IAPN
INSTITUTE OF
APPLIED PLANT NUTRITION

ANNUAL REPORT 2014

RESEARCH ON SUSTAINABLE PLANT NUTRITION

Imprint

Author:	Institute of Applied Plant Nutrition (IAPN)
Editorial staff:	Prof. Klaus Dittert, Prof. Mehmet Senbayram, Dr. Heike Kuhnert
Pictures:	Dach, Herwig, Jákli, Schröder, Tavakol, Tränkner

November 2015

Institute of Applied Plant Nutrition (IAPN)

at Georg-August-Universität Göttingen

Carl-Sprengel-Weg 1

37075 Göttingen, Germany

www.iapn.de

Preface

In 2014, the focus of IAPN was on a number of complex ongoing research projects, all of which shared resource efficiency as a common denominator, as well as on how to best disseminate the results of this research. And while the IAPN contributed to classical research and tuition at the University, it also struck out in new directions in order to bring new findings to practicioners. By the end of the year, the IAPN's staff had grown to include a team of eight. Research aspects were further broadened by several visiting scientists from abroad, one of them the winner of the Georg Forster Research Award of the Alexander von Humboldt-Foundation.

Join us on a short excursion into the year 2014. The report at hand provides insights into the IAPN-activities, and invites you to partake in the most important results. We are particularly proud of our success regarding the transfer of knowledge. The series of events "IAPN in Dialogue" drew visitors from all over the region, offering international scientists an opportunity to present their work to researchers, students and interested professionals. On an international level, the IAPN together with its partners abroad provided new impulses for an interdisciplinary exchange on the importance of the element magnesium with its 2nd International Symposium on Magnesium, in November 2014 in São Paulo, Brazil.

Vitality and inquisitiveness of our – mostly – young team of scientists characterizes life at the IAPN. This very special atmosphere may be felt during lectures, and also during hands-on greenhouse and lab courses at the IAPN. Scientific enthusiasm is contagious, and students are fascinated by their discovery of the great importance proper plant nutrition has for climate changes and for food security worldwide, for humans and for animals. And it doesn't hurt to know that a master thesis at the IAPN may be awarded with the sponsorship award of the agricultural economy.

Prof. Klaus Dittert
Scientific Director IAPN

The IAPN

Structure and development of the Institute of Applied Plant Nutrition – a public-private partnership at the Georg-August-Universität Göttingen

The Institute of Applied Plant Nutrition (IAPN) in Göttingen was founded in November 2010 as a public-private partnership by Georg-August University Göttingen and K+S KALI GmbH, in order to promote research on applied crop nutrition. The IAPN has the status of Associated Institute under Lower Saxony's tertiary education legislation. This means that it is attached to the University and carries out both tuition and research in support of the University's core responsibilities. The common rules of good scientific practice also apply to Georg-August University's Associated Institutes with regard to both tuition and research. These aim to increase specialist knowledge from various disciplines that is available to the public, and to work towards its dissemination.

IAPN began its work in spring of 2012, after the completion of renovation works on a building on the University campus. While being in close physical proximity to the University's Plant Nutrition and Crop Physiology working group, the IAPN's tuition and research activities connect in numerous ways with the activities of this working group and other sections within the Department of Crop Sciences in the Faculty of Agricultural Sciences. Thus the IAPN is very closely linked in with the University and is able to both contribute its own expertise and use that of the University.

2013 was a year of major developments at the IAPN. The increase in the size of the team and the improvements in infrastructure that was started in 2012, was continued in 2013: much of the acquisition and installation work on the equipment was completed, there was a further increase in staff, and numerous research methods were firmly established. So in parallel to starting first experimental activities, 2013 was still a year of numerous test-series and much quality control work.

In 2014 the emphasis was on the intensive work on research projects that were running at the time. At two events in the "IAPN in Dialogue" series, visitors Prof. Ismail Cakmak and Christine Kyomugisha provided fascinating insights into their work. With the 2nd International Symposium on Magnesium that took place in November 2014 in São Paulo (Brazil), the IAPN and its organizational partners provided a major impetus to interdisciplinary exchanges around the importance of magnesium for human, animal and plant health.

View into the greenhouse of IAPN. (Photo: Herwig)

IAPN's Mission

IAPN's responsibilities and goals are, through scientific research and teaching in the field of applied plant nutrition, to work towards there being sufficient, good quality agricultural products for the general population – under both current and future economic, ecological and demographic circumstances. This is to be achieved efficiently and with the lowest possible impact on the environment. At the IAPN, research is carried out with this aim and the Institute also provides academic education and training for the next generation of scientists.

A key feature of the IAPN is the way that it maintains close contact with agricultural practice, in order to pick up on current issues and respond with technical know-how as quickly as possible, whether that information has been obtained by searching through existing knowledge-bases or is the product of new research. So on one hand the IAPN involves itself in the traditional teaching activities at the University, but on the other it finds new ways to bring this information to end-users.

The close proximity between the IAPN and the University helps both organizations achieve their goals:

- **Research in applied plant nutrition:** Research at the IAPN is oriented to contribute to urgent questions of socio-economic relevance and scientific impact. In many cases, questions in applied plant nutrition can be answered by thoroughly studying published research results that may have been conducted in other environments or other contexts. While assistance in such situations is important, it is one of IAPN's central goals to bring forward its own original research in relevant fields.
- **Transfer of research methods and results within the teaching context:** Staff at the IAPN involve themselves actively in the conception and implementation of teaching events, so that new methodologies and research results immediately flow into lectures and student laboratory courses.
- **New skills and ideas for research:** Thanks to options within BSc, Msc and PhD study and the supervision of dissertations, interested students can get to know the IAPN and its research areas – during their studies, rather than after. This means they can enjoy direct contact with the field of applied plant nutrition at an early stage: during their undergraduate and postgraduate studies.
- **Knowledge transfer to the farming sector via local experts:** It is possible for young scientists to do an internship at the IAPN for a limited period. Participants are often from abroad. The main aim of IAPN internships is that participants go back and pass on their newly-acquired knowledge at their place of work.

The IAPN Team

During 2013 the IAPN team was substantially increased in size, and by the end of 2014 consisted of eight people. For more information about the IAPN's employees and their areas of responsibility, see www.iapn.de.

Starting in 2012 shortly after the IAPN's inception, Merle Tränkner was the first PhD student of this new institute. Her research focusses on the significance of essential plant nutrients for drought-stress tolerance in crops. Then in 2013, PhD students Bálint Jákli and Ershad Tavakol commenced working at the IAPN on the research project "Potential for enhancing water-usage efficiency and drought-stress tolerance in agricultural crops through improved fertilizer management systems, with particular consideration of physicochemical soil processes", which is jointly supervised by Junior Professor Mehmet Senbayram and Professor Klaus Dittert. Annika Lingner joined the team in 2014. Her research work is embedded in the framework of the IMPAC project "Novel genotypes for mixed cropping allow for improved sustainable land use across arable land, grassland and woodland".

The IAPN office is managed by Martina Renneberg. Kirsten Fladung works in the laboratory, focusing on minerals analysis. Her colleague Ulrike Kierbaum is responsible for much of the biochemical work, in particular the investigation of reactive oxygen species and various enzyme activities. Much essential support work for the IAPN was received from a number of student research assistants, who worked hard in looking after plant experiments and on the preparation of numerous samples.

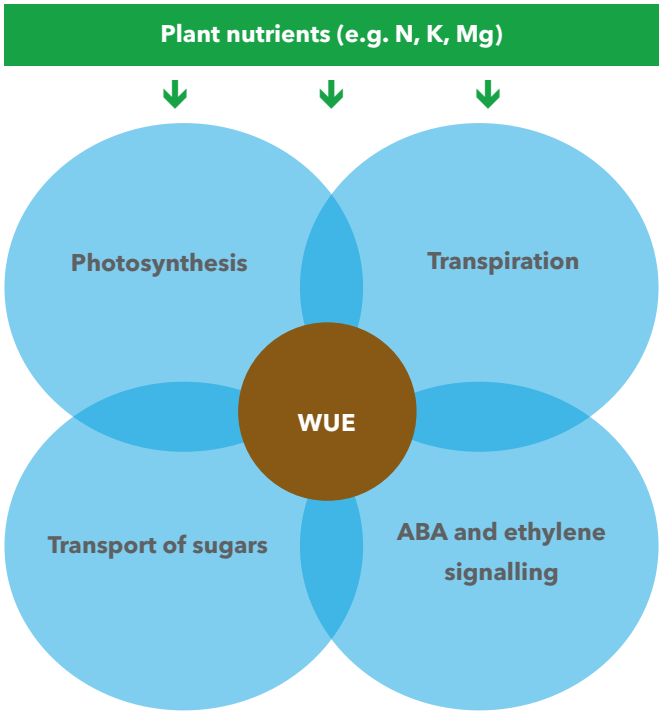
Successful partnership: Employees of the IAPN, of the Department for Crop Science at Georg-August University and of K+S KALI GmbH together with Prof. Ismail Cakmak (Georg-Forster laureate), Prof. Achim Spiller (Dean of the Faculty of Agricultural Sciences), Dr. Andreas Radmacher (Member of K+S Board of Executive Directors), Prof. Andreas Gransee (Managing Director of IAPN and Head of Research & Advisory K+S KALI GmbH), Prof. Klaus Dittert (Scientific Director of IAPN) at a meeting in Göttingen. (Photo: Dach)

Team of the IAPN in summer of 2014 (left to right): Martina Renneberg, Kirsten Fladung, Ulrike Kierbaum, Bálint Jákli, Klaus Dittert, Merle Tränkner, Ershad Tavakol, Mehmet Senbayram. (Photo: Dach)

Junior Professor Mehmet Senbayram and graduate students Annika Lingner (left) and Merle Tränkner (right) discuss a running experiment in the IAPN´s greenhouse. (Photo: Herwig)

Research at IAPN

Agricultural production is increasingly threatened by seasonal droughts globally and even in temperate regions such as middle Europe. This led to growing awareness for questions of drought tolerance and freshwater scarcity and in crop research it brought crop traits like water use efficiency (WUE) and its relation to nutrient management into attention. These new research activities focus on improving the efficiency of crop plants in converting light, nutrients and water into harvestable plant products (higher WUE). In order to improve WUE, breeders, plant physiologists and molecular geneticists work on identifying genes that are responsible for drought stress tolerance in order to increase the genetic potential for higher crop yield under water-limited conditions. On the other hand, improved genetic potential against abiotic tolerance is likely to lead to higher demand for key plant nutrients as many plant physiological processes that are related to drought tolerance (e.g. rate of photosynthesis, stomatal control, transport of photosynthetic products from source to sink organs, reactive oxygen species scavenging processes, morphological changes in leaves to escape high-light intensities or reducing cuticular water loss) are highly dependent on the availability of key plant nutrients. In order to develop new management strategies, as a first step, we need better understanding about the role of common plant nutrient limitations (e.g. nitrogen, potassium and magnesium) on drought tolerance and WUE. Therefore, one of the major research focuses at IAPN is to study the effect of plant nutrients (N, K, Mg) on traits related to the water use efficiency (WUE) of arable crops.

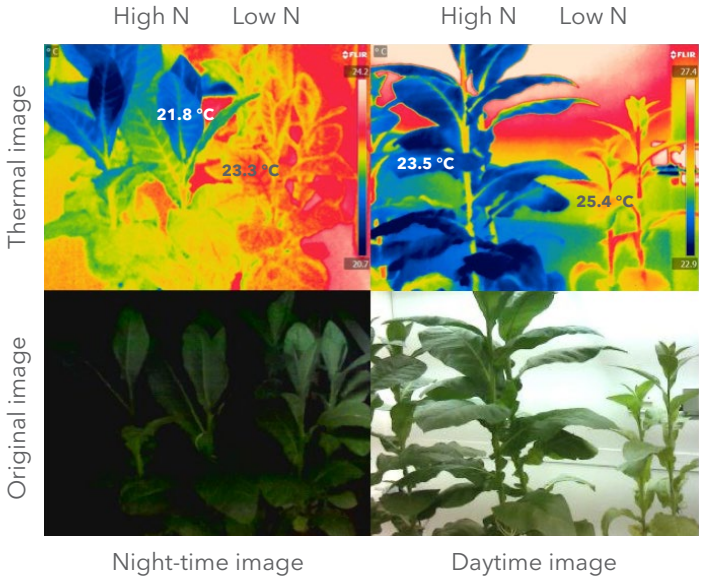


IAPN Topics

In 2012-2013, Merle Tränkner, Ershad Tavakol and Bálint Jákli started their PhD research projects at IAPN. Their studies focus on effects of Mg and K supply on water use efficiency (WUE) and drought responses such as reactions to oxidative stress and protein expression related to drought tolerance (proteomics). In 2014, Annika Lingner started her PhD at IAPN within the frame of the newly funded research project IMPAC (Novel genotypes for mixed cropping allow for IMProved sustainable land use ACross arable land, grassland and woodland). In the following, we report on their research activities in 2014.

