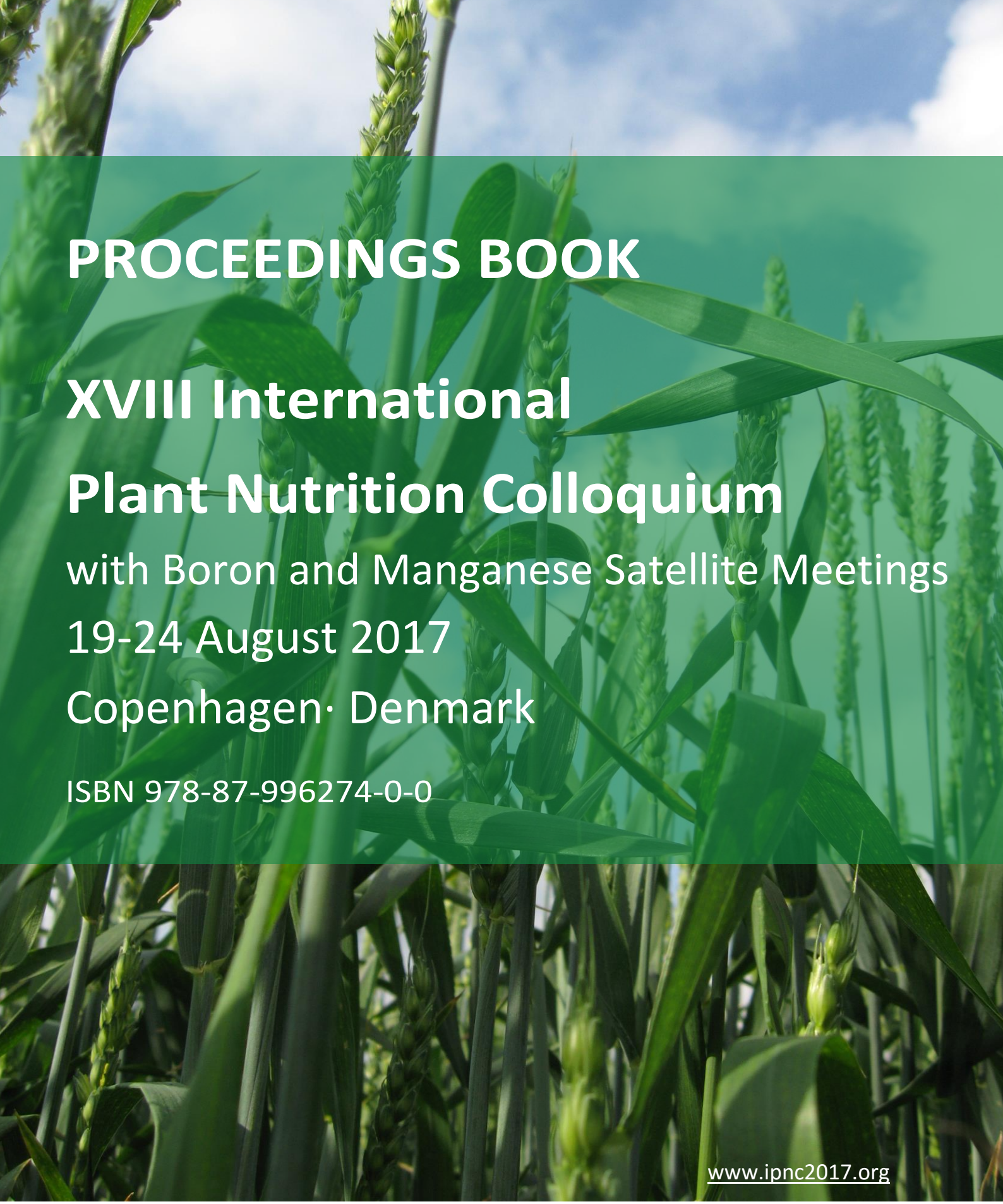

PROCEEDINGS BOOK

XVIII International Plant Nutrition Colloquium

with Boron and Manganese Satellite Meetings

19-24 August 2017

Copenhagen· Denmark

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PROCEEDINGS BOOK

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Dear Colleagues,

The 18th International Plant Nutrition Colloquium (IPNC) took place 21-24 August 2017 at the Tivoli Congress Center in Copenhagen, Denmark. As a lead-up to IPNC 2017, satellite meetings on boron and manganese were organized 19-20 August at the Copenhagen Plant Science Centre.

The IPNC is held every fourth year and has since its start back in 1954 grown to become the most important international meeting on fundamental and applied plant nutrition. The IPNC is organised by the International Plant Nutrition Council, which seeks to advance science-based non-commercial research and education in plant nutrition in order to highlight the importance of this scientific field for crop production, food security, human health and sustainable environmental protection.

The main theme of IPNC 2017 was *Plant Nutrition for Global Green Growth*. This theme was chosen to highlight that plant nutrients are fundamental drivers for the successful intensification of the global crop production, which is required in order to meet the demands of the future bio-based society for nutritious food, feed and raw materials. The themes of IPNC 2017 covered a broad range of topics in plant nutrition and nutrient management. As a new initiative, a session on new analytical techniques in plant nutrition was organised. The *Marschner Young Scientist Award* for outstanding PhD students and early-career researchers with a potential to become future research leaders was during IPNC 2017 handed out to four young scientists allowing them to present their outstanding work in a general session of the colloquium.

Close to 600 participants from more than 50 different countries attended IPNC 2017, while the two satellite meetings hosted about 150 participants. The meetings provided an excellent frame for exchange and transfer of information on new developments in the field of plant nutrition. The essence of the presented information is disseminated in this e-book, which we hope will be a valuable source of information for all with an interest in the field of plant nutrition.

The next IPNC will take place in Brazil in 2021. Look forward to meet you there.

Jan K. Schjoerring

Chairman of IPNC 2017

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ABSTRACTS BORON AND MANGANESE SATELLITE MEETINGS

ORAL AND POSTER PRESENTATIONS

SCIENTIFIC PROGRAMMES

XVIII International Plant Nutrition Colloquium 2017 Location: Tivoli Congress Center, Copenhagen, Denmark	
17:00-21:00	20 August, Sunday **Registration and poster mounting** **Welcome reception from 19:30 – Tivoli Foyer**
	21 August, Monday
9:00-10:20	**Opening session – Tivoli Congress Hall** Chair: **Ismail Cakmak, Turkey** Past President of the International Plant Nutrition Council **9:00-9:10** **Welcome by Jan K. Schjoerring, Denmark** Chairman of the Colloquium and President of International Plant Nutrition Council **9:10-9:20** **Welcome by Thomas Bjørnholm, Denmark** Pro-rector for Research, University of Copenhagen **9:20-9:40** **H.C. Andersen parade** **9:40-10:20** **Opening plenary presentation** Plant nutrition for global green growth - Designing next generation fertilizers for crop nutrition **Mike McLaughlin, Australia**
10:20-10:50	Coffee break and poster viewing (Theme 1-2)
10:50-12:30	**Plenary keynote presentations – Tivoli Congress Hall** Chair: **Walter Horst, Germany** **10:50-11:15** Exploiting the root-soil microbiome for benefit to plant nutrition **Alan E. Richardson, Australia** **11:15-11:40** Phosphorus promotes nitrogen fixation in soybean **Hong Liao, China** **11:40-12:05** Non-mycorrhizal strategies to acquire phosphorus from soils with very low phosphorus availability **Hans Lambers, Australia** **12:05-12:30** Plant nutrients - The functional ionome **Philip White, UK**
12:30-14:00	Lunch, poster viewing and speakers corner (Theme 1-2)

	21 August, Monday	
14:00-15:45	Parallel sessions	
	Theme 1: Plant-microorganism interactions and nutrient acquisition – Tivoli Congress Hall Chair: **Iver Jakobsen, Denmark**	**Theme 2: Nutrient functions in plants – Carstensen Auditorium** Chair: **Toru Fujiwara, Japan**
14:00-14:15	Bio-effectors for alternative plant nutrition strategies: practical aspects for successful applications in crop production **Günther Neumann, Germany**	Potassium supply mitigates photo-oxidative damage under osmotic stress by avoiding ROS generation and improving metabolism **Ershad Tavakol, Germany**
14:15-14:30	A quantitative analysis of phosphorus acquisition efficiency of direct pathway and mycorrhizal pathway of maize **Gu Feng, China**	Photoprotective responses and PSII functionality under magnesium deficiency **Merle Tränkner, Germany**
14:30-14:45	The root external mycelium of mycorrhizal fungi has a key role in plant nutrition but is suppressed by the soil microbiota **Carla Cruz Paredes, Denmark**	Functional impacts of phosphorus deficiency on the photosynthetic machinery **Andreas Carstensen, Denmark**
14:45-15:00	Identifying the mechanisms behind mycorrhiza-enhanced plant zinc nutrition **Stephanie Watts-Williams, Australia**	Frost increases internal potassium requirements for alleviation of sterility and grain yield of wheat **Richard Bell, Australia**
15:00-15:15	Small signalling peptides – New regulators of symbiotic interactions **Thomas de Bang, Denmark**	Limiting physiological processes for maize growth under magnesium deficiency **Stephan Jung, Germany**
15:15-15:30	Complementarity between citrate and phytase exudation enhances acquisition of soil phosphorus by plants **Timothy George, UK**	Potassium–silicon interaction under drought stress condition in barley **Seyed Abdollah Hosseini, France**
15:30-15:45	Do bioeffectors matter? - A meta-analysis of more than 150 experiments **Jonas Duus Stevens Lekfeldt, Denmark**	Sulfur deficiency negatively affects nitrate root-to-shoot translocation and leaf cytokinin concentration in wheat **Jose Maria García-Mina, Spain**
15:45-16:45	Coffee break, poster viewing and speakers corner (Theme 1-2)	

	21 August, Monday
16:45-18:00	**Marschner session: Nurturing the future – Tivoli Congress Hall** Chair: **Jan K. Schjoerring, Denmark** **16:45-17:00** **Award ceremony** **17:00-17:15** Role of soil micronutrients and fertilizer management in crop nutrition under variable smallholder cropping **Muneta Grace Manzeke, Zimbabwe** **17:15-17:30** Identification of transporters involved in metal stress tolerance in plants **Kengo Yokosho, Japan** **17:30-17:45** Proteaceae from severely phosphorus-impoverished habitats preferentially allocate phosphorus to photosynthetic cells **Patrick E. Hayes, Australia** **17:45-18:00** Multi-dimensional stable isotope analysis – A novel analytical tool in plant nutrition **Kristian Holst Laursen, Denmark**
18:00-18:10	**18:00-18:10** **SOPIB Award ceremony** Chair: **Michel Marchand, France** SOPIB Awardee: **Dilek Anaç, Turkey**
Evening	Poster viewing and welcome reception – City Hall

	22 August, Tuesday
8:30-10:10	**Plenary keynote presentations – Tivoli Congress Hall** Chair: **Patrick Brown, USA** **8:30-8:55** A paradigm of nutrient management for fertilizer industry and global society **Fusuo Zhang, China** **8:55-9:20** Factors affecting the permeability and efficacy of foliar fertilisers: An update **Victoria Fernandez, Spain** **9:20-9:45** Molecular mechanisms for distribution of mineral elements in plants **Jian Feng Ma, Japan** **9:45-10:10** Silicon mediates ion uptake, transport and homeostasis in plants under mineral stress **Miroslav Nikolic, Serbia**
10:10-10:45	Coffee break and poster viewing (Theme 3-4)

	22 August, Tuesday	
10:45-12:30	Parallel sessions	
	Theme 3: Nutrient management and fertilizers in crop production – Tivoli Congress Hall Chair: **Karl H. Muehling, Germany**	**Theme 4: Nutrient uptake, transport and homeostasis – Carstensen Auditorium** Chair: **Nicolaus von Wirén, Germany**
10:45-11:00	From research to farmers: An example of knowledge transfer on potassium benefit in Turkey **Dilek Anaç, Turkey**	Iron-nicotianamine transporters regulate long distance shoot to root signalling of iron deficiency in Arabidopsis **Elsbeth Walker, USA**
11:00-11:15	Efficiency of foliar applications of potassium sulphate on field crop production **Michel Marchand, France**	The iron-chelate transporter OsYSL9 is crucial in iron distribution in developing rice grain **Naoko Nishizawa, Japan**
11:15-11:30	Establishing high-yielding maize system for sustainable intensification in China **Xinping Chen, China**	Associative transcriptomics reveals potential new targets for calcium and magnesium uptake in *Brassica napus* **Thomas Alcock, UK**
11:30-11:45	Proximal and remote quantification of nitrogen fertilizer demand – A case study in sugar beet **Frank Liebisch, Switzerland**	Increasing rice nitrogen use efficiency by altering nitrate transporter activity **Guohua Xu, China**
11:45-12:00	Effects of split nitrogen application on grain protein concentration and composition in winter wheat at different nitrogen fertilisation rates **Anne Rossmann, Germany**	The kinase CIPK23 inhibits ammonium transport in *Arabidopsis thaliana* **Benjamin Neuhäuser, Germany**
12:00-12:15	Nutrient management increases crop water use efficiency **Dejene Eticha, Germany**	The strigolactone transporter PDR1 as a tool to enhance plant yield on nutrient poor soil **Lorenzo Borghi, Switzerland**
12:15-12:30	Comparing ammonium sulfate to recent sulfur fertilizers in sulfur availability to crop growth **S.H. (Norman) Chien, USA**	Cis- and epi-regulation of amino acid transporters contribute to inhibition of ear growth by nitrogen limitation in maize **Xuexian Li, China**
12:30-14:00	Lunch, poster viewing and speakers corner (Theme 3-4)	

	22 August, Tuesday
14:00-15:40	**Plenary keynote presentations – Tivoli Congress Hall** Chair: **Leon Kochian, Canada** **14:00-14:25** The root endodermis acts as a gateway for vascular transport **David E. Salt, UK** **14:25-14:50** AMT-type transporters mediate radial transport pathways and root-to-shoot translocation of ammonium **Nicolaus von Wirén, Germany** **14:50-15:15** Making waves ... Einstein's lessons for crop nutrition research **Paul E. Fixen, USA** **15:15-15:40** Plant nutritional challenges in an industrialized agriculture – The Danish lesson **Leif Knudsen, Denmark**
15:40-16:30	Coffee break, poster viewing and speakers corner (Theme 3-4)

	22 August, Tuesday	
16:30-18:30	Parallel sessions	
	Theme 3: Nutrient management and fertilizers in crop production – Tivoli Congress Hall Chair: **Fusuo Zhang, China**	**Theme 4: Nutrient uptake, transport and homeostasis – Carstensen Auditorium** Chair: **Patrick Bienert, Germany**
16:30-16:45	Phosphorus availability of fertilizers recycled from urban waste water in combination with bioeffectors – Pot and field experiments **Iris Wollmann, Germany**	Natural variation in *Arabidopsis thaliana* to identify genes underlying zinc deficiency response **Valeria Ochoa, The Netherlands**
16:45-17:00	Improving soil of low phosphorus availability with biochar produced from bonemeal **Sander Bruun, Denmark**	Zinc controls leaf length via FLOWERING LOCUS T in early-flowering *Arabidopsis thaliana* **Uwe Ludewig, Germany**
17:00-17:15	Rock phosphate-enriched compost in combination with PGPR; a cost-effective source for better soil health and wheat productivity **Motsim Billah, Pakistan**	Systemic regulation of the response to zink deficiency **Scott A. Sinclair, Germany**

	22 August, Tuesday	
17:15-17:30	The effects of pH on root morphology and physiology of narrow-leaf lupine, grown with a recycled phosphorus source **Ana A. Robles Aguilar, Germany**	Proteomic responses to zinc deficiency stress in maize (*Zea mays* L.) **Wang Hong, China**
17:30-17:45	BASS - A new sulfur fertilizer **Diedrich Steffens, Germany**	Role of trichomes, stomata, and the cuticle in the absorption of foliar-applied zinc fertiliser **Cui Li, Australia**
17:45-18:00	Efficiency of polyhalite as a fertilizer supplying potassium, magnesium, calcium and sulfate **Uri Yermiyahu, Israel**	Absorption and distribution of foliar-applied zinc (^{70}Zn) in maize and wheat grown with low or adequate zinc supply **Raheela Rehman, Turkey**
18:00-18:15	Tomato responses to polyhalite in comparison to other conventional potassium fertilizers in Southeast Brazil **Kiran Pavuluri, UK**	Rice HRZ ubiquitin ligases are involved in both iron deficiency and excess responses and jasmonate signalling **Takanori Kobayashi, Japan**
18:15-18:30	Leaching rate of selected sulphur fertilizers; understanding selenate - sulphate competition **Linxi Jiang, UK**	Jack of all trades: Inositol polyphosphates regulate phosphorus and mineral cation nutrition as well as jasmonate-dependent defenses **Gabriel Schaaf, Germany**
Evening	Poster viewing	

	23 August, Wednesday
8:30-10:10	**Plenary keynote presentations – Tivoli Congress Hall** Chair: **Ciro A. Rosolem, Brazil** **8:30-8:55** The role of high throughput root phenotyping in crop improvement for adaptation to acid soils **Leon Kochian, Canada** **8:55-9:20** Genetic architecture of root system architecture in maize determined by genome-wide association analyses **Lixing Yuan, China** **9:20-9:45** Arsenic biogeochemistry in paddy systems and impacts on crop production and quality **Fang-jie Zhao, China** **9:45-10:10** Novel green fertilizers and soil amendments promoting recirculation of plant nutrients **Lars Stoumann Jensen, Denmark**
10:10-10:45	Coffee break and poster viewing (Theme 5-7)

	23 August, Wednesday	
10:45-12:30	Parallel sessions	
	Theme 5: Nutrient availability in soils, toxicity and remediation – Tivoli Congress Hall Chair: **Rufus Chaney, USA**	**Theme 6: Roots and genetics of crop nutrient uptake – Carstensen Auditorium** Chair: **Jian Feng Ma, Japan**
10:45-11:00	How does phosphorus accumulate in a clayey tropical soil under fertilizer sources and cover crops? **Amin Soltangheisi, Brazil**	Genetic control of root type-specific response of lateral roots to local high nitrate in maize **Peng Yu, China**
11:00-11:15	Bread from stone: Greenlandic glacial flour as soil amendment for tropical weathered soils **Andreas de Neergaard, Denmark**	Nutrient uptake-based assessment of genetic variation of nitrogen and phosphorus response in rice **Yoshiaki Ueda, Japan**
11:15-11:30	Effect of deoxymugineic acid application to calcareous soil compared with other chelating agents **Motofumi Suzuki, Japan**	Genetic variation for nitrogen responsiveness in Australian spring wheat **Mamoru Okamoto, Australia**
11:30-11:45	The positive effects of the Silicic Acid Agro Technology **Henk-Maarten Laane, The Netherlands**	Genetic variants associated with the root system architecture of oilseed rape under contrasting phosphate supply **Lei Shi, China**
11:45-12:00	Nutrient uptake by barley grown in chemically amended salt affected soil **Ibrahim Abdulrazzaq, Iraq**	Categorizing wheat genotypes for phosphorus efficiency; parameters vs methods **Tariq Aziz, Pakistan**
12:00-12:15	Phytoremediation by elucidating chemical compounds which alter accumulation of or response to caesium in plants **Shin Ryoung, Japan**	Dynamics of localised supply of nitrogen-species in soil and their relevance for root system morphology – What have we learned from Drew? **Sebastian Blaser, Germany**
12:15-12:30	Identification of glycosyltrans-ferases involved in biosynthesis of hydrolyzable tannins in an aluminum-resistant eucalyptus tree **Ko Tahara, Germany**	Taking the phosphorus: Genetic mapping of QTLs for soybean protein, volume, seed and pod weight **Gokhan Hacisalihoglu, USA**
12:30-14:00	Lunch, poster viewing and speakers corner (Theme 5-7)	

	23 August, Wednesday
14:00-15:30	**Plenary keynote presentations – Tivoli Congress Hall** Chair: **Michael A. Grusak, USA** **14:00-14:25** Fighting human malnutrition with plant nutrition **Ismail Cakmak, Turkey** **14:25-14:50** GeoNutrition: Spatial aspects of hidden hunger **Martin R. Broadley, UK** **14:50-15:10** Identification and characterization of novel metal homeostasis genes in bread wheat **Alexander Johnson, Australia** **15:10-15:30** Genotype behaviour, water management and zinc fertilization in different rice systems; their implications for grain zinc biofortification **Hafeez ur Rehman, Pakistan**
15:30-16:00	Coffee break and poster viewing (Theme 5-7)

	23 August, Wednesday	
16:00-17:30	Parallel sessions	
	Theme 5: Nutrient availability in soils, toxicity and remediation – Tivoli Congress Hall Chair: **Lars Stoumann Jensen, Denmark**	**Theme 7: Plant nutrition and food quality – Carstensen Auditorium** Chair: **Ross Welch, USA**
16:00-16:15	Root/rhizosphere processes and management for improving nutrient use efficiency and yield in Chinese maize-cropping systems **Jianbo Shen, China**	Biofortification of cassava storage roots to achieve nutritionally significant levels of iron and zinc **Michael A. Grusak, USA**
16:15-16:30	Restricted CO_2 diffusion through the leaf mesophyll and not stomatal regulation limits photosynthesis in potassium deficient sunflower **Bálint Jákli, Germany**	Integrated fertilizer management harvests more grain zinc of wheat **Chunqin Zou, China**
16:30-16:45	Growth rate, crop duration, nitrogen, phosphorus and potassium accumulation of rice when grown in fertile and low-fertile soils **Lalith Suriyagoda, Sri Lanka**	Overexpression of OsPCS1 reduces arsenic concentration in rice grain **Satoru Ishikawa, Japan**

	23 August, Wednesday	
16:45-17:00	Interactive effects of bicarbonate and two types of Iranian local squash as rootstock on the nutrient uptake in cucumber plants **Hamid Reza Roosta, Iran**	Influence of fertilization strategies on the mineral nutrient content in cereal grains **Karin Hamnér, Sweden**
17:00-17:15		Soil amendments to reduce cadmium accumulation by leafy vegetables from cadmium-mineralized lockwood loam **Rufus Chaney, USA**
17:15-17:30		Effects of foliar application and fertigation of potassium on yield and fruit quality of apple cv Gala **Mehdi Ben Mimoun, Tunis**
Evening	Poster viewing and Gala dinner – Langelinie Pavilion	

	24 August, Thursday
8:30-10:10	**Plenary keynote presentations – Tivoli Congress Hall** Chair: **Sylvester Oikeh, Kenya** **8:30-8:55** Impact of climate change in plant nutrition **Marta Vasconcelos, Portugal** **8:55-9:20** Achieving nutrient efficient cropping systems with higher productivity and lower emissions **Jørgen E. Olesen, Denmark** **9:20-9:45** Imaging and molecular speciation analysis of essential plant nutrients **Søren Husted, Denmark** **9:45-10:10** Synchrotron X-ray approaches for examining trace metals in plants **Peter Kopittke, Australia**
10:10-10:45	Coffee break and poster viewing (Theme 8-10)

	24 August, Thursday	
10:45-12:30	Parallel sessions	
	Theme 8: Nutrient cycling, ecosystems and climate change – Tivoli Congress Hall Chair: **Jørgen E. Olesen, DK**	**Theme 9: New analytical methods in plant nutrition – Carstensen Auditorium** Chair: **Philip White, UK**
10:45-11:00	Nitrous oxide and methane emissions from paddy soils as affected by cropping systems and nitrogen management **Xuejun Liu, China**	Live imaging of ion movement in plants by Real-Time Radioisotope Imaging System (RRIS) **Ryohei Sugita, Japan**
11:00-11:15	Post-harvest N_2O emissions in bioenergy oilseed rape rotations regulated by soil residual nitrogen not by residue properties **Sarah Köbke, Germany**	Multi element bioimaging of *Arabidopsis thaliana* roots **Daniel Persson, Denmark**
11:15-11:30	Management of nitrogen fertilizer to reduce nitrous oxide (N_2O) emission and ammonia (NH_3) volatilization from coffee plantation **Ana Paula Packer, Brazil**	Magnesium, but not calcium, co-localises with phosphorus in specific cell types in leaves **Paula Pongrac, UK**
11:30-11:45	Growth and distribution of upland NERICA rice roots in low-nitrogen management system in West Africa **Sylvester Oikeh, Kenya**	Revealing radial ion transport pathways in roots by combining the fluorescence activated cell sorting with inductively coupled plasma mass spectrometry **Paulina Flis, UK**
11:45-12:00	Closing the yield gap and improving soil fertility with fertilizer and HNUE hybrids in Sub-Saharan Africa **Heather Pasley, USA**	Non-destructive growth analysis identifies major differences in nitrogen response in wheat **Trevor Garnett, Australia**
12:00-12:15	Effect of predicted climate change on yield and quality of wheat under varied zinc and nitrogen fertilization **Muhammad Asif, Turkey**	Hyperspectral imagery for insight into large-scale indoor vertical farming **April Agee Carroll, USA**
12:15-12:30	Yield, land productivity, nitrogen use and transformations in oat beans intercrops in semi-arid region of Northeast China **Xiaomin Feng, China**	Photosynