulated which indicates an oxidative stress under Mg deficiency.

The next step in her PhD project was to study if non-photochemical quenching (NPQ) would have been influenced adversely under Mg deficiency, where the xanthophyll cycle is one of the main cycles involved in NPQ. During the conference, Setareh Jamali Jaghdani intensively exchanged current knowledge with other participants and discussed vividly the results of her experiment with Professor Dr. Peter Jahns, which initiated a cooperation for her next experiment. Peter Jahns is the head of the working group of "Photosynthesis and stress physiology of plants" at the Heinrich Heine University Düsseldorf. He contributed to Setareh Jamali Jaghdani's project with his expert knowledge on NPQ and quantification of the xanthophyll cycle pigments. Results of the work were jointly published in November 2020.

The conference was organized by the Section Plant Physiology and Molecular Biology, which is an independent network for plant physiology and molecular biology in the genomic age and the largest experts' group within the German Society for Plant Sciences (Deutsche Botanische Gesellschaft, DBG).



IAPN's PhD student Setareh Jamali Jaghdani presents latest results of her research on a poster at the 33rd Conference Molecular Biology of Plants (MBP). (Photo: Tränkner)

Guests at IAPN

In October 2020, **Lílian Angélica Moreira, PhD student from Brazil**, successfully completed her eight-month research at IAPN. During her stay, she conducted and evaluated experiments in order to understand the influence of molybdenum (Mo) on N assimilation and amino acid composition in plants. The experiments relied on the stable ^{15}N-isotope technique in order to explore whether Mo supply can alter the preferred form of N taken up by plants (nitrate or ammonium). The effects of Mo applications via root and leaf on aforesaid and further parameters such as CO_2 assimilation were assessed, seeking practical alternatives for increasing the N-use efficiency by crops such as corn and sugar cane. The project was supervised by Merle Tränkner.

PhD student Lílian Angélica Moreira conducted research at IAPN from March until October 2020. (Photo: IAPN)

KALI Academy webinar on water-use efficiency

Prolonged periods of drought can lead to significant yield losses. At a webinar held in January and October 2020 on KALI Academy, the knowledge platform of K+S dedicated to plant nutrition, Klaus Dittert gave insight into IAPN's research on the role of K in water-use efficiency (WUE) of plants.

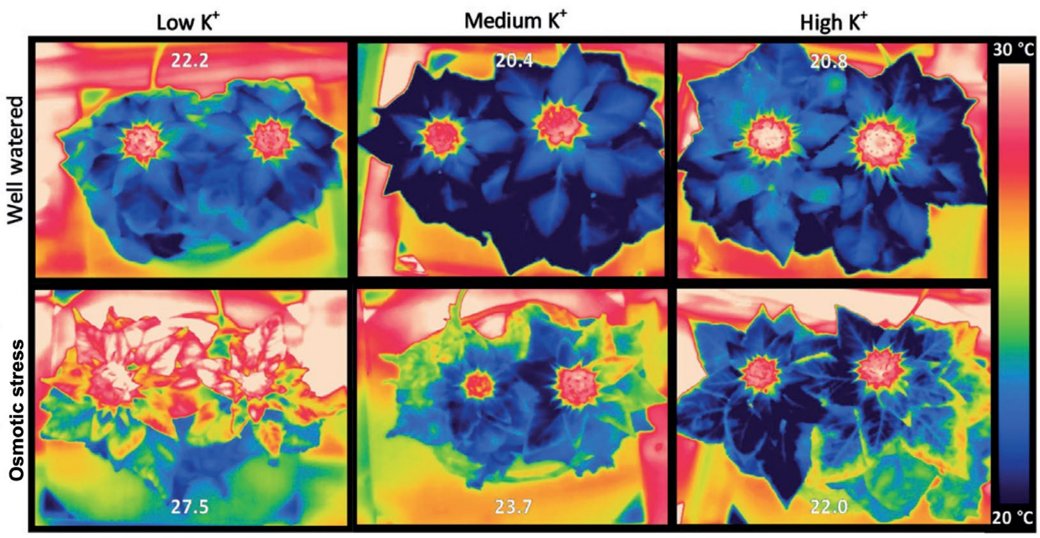
In order to grow, plants need to absorb CO_2 from the atmosphere and water from the soil so that they can convert them into sugar in the process of photosynthesis. The CO_2 enters the leaf interior through tiny stomata on the leaf surface. Each stoma opening consists of two guard cells. When the plant needs fresh CO_2 for photosynthesis, it changes the shape of the guard cells so that the stomata allow gas exchange between the inside of the leaf and the atmosphere. As soon as enough CO_2 has reached the inside of the leaves, the stomata close again. For this regulation of the guard cells the plants need K.

During the CO_2 uptake, gaseous water escapes from the inside of the leaf into the atmosphere through the stomata. This process, known as transpiration, cools the leaf surface. Research at IAPN has shown that K deficiency leads to decreased gas exchange due to decreased guard cell function. Although more K initially increases transpiration, the plant can regulate the opening and closing of the stomata much better and thus avoid unproductive water loss.

In addition, IAPN scientists were able to demonstrate that a sufficient supply of K improves the mesophyll and stomatal conductivity required for photosynthesis. While stomatal conductance is responsible for CO_2 from the atmosphere reaching the inside of the leaf, mesophyll conductance determines how much of this CO_2 reaches the chloroplasts. In these small, green "power stations", the actual photosynthetic reaction takes place, in a light-dependent reaction and in a light-independent reaction. The enzymes that are relevant for this also require K.

K is also needed for the transportation of the sugars produced (assimilates) from the leaves to the harvest organs or, at a younger stage of growth, to the roots and shoots. Thus, K deficiency can result in not only the shoot but also the root system remaining smaller. This in turn means that water and nutrients can no longer be taken up by the plant root to the required extent.

Finally, the accumulation of sugars in the leaves due to K deficiency has the effect that photosynthesis virtually comes to a standstill, although the leaves are usually still exposed to sunlight. The leaves come under so-called oxidative stress, because reactive oxygen species (ROS) such as ozone or hydrogen peroxide are now formed in the leaf from the light energy that continues to reach it. These very aggressive compounds lead to damage inside the leaves, which can be observed with the naked eye in the form of chlorosis and necrosis of the leaves.



Leaf temperature of plants supplied with different amounts of K and water. The upper part of the figure shows plants without drought stress: they are consistently cooler (blue colors) because there is a lot of transpiration. The plants in the lower area were exposed to drought stress. Here, the plant with the lowest K supply was the worst able to regulate its transpiration. Due to its unproductive water loss, it consumed the available water the fastest and eventually cannot cool itself due to lack of water. (Source: B. Jákli, IAPN)

Publications

Work published in peer-reviewed journals and proceedings (including non-IAPN publications of IAPN employees, e.g., reports on previous research activities)

Cabrita, P. (2020) Holocrine secretion and kino flow in angiosperms: Their role and physiological advantages in plant defence mechanisms. Trees 34, 1183–1204, doi.org/10.1007/s00468-020-01990-z

Guo, L.; Liu, M.J.; Tao, Y.Y.; Zhang, Y.N.; Li, G.Y.; Lin, S. and Dittert, K. (2020) Innovative water-saving ground cover rice production system increases yield with slight reduction in grain quality. Agricultural Systems 180

Hou, W.; Tränkner, M.; Lu, J.; Yan, J.; Huang, S.; Ren, T.; Cong, R. and Li, X. (2020) Diagnosis of nitrogen nutrition in rice leaves influenced by potassium levels. Frontiers in Plant Science, doi.org/10.3389/fpls.2020.00165

Ivens, S.; Wiese, G.; Dittert, K.; Musshoff, O. and Oberle, M. (2020) Bringing policy decisions to the people-education for sustainable development through a digital simulation game. Sustainability 12, 8743, doi.org/ 10.3390/su12208743

Jamali Jaghdani, S.; Jahns, P. and Tränkner, M. (2020) Mg deficiency induces photo-oxidative stress primarily by limiting CO_2 assimilation and not by limiting photosynthetic light utilization. Plant Science, doi.org/10.1016/j.plantsci.2020.110751

Mugo, J.N.; Karanja, N.N.; Gachene, C.K.; Dittert, K.; Nyawade, S.O. and Schulte-Geldermann, E. (2020) Assessment of soil fertility and potato crop nutrient status in central and eastern highlands of Kenya. Scientific Reports 10, 7779, doi.org/10.1038/s41598-020-64036-x

Nogueira, A.F. Jr.; Tränkner, M.; Ribeiro, R.V.; von Tiedemann, A. and Amorim, L. (2020) Photosynthetic cost associated with inducible defenses to *Plasmopara viticola* in grapevine. Frontiers in Plant Science – Plant Microbe Interactions, doi.org/10.3389/fpls.2020.00235

Rummel, P.S.; Well, R.; Pfeiffer, B.; Dittert, K.; Flossmann, S. and Pausch, J. (2020) Nitrate uptake and carbon exudation – do plant roots stimulate or inhibit denitrification? Plant and Soil, doi.org/10.1007/s11104-020-04750-7

Rummel, P.S.; Pfeiffer, B.; Pausch, J.; Well, R.; Schneider, D. and Dittert, K. (2020) Maize root and shoot litter quality controls short-term CO_2 and N_2O emissions and bacterial community structure of arable soil. Biogeosciences, 17: 1181–1198, doi.org/10.5194/bg-17-1181-2020

Surey, R.; Schimpf, C.M.; Sauheitl, L.; Mueller, C.W.; Rummel, P.S.; Dittert, K.; Kaiser, K.; Böttcher, J. and Mikutta, R. (2020) Potential denitrification stimulated by water-soluble organic carbon from plant residues during initial decomposition. Soil Biology and Biochemistry 147: 107841, doi.org/10.1016/j.soilbio.2020.107841

Suriyagoda, L.; Tränkner, M. and Dittert, K. (2020) Effects of potassium nutrition and water availability on iron toxicity of rice at seedling stage. Journal of Plant Nutrition, 43, 2350-2367, doi.org/10.1080/01904167.2020.1771578

Wang, H.T.; Beule, L.; Zang, H.D.; Pfeiffer, B.; Ma, S.T.; Karlovsky, P. and Dittert, K. (2020) The potential of ryegrass as cover crop to reduce soil N_2O emissions and increase the population size of denitrifying bacteria. European Journal of Soil Science. doi.org/10.1111/ejss.13047

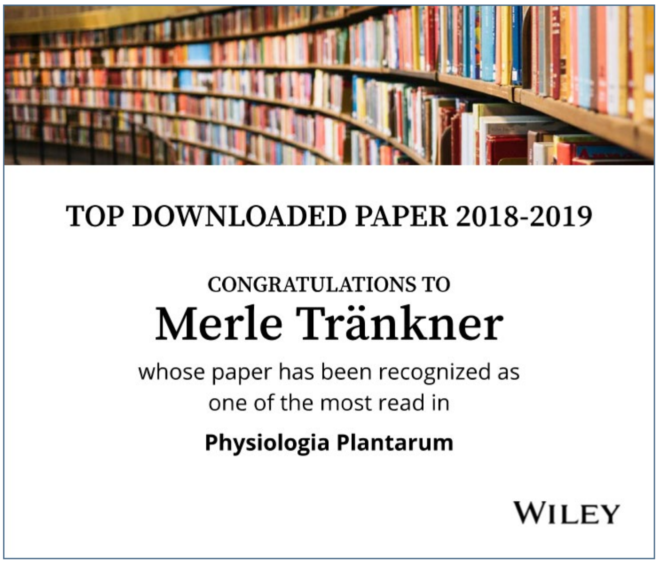
Wang, H.T.; Köbke, S. and Dittert, K. (2020) Use of urease and nitrification inhibitors to reduce gaseous nitrogen emissions from fertilizers containing ammonium nitrate and urea. Global Ecology and Conservation 22, doi.org/10.1016/j.gecco.2020.e00933

Wang, H.T.; Ma, S.T. and Dittert, K. (2020) Straw amendments did not induce high N_2O emissions in non-frozen wintertime conditions: A study in northern Germany. Soil Use and Management 36:693-703, doi.org/10.1111/sum.12643

Conference talks – papers – posters

Jamali Jaghdani, S. and Tränkner, M. (2020) Influence of magnesium on photosynthesis and photoprotection in barley. 33rd Conference Molecular Biology of Plants (MBP), February 11th – 14th 2020, Maria in der Aue, Dabringhausen, Germany

In 2020, due to the pandemic, many conferences were canceled. Among other events, IAPN scientists had planned to attend the "Plant Biology Europe Congress" (PBE2020) in Turin, Italy, that was jointly organized by the Federation of European Societies of Plant Biology (FESPB) and the European Plant Science Organisation (EPSO). For this event, poster presentations by Merle Tränkner and Setareh Jamali Jaghdani – who won a FESPB Support Grant for this congress – had been confirmed. Unfortunately, the conference had to be postponed to 2021 as an online event. Also, the annual conference of the German Society of Plant Nutrition (Deutsche Gesellschaft für Pflanzenernährung, DGP) in Kiel, Germany, was canceled.



The review article by Merle Tränkner, Ershad Tavakol, and Bálint Jákli about K and Mg in photosynthesis and photoprotection has been recognized as a "Top Downloaded Paper 2018 – 2019" in *Physiologia Plantarum*. (Source: Tränkner)

IAPN publication recognized as "Top Downloaded Paper"

In spring 2020, publisher Wiley has congratulated Merle Tränkner on the success of her review article "Functioning of potassium and magnesium in photosynthesis, photosynthate translocation and photoprotection". Being a "Top Downloaded Paper 2018 – 2019", the article belongs to the top 10 % most downloaded papers among works published between January 2018 and December 2019 in the scientific journal *Physiologia Plantarum*.

Co-authors are the former IAPN scientists Dr. Ershad Tavakol and Dr. Bálint Jákli. Together with Merle Tränkner, they had formed the first group of IAPN PhD students. The jointly written article provides an overview of their PhD research results. Topic of the paper is the functioning of K and Mg in processes that are associated with photosynthesis. The article focusses on chloroplast ultrastructure, light-dependent and light-independent reactions of photosynthesis and the diffusion of CO_2 into chloroplasts. Additionally, the paper discusses the role of K and Mg in phloem-loading and long-distance transport of photoassimilates and in the photoprotective mechanisms of the photosynthetic apparatus.

Cooperation in Science

Partner	Location
Al-Quds Open University	Jerusalem, Palestine
Bodengesundheitsdienst	Ochsenfurt, Germany
Chamber of Agriculture	Hannover and Oldenburg, Germany
China Agricultural University	Beijing, China
Institute of Sugar Beet Research (IfZ)	Göttingen, Germany
International Magnesium Institute (IMI)	Fuzhou, China
Julius Kühn-Institut, Institute for Crop and Soil Science	Braunschweig, Germany
K+S Analytik- und Forschungszentrum (AFZ)	Unterbreizbach, Germany
K+S Minerals and Agriculture GmbH	Kassel, Germany
LUFA Nord-West, Institut für Düngemittel und Saatgut	Hameln, Germany
Sabanci University, Biological Sciences and Bioengineering Program	Istanbul, Turkey
SKW Stickstoffwerke Piesteritz GmbH	Lutherstadt Wittenberg, Germany
Spacenus GmbH	Darmstadt, Germany
Thünen-Institute – Institute of Climate-Smart Agriculture	Braunschweig, Germany
University of Düsseldorf	Düsseldorf, Germany
University of Göttingen	Göttingen, Germany
Agroecology Group	
Division of Quality of Plant Products	
Functional Agrobiodiversity	
Plant Pathology and Crop Protection	
University of Halle, Institute of Plant Nutrition	Halle, Germany
University of Hannover, Institute of Botany	Hannover, Germany
University of Kassel, Organic Plant Production and Agroecosystems Research	Witzenhausen, Germany
University of Peradeniya	Peradeniya, Sri Lanka
University of São Paulo	São Paulo, Brazil

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