Plant mineral nutrients regulate crop water use efficiency and tolerance to excess light energy (Merle Tränkner, MSc. agr.)

Merle Tränkner started her PhD studies at IAPN in 2012 and her main research focus is on evaluating effects of various plant nutrients (N, Mg, and K) on water use efficiency (WUE) of crop plants and exploring related key plant physiological mechanisms. During her study, she applies a number of quite different plant analysis methods, e.g. gas exchange analysis systems (leaf level), modelling of plant growth, stable isotopes (^{13}C and ^{18}O), proteomics and thermal imaging.



Effect of N supply on leaf temperature during night and day. Thermal images were taken 9-13 days after the start of nitrogen deficiency. Mean leaf temperatures of the youngest fully expanded leaves are given on each treatment (Senbayram et al., 2015). (Photos: Senbayram)

Nitrogen (N)

In 2014 Merle Tränkner successfully submitted her first publication entitled "Daytime leaf water use efficiency does not explain the relationship between plant N status and biomass water use efficiency of tobacco under non-limiting water supply" (issued in Journal of Plant Nutrition and Soil Science in 2015). In brief, the main results are:

- Experiments clearly showed that shoot and biomass WUE were not affected by N supply. Night-time respiration and g_{night} (night-time stomatal conductance) were significantly higher in high N than in low N plants. Variation in both traits (night-time respiration and transpiration) under high N than under low N supply counterbalanced the positive effect of N supply on leaf-WUE (59%) resulting in no overall change in biomass-WUE with higher N supply (see photos of leaf temperature).
- In the experiment, day-time gas exchange parameters (leaf-WUE) alone did not prove to be a reliable indicator of changes in biomass-WUE. However, $\delta^{13}C$ signatures were found to be effective proxies for assessments of biomass-WUE.
- Based on the experimental results it is concluded that positive effects of N supply on biomass-WUE and $\delta^{13}C$ values reported in pot or field experiments may be due to indirect effects of N supply rather than a direct effect of N supply on day-time leaf-WUE, e.g. hidden drought.

Magnesium (Mg)

Magnesium (Mg) is one of the nine essential plant macro nutrients. It is known that Mg deficiency attenuates the detrimental conversion of light energy to chemical energy. This conversion leads to the formation of reactive oxygen species (ROS) like hydrogen peroxide (H_2O_2; see photos of barley and sugar beet). To prevent the formation of ROS, plants have certain capacities to dissipate excessive excitation energy by non-photochemical quenching (NPQ). Previous studies had revealed an impact of plant nutrients on the biomass WUE, but still too little is known about the impact of magnesium on plant physiological processes especially with respect to photosynthesis and responses to excessive reception of light energy.

The major research activities in the field of Mg physiology focussed on studying the photosynthetic performance by means of gas exchange, chlorophyll fluorescence (incl. non-photochemical quenching) and biomass production of barley under mild and severe magnesium deficiency. Measurements of hydrogen peroxide concentrations, ROS detoxifying enzyme activities and the concentrations of the secondary amino acid proline were included to gain insight into the extent of stress at the leaf level. Furthermore, analysis of $\delta^{13}C$ signatures and sugar contents in the plant helped understanding photosynthate translocation. The biomass water use efficiency was measured and evaluated on a daily scale to assess the progressive influence of magnesium deficiency on transpiration and assimilation. The results confirmed those obtained during an experiment already in 2013, and they were presented at the "International Plant Nutrition Colloquium" and the "2nd International Symposium on Magnesium in Crop Production, Food Quality and Human Health".

Studies on the proteome of wheat

Potassium (K^+) is the most abundant cation in plants and plays a crucial role for several biophysical and biochemical functions. Potassium uptake by the root is mediated by kinetically different channel systems which vary in response to K^+ starvation. Under drought situations, the root is the first plant organ to sense drought and changes on the protein expression and composition to occur. To gain deeper insights into the changes of potassium channel activities in plants as influenced by potassium deficiency and drought, a study on protein expression was started in 2013. In 2014, proteins extracted from these plant samples were separated by 2-dimensional gel electrophoresis and stained to visualize the protein spots on the gels. Imaged gels were started to be analysed for differences in expression patterns. The work is scheduled to continue in 2015 with the sequencing of interesting proteins.

Magnesium deficiency on barley (left) and sugar beet (right). (Photos: Tränkner)

Gas exchange measurement with barley (left) and fully automated balance system (right) at IAPN. (Photos: Tränkner)

Physiological and molecular mechanisms of drought tolerance in crop plants – the role of potassium (Ershad Tavakol, MSc.)

Potassium being a major inorganic solute in plants is the most important crop nutrient related to osmotic regulation in plants. Particularly under drought conditions, improved osmoregulation contributes to a better water balance and stomatal regulation that may enhance water use efficiency (WUE) of crop plants. In addition, adequate K supply in crop plants is required for the translocation of photo-assimilates within plants as well as in activating many enzymes. In K deficient plants, translocation of assimilates to the sink organs is reduced which results in increased and often toxic concentrations of reactive oxygen species (ROS). High ROS contents in cells damage many important compounds often including chlorophyll and may eventually lead to cell death. In order to mitigate the negative impacts of excessive ROS production, plants produce a number of antioxidant enzymes that detoxify ROS (see photos of leaf necrosis in sunflower). However, the capacity of antioxidants to detoxify ROS may be also limited by the nutrient status of the plants. Ultimately, in drought situations, adequate K supply is known to i) maintain the ROS and antioxidant balance, ii) improve the stomatal regulation and iii) preserve CO_2 assimilation under drought conditions favouring plant water use efficiency (WUE). Within the scope of his PhD research, Ershad Tavakol aims at improved understanding of the role of potassium (K) nutrition on various physiological and molecular mechanisms related to drought tolerance of arable crops.

The main objectives of his study are:

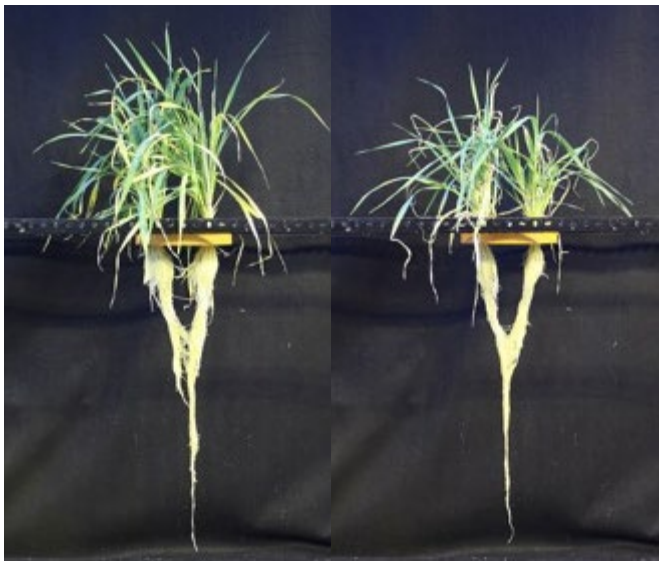
- studying the relationship between WUE, K supply and related mechanisms (phyto-hormone signalling, photosynthesis and stomatal regulation),
- quantification of toxic reactive oxygen species along with a study of scavenging enzyme activities that detoxify ROS under various conditions of potassium supply and drought,
- studying the expression levels of candidate genes accountable for the initiation of plant responses (related to stomatal regulation and ROS detoxification) under potassium deficiency and drought conditions.

Effect of K supply on leaf necrosis in sunflower. The right leaf is suffering from K deficiency. The necrosis can be attributed to the high concentration of reactive oxygen species (ROS) causing degradation of chlorophyll. (Photos: Tavakol)

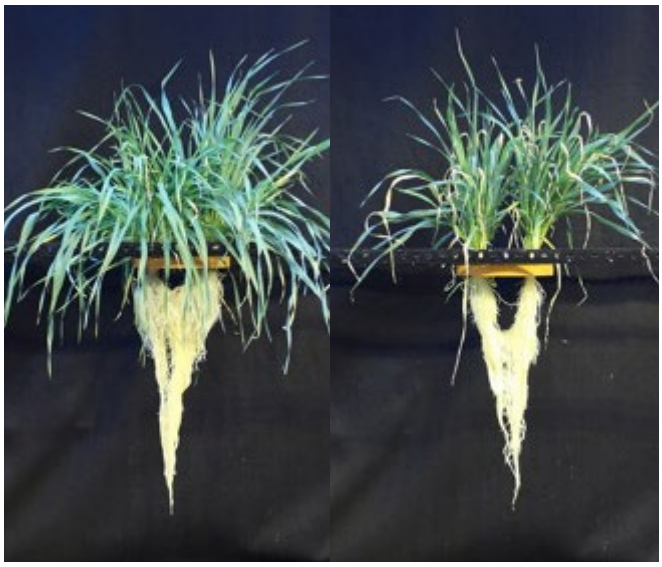
In 2013, all spectrophotometric methods related to ROS and antioxidant enzyme activity were established, e.g. ascorbate peroxidase (APX), catalase (CAT), glutathione reductase (GR) and superoxide dismutase (SOD). Following that, preliminary experiments were performed on wheat, sugar beet and sunflower grown in nutrient solution focusing first on direct K effects on above mentioned parameters. First results showed that hydrogen peroxide concentration in crop plants were very sensitive to the plant's K status indicating high plant sensitivity to excess light energy.

In 2014, a set of experiments was established with varied K and drought levels based on the findings in the previous year. Here in one of the key experiments, barley (two distinct varieties) was chosen as a crop plant for simplification of the molecular analysis. The aim of this study was to investigate the role of K supply on plant response mechanisms to excess light energy (e.g. ROS generation, ROS scavenging enzymes) in drought situations (Fig. 4). Overall, there was a significant correlation between H_2O_2 concentrations and leaf K content. Furthermore, the study clearly showed that the effect of leaf K level on leaf H_2O_2 concentration was more pronounced than the effect of drought stress. Under drought, catalase (CAT) activity was higher in Low-K plants, but in later stages (during the recovery stage) ascorbate peroxidase (APX) activity showed higher correlation with leaf K content. Further investigations are needed to quantify the importance of various ROS scavenging enzymes under various abiotic stress situations. In 2014, Ershad Tavakol also joined an ongoing field experiment in Hannover-Ahlten to study similar physiological parameters in relation to magnesium (Mg) supply in wheat.

0.02mM K | 0.02mM K Drought



0.4mM K | 0.4mM K Drought



Spring barley treated with low potassium (0.02 mM K) and adequate K supply (0.4 mM K) under well-watered and drought conditions. (Photos: Tavakol)

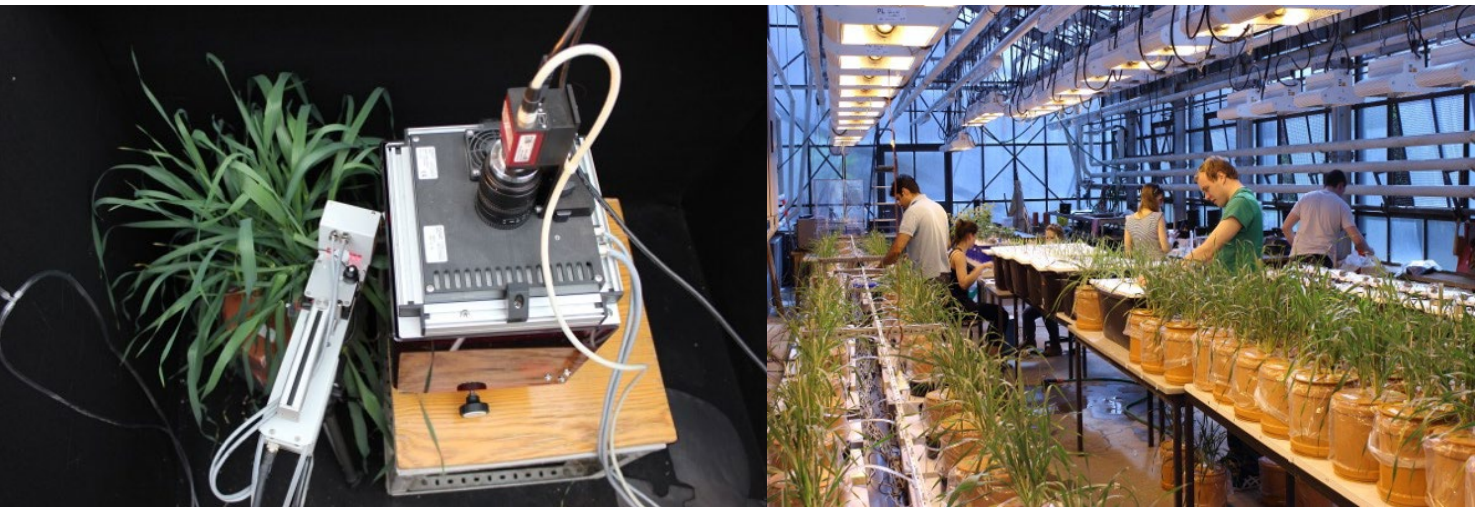
In 2015, molecular analyses will be performed on the plants samples collected in the barley experiment in 2014. The method is based on high-throughput RNA sequencing reading copy numbers of transcribed RNA molecules in the plant cells. The goal of using this study is to assess responses to the abiotic stresses such as drought and potassium deficiency at the genome level. Moreover, based on the findings of this study and the results of earlier experiments, more experiments will be set up in order to study the plants' potential in avoiding phytotoxicity and the responses of candidate genes involved in the respective detoxifying biochemical pathways.

Role of potassium in biomass and intrinsic water use efficiency of cereals under drought (Bálint Jákli, MSc.)

Potassium (K), the major inorganic osmoticum in plants, plays a crucial role in plant-water relations. The consumption of water through transpiration of crop plants is more or less exclusively regulated by stomatal movement, which is facilitated by K. K also enables the transport of assimilates and metabolites to the plant's sink organs like roots and other growing tissues. Mild K deficiency might not show any visible symptoms under optimum environmental conditions however, when plants are exposed to abiotic stresses such as drought, their K demand increases in the course of their metabolic acclimation to such unfavourable conditions.

A major focus of IAPN is to screen, adapt or develop remote sensing techniques for early in vivo detection of plant stresses. Radiation reflected or re-emitted from plant surfaces across the visible and infrared light spectrum provides a range of information about the plant's status. In 2014, a number of experiments were conducted in the IAPN greenhouse in order to study the combined effects of K deficiency and drought on non-invasively accessible information about the performance of various crops. In these studies, the visualization of leaf or canopy temperatures as an indicator for transpiration was of special interest.

Remote sensing provides a wealth of data whose interpretation requires improved understanding of the interactions between crops and their environment across temporal and spatial scales. Thus in 2014, research activities were expanded for example to the interaction between K nutrition and water availability focusing on gas exchange processes within the crop plant agro-ecosystem. Transpiration in relation to K availability was studied on the level of single leaves to entire plants and complex canopies under both greenhouse and field conditions. The integration of processes determining water use efficiency on the leaf level to more intricate systems such as entire plants and canopies still remains a challenging task for 2015.



Measuring leaf gas exchange (GFS 3000, Walz, Germany) and chlorophyll fluorescence (Imaging PAM MAXI, Walz, Germany) of barley grown in nutrient solution (left). IAPN team members at harvest in the greenhouse (right). (Photos: Jákli)

Water and nutrient use efficiency in mixed cropping systems (Annika Lingner, MSc.)

On the background of the present demographic development and climate change there is a growing need to improve the sustainability and productivity of agricultural systems. To this end it is promising to explore innovative management systems with improved resource use efficiency. Intercropping, defined as any system of multiple cropping within the same space, has been recognized earlier and can be used as an alternative for example in bio-energy cropping systems. Intercropping of cereals with legumes is particularly common and, introducing N_2-fixing legumes into cereal-based crop rotations may reduce mineral N fertilizer use. Cropping systems like multi-species crop stands that are more complex are likely to be less dependent on external inputs as for example their rooting patterns are expected to be more diverse and responsive to soil heterogeneity. Knowledge of resource use efficiency (water, light and nutrients) is essential to understand the performance of mixed-cropping systems. However partitioning of water, nutrients and light between component crops is difficult to study, principally because of difficulties in measuring and modelling their resource utilization.

As climate scenarios predict more frequent incidents of temporary drought in many regions world-wide and, as in future more production will be located in drought-prone environments, today's plant breeding activities for such complex cropping systems need to include drought tolerance as breeding target. Therefore, among others, water use efficiency (WUE) and/or effective use of water (EUW) are important determinants of plant production under drought conditions.

At the University of Göttingen, a research and development consortium was established in 2014 to amalgamate scientists from a broad range of disciplines from Plant Breeding to Agronomy, Grassland Science, Forest Sciences, Plant Nutritional Physiology, Plant Pathology, Ecology and Socio-Economy with private breeding companies. This activity is entitled "Novel genotypes for mixed cropping allow for IMProved sustainable land use ACross arable land, grassland and woodland" (IMPAC). The overall hypothesis is that novel genotypes designed for mixed cropping will markedly improve production without increasing inputs. In the scope of this project, Annika Lingner started using two separate approaches to measure water use efficiency and effectiveness in water use of each crop stands during the first two years of the field experiments. By measuring changes in gravimetric soil water content and biomass production, Annika Lingner will estimate the agronomic WUE. Stable isotope analysis (^{13}C and ^{18}O) in plant tissues will be used to measure intrinsic WUE in critical phases of the vegetation period. Secondly, an unmanned airborne vehicle (drone) is used to take thermography and NDVI images in order to calculate transpiration, biomass and leaf area index and evaporative water demand. After selecting promising breed lines in the field experiment, more detailed physiological research will be done under controlled conditions in greenhouse studies.

Annika Linger started her position at IAPN in September 2014 for training and setting up a number of greenhouse pre-experiments within ongoing IAPN magnesium research activities. Here, coffee and sugar beet studies were set up in close collaboration with Prof. Dr. Ismail Cakmak. These experiments were focused on the investigation of light sensitivity in coffee and sugar beet plants under varying Mg and water supply.

Knowledge Transfer

Teaching at the Georg-August-Universität Göttingen

An important aim of the IAPN is to provide students with a solid training in plant nutrition physiology. For this, alongside traditional lectures, seminars and lab training, innovative forms of teaching are also used, which mean that university education is closely tied in with current research and practice. In this way, students are able to obtain insights into the global issues of plant nutrition during the course of their studies rather than having to wait until they have graduated. Interaction with visiting scientists at the IAPN is particularly encouraged; they often bring current themes from agricultural practices in their home countries, and by exchanging ideas with students and scientists at the IAPN are able to identify and work on knowledge gaps, in order to obtain rapid feedback from real-world agriculture.

One of the topics available during the winter semester is the postgraduate module "Plant-Water-Nutrient Relations in Semi-arid and Arid Agriculture". In this module, students learn about water-shortage problems in crop cultivation (seasonal and temporary drought), CO_2 assimilation and transpiration in C3 and C4 plant species, nutrient cycles in semi-arid and arid climates and the influence of plant-water-nutrient relations on water-usage efficiency. In the module's exercises, students become familiar with analysis methods for determining water-usage efficiency, gas exchange, thermography, chlorophyll fluorescence and working with stable isotopes for water-usage efficiency research. In addition, Prof. Senbayram has taken responsibility for designing and leading several exercises within the framework of the "Nutrient Dynamics in the Root-Soil Contact Space" and "Multisensing Approach for Research on Water Use Efficiency", which are part of the agronomy Master's syllabus. Of course, students have the option of doing their dissertations at the IAPN, at undergraduate, Master's and PhD level.

Completed Thesis in 2014

Christian Wenthe, BSc Thesis (2014):
Emissions of N_2O from mixed cropping systems e.g. arable land and woodland.

Moritz Bredemeier, BSc Thesis (2014):
Einfluss verschiedener Magnesiumchlorid-Konzentrationen auf die NH_3-Emission aus landwirtschaftlich genutzten Böden nach Gärrestapplikation. ("The influence of different magnesium chloride concentrations on NH_3 emission from soils used for agriculture after digestate application")

Salim Trouchaud, BSc Thesis (2014):
Thermografische Erfassung von Trockenstress an Linsen-Selektionen von Standorten mit unterschiedlicher Wasserversorgung. ("Thermographic measurement of drought stress on types of lentil in locations with varying water supply")

Matthias Damm, BSc Thesis (2014):
Einfluss von Trockenstress und Magnesiummangel auf die CO_2-Assimilation und Ertragsbildung von Gerste. ("The influence of drought stress and magnesium deficiency on CO_2 assimilation and yield levels of barley.")

Junior Professor Dr. Mehmet Senbayram and MSc students discuss experiment results and the role of magnesium in sunflowers experiencing drought stress in pot experiments. (Photo: Schröder)

PhD student Ershad Tavakol and teaching assistant Ulrike Kierbaum demonstrate for MSc students how to measure hydrogen peroxide concentrations in damaged sunflower plant tissue. (Photo: Schröder)

The event "IAPN in dialogue" sometimes takes place at the premises of the institute's greenhouse. (Photo: Dach)

New forms of knowledge transfer: "IAPN in Dialogue"

In September 2013 the first event "IAPN in Dialogue" took place in the IAPN's greenhouse. Within the series of events "IAPN in Dialogue" researchers and practitioners from around the world report about their projects. In May 2014 participants were invited to discuss the topic of "Micronutrients in crop production and human health in developing countries" with Prof. Ismail Cakmak from Sabanci University in Istanbul. The discussion highlighted the influence of zinc deficiency on crop cultivation and on human nutrition, particularly in developing and threshold countries. "Zinc deficiency due to malnutrition causes significant health problems, especially in children," said Prof. Cakmak. "Nearly 50% of the global cereal crops are affected by zinc deficiency. This reduces yields and decreases the zinc content of grains, thereby also shrinking the zinc content of cereal-based foods. Prof. Cakmak introduced agricultural solutions for alleviating zinc deficiency in crops.

At "IAPN in Dialogue" in September 2014 Christine Kyomugisha of the Sasakawa Africa Association (SAA) presented in an inspiring lecture on the concept of Farmer Learning Platforms, which is used for knowledge transfer to smallholder farmers in Uganda. She was a guest at IAPN in September to gain knowledge of applied plant nutrition and specialized methods of soil and plant analysis. Similar to Daniel Olol, who visited IAPN for some weeks in 2013, Christine Kyomugisha works as "Program Officer Crop Productivity Enhancement" within the project "Growth for Uganda". The Farmer Learning Platforms are a group-based learning approach. They include class room training, practical training, field demonstrations and field days.

Prof. Ismail Cakmak stayed as a guest researcher at the IAPN in 2014. The Humboldt Foundation award winner gave a speech on possible ways of overcoming zinc-deficiency in food by fertilization at the second "IAPN in Dialogue". (Photo: Dach)

Christine Kyomugisha of the Non-Governmental Sasakawa Africa Association (SAA) presented the concept of Farmer Learning Platforms, which is used for knowledge transfer to smallholder farmers in Uganda. She was a guest at IAPN in September 2014. (Photo: Dach)

Impetus for an interdisciplinary dialogue: the International Symposium on Magnesium in Crop Production, Food Quality and Human Health

The first international symposium on the role of magnesium as a mineral crop nutrient for improving the quality of food products and for human health was held from 8-9 May 2012, and drew more than 120 participants from 30 countries. The conference was hosted by the Institute of Applied Plant Nutrition (IAPN) at the Georg-August University in Göttingen, which had been ceremoniously opened only one week earlier. The symposium was organized in cooperation with the Sabanci University, Istanbul, and the Center for Magnesium Education and Research, Hawaii.

The symposium was intended to kick off an intense interdisciplinary discourse by internationally leading magnesium researchers. "Normally, plant researchers, animal food producers and physicians meet at their respective expert or trade conferences," said Prof. Klaus Dittert, the scientific director of the IAPN and co-organizer of the symposium. "This symposium has successfully facilitated the very first interdisciplinary exchange of knowledge on the functions and characteristics of magnesium." International speakers as well as participants would now like to continue this discourse, and jointly promote a higher degree of recognition for the relevance of magnesium in all disciplines.

Participants of the 1st International Symposium on Magnesium 2012 in Göttingen. (Photo: Herwig)

The interdisciplinary dialogue continues

At the 2nd International Symposium on Magnesium held with approximately 100 people in São Paulo, the importance of the element magnesium for the health of humans, animals and plants was discussed intensively for the first time in Brazil. Fertilization with magnesium has not as yet been customary in Brazilian agriculture, but so far, there is much evidence that the element's importance for soil fertility and the quality of the crops in Brazil is not adequately recognized. "The current situation in Brazil was an important reason for us to organize the second symposium on magnesium in Brazil", said Prof. Klaus Dittert, scientific director of the IAPN and co-organizer of the symposium. "With the symposium, we were able to initiate a dialogue together with our Brazilian research partners on the importance of magnesium in agriculture. It is very important to put the already available knowledge about magnesium fertilization into practice more intensively, but also to formulate open research questions jointly with national and local practitioners and scientists."

The organising team of the 2014 Magnesium Symposium: Luís Prochnow, Ismail Cakmak, Andrea Rosanoff, Klaus Dittert, Andreas Gransee (from left to right). (Photo: IAPN)

Participants of the 2nd International Symposium on Magnesium 2014 in São Paulo, Brazil. (Photo: IAPN)

Participants registering for the 2nd International Symposium on Magnesium 2014 in São Paulo, Brazil. (Photo: IAPN)

Guests at IAPN

The transfer of knowledge and building up of worldwide networks in the area of plant nutrition are important tasks of the IAPN. Visiting scientists and visiting students are therefore very welcome at the institute. Apart from students spending time at IAPN for an internship, three visiting researchers stayed at IAPN in 2014.

One of them was **Prof. Ismail Cakmak** from Sabanci University, Istanbul, who was awarded the renowned Georg Forster Research Award of the Alexander-von-Humboldt Foundation. During his one-year stay in Göttingen, Prof. Cakmak focused on the relevance of potassium and magnesium for partitioning of photo assimilates within plants, and their effects on plant shoot and root growth.

For the second time **Prof. Jehad Abbadi** stayed at IAPN. He is an Associate Professor of Biology at the Al-Quds University in East Jerusalem, Palestine. Sponsored by the Al-Quds University, he conducted research at the IAPN for two months in summer 2014. As a visiting scientist, his work served to deepen and to evaluate studies that he had commenced within the scope of a previous research visit, which had been sponsored by the DAAD, on the effects of potassium on safflower and sunflower. In semi-arid regions, both of these plants are important oil crops. Due their substantial demand for potassium, soil availability of K may not suffice to adequately nourish sunflowers and safflower – in particular when water gets short.

A guest from Uganda was **Christine Kyomugisha**. Within the project "Growth for Uganda", she works as a "Program Officer Crop Productivity Enhancement". She is employed by the Sasakawa Africa Association (SAA) – an NGO working to combat hunger and to improve the livelihoods of small scale farmers. Christine Kyomugisha visited the IAPN in September 2014, in order to learn more about plant nutrition and on soil and plant analysis methods.

Publications

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

Cabeza, R.; Köster, B.; Liese, R.; Lingner, A.; Baumgarten, V.; Dirks, J.; Salinas-Riester, G.; Pommerenke, C.; Dittert, K. & Schulze, J. (2014) A RNA sequencing transcriptome analysis reveals novel insights into molecular aspects of the nitrate impact on the nodule activity of Medicago truncatula. Plant Physiol., 164, 400-411.

Cabeza, R.A.; Liese, R.; Lingner, A.; von Stieglitz, I.; Neumann, J.; Salinas-Riester, G.; Pommerenke, C.; Dittert, K. & Schulze, J. (2014) RNA-seq transcriptome profiling reveals that Medicago truncatula nodules acclimate N_2 fixation before emerging P deficiency reaches the nodules. J. Exp. Bot. 65, 6035-6048.

Cabeza, R.A.; Lingner, A.; Liese, R.; Sulieman, S.; Senbayram, M.; Tränkner, M.; Dittert, K. & Schulze, J. (2014) The activity of nodules of the supernodulating mutant Mt(sunn) is not limited by photosynthesis under optimal growth conditions. International Journal of Molecular Sciences 15, 6031-6045.

Chen, R.R.; Senbayram, M.; Blagodatsky, S.; Myachina, O.; Dittert, K.; Lin, X.G.; Blagodatskaya, E. & Kuzyakov, Y. (2014) Soil C and N availability determine the priming effect: microbial N mining and stoichiometric decomposition theories. Global Change Biology, 20, 2356-2367

Claus, S.; Taube, F.; Wienforth, B.; Svoboda, N.; Sieling, K.; Kage, H.; Senbayram, M.; Dittert, K.; Gericke, D.; Pacholski, A. & Herrmann, A. (2014) Life-cycle assessment of biogas production under the environmental conditions of northern Germany: greenhouse gas balance. J. Agric. Sci. 152, S172-S181.

Köster, J.R.; Dittert, K.; Mühling, K.H.; Kage, H. & Pacholski, A. (2014) Cold season ammonia emissions from land spreading with anaerobic digestates from biogas production. Atmospheric Environment, 84, 35-38.

Lebender, U.; Senbayram, M.; Lammel, J. & Kuhlmann, H. (2014) Effect of mineral nitrogen fertilizer forms on N_2O emissions from arable soils in winter wheat production. J. Plant Nutr. Soil Sci. 177, 722–732.

Lebender, U.; Senbayram, M.; Lammel, J. & Kuhlmann, H. (2014) Impact of mineral N fertilizer application rates on N_2O emissions from arable soils under winter wheat. Nutr. Cycl. Agroecosystems 100, 111–120.

Lewicka-Szczebak, D.; Well, R.; Köster, J.R.; Fuß, R.; Senbayram, M.; Dittert, K. & Flessa, H. (2014) Experimental determinations of isotopic fractionation factors associated with N_2O production and reduction during denitrification. Geochim. Cosmochim. Acta 134, 55-73.

Schmeer, M.; Loges, R.; Dittert, K.; Senbayram, M.; Horn R. & Taube, F. (2014) Legume-based forage production systems reduce nitrous oxide emissions. Soil & Tillage Research 143, 17-25.

Senbayram, M.; Chen, R.; Wienforth, B.; Herrmann, A.; Kage, H.; Mühling, K.H. & Dittert, K., (2014) Emission of N_2O from Biogas Crop Production Systems in Northern Germany. BioEnergy Res. 4, 1223-1236.

Tao, Y.Y.; Qu, H.; Li, Q.J.; Gu, X.H.; Zhang, Y.N.; Liu, M.J.; Guo, L.; Liu, J.; Wei, J.J.; Wei, G.J.; Shen, K.R.; Dittert, K. & Lin, S. (2014) Potential to improve N uptake and grain yield in water saving Ground Cover Rice Production System. Field Crops Res. 168, 101-108.

Zörb, C.; Senbayram, M. & Peiter, E. (2014) Potassium in agriculture - status and perspectives. J. Plant Physiol. 171, 656–669

Conference Papers – Posters

Jákli, B., M. Tränkner and K. Dittert (2014) Effects of potassium deficiency on water use efficiency of Triticum aestivum. International Conference "Plant Nutrition 2014 – From Basic Understanding to Better Crops" of the German Society of Plant Nutrition (DGP), Halle (Saale), 10-12 September 2014.

Tavakol, E., M. Tränkner, B. Jàkli, K. Dittert and M. Senbayram (2014) Adequate K supply enhances tolerance to drought situations via optimized NPQ and antioxidant activity in spring wheat. International Conference "Plant Nutrition 2014 – From Basic Understanding to Better Crops" of the German Society of Plant Nutrition (DGP), Halle (Saale), 10-12 September 2014.

Tränkner, M., E. Tavakol, K. Dittert and M. Senbayram (2014) Adequate magnesium supplied barley plants have higher biomass-water use efficiency and display lower sensitivity to high light. International Conference "Plant Nutrition 2014 – From Basic Understanding to Better Crops" of the German Society of Plant Nutrition (DGP), Halle (Saale), 10-12 September 2014.

Tränkner, M. (2014) Magnesium deficient barley plants have lower biomass water-use efficiency and display increased sensitivity to high light. 2nd International Symposium on Magnesium in Crop Production, Food Quality and Human Health, São Paulo, 5th November 2014.

Cooperation

In Science

Partner	Location
Al-Quds Open University	Jerusalem, Palestine
Bodengesundheitsdienst	Ochsenfurt, Germany
Bordeaux Sciences Agro – INRA	Bordeaux, France
CIP International Potato Institute, Central Africa Branch	Nairobi/Kenya, Germany
Deutsche Landwirtschafts-Gesellschaft (DLG)	Frankfurt/Bernburg, Germany
Ege University, Department of Soil Science and Plant Nutrition	Izmir/Turkey
Forschungszentrum Jülich, Institut für Bio- und Geowissenschaften, Agrosphere	Jülich, Germany
Harran University, Department of Soil Science and Plant Nutrition	Sanliurfa, Turkey
Institute of Sugar Beet Research (IfZ)	Göttingen, Germany
International Plant Nutrition Institute	George Town, Malaysia
K+S KALI GmbH	Kassel, Germany
K+S Analytik- und Forschungszentrum (AFZ)	Unterbreizbach, Germany
KWS SAAT SE	Einbeck, Germany
Land-Data GmbH	Visselhövede, Germany
Leuphana University of Lüneburg – Nachhaltige Landwirtschaft in der Region	Lüneburg, Germany
LUFA Nord-West, Institut für Düngemittel und Saatgut	Hameln, Germany
Norwegian University of Life Sciences, Nitrogen Group	As, Norway
Rothamsted Research, Sustainable Soils and Grassland Systems	North Wyke, UK
Sabanci University, Biological Sciences and Bioengineering Program at Sabanci University	Istanbul, Turkey
Sasakawa Africa Association	Kampala, Uganda
Thünen-Institute – Institute of Climate-Smart Agriculture	Braunschweig, Germany
University of Gießen, Institute of Plant Nutrition	Gießen, Germany
University of Halle, Institute of Plant Nutrition	Halle, Germany
University of Hohenheim, Quality of Plant Products	Stuttgart, Germany
University of Kassel, Organic Plant Production and Agroecosystems Research	Witzenhausen, Germany
University of Kiel, Institute of Plant Nutrition and Soil Science	Kiel, Germany
University of Verona, Department of Biotechnology	Verona, Italy
University of Western Australia, School of Plant Biology	Perth, Australia
Hanninghof Research Station – Yara Int. ASA	Dülmen, Germany

In Teaching

Prof. Holger Brück
YARA GmbH & Co. KG, Dülmen

Prof. Andrea Carminati
Georg-August-Universität Göttingen

Dr. Hendrik Führs
Landwirtschaftskammer Niedersachsen

Dr. Mohsen Zarebanadkouki
Georg-August-Universität Göttingen

Dr. Heike Thiel
K+S KALI GmbH

Dr. Bernd Ditschar
K+S KALI GmbH

Institute of Applied Plant Nutrition (IAPN)
at Georg-August-Universität Göttingen
Carl-Sprengel-Weg 1
37075 Göttingen, Germany
www.iapn-goettingen.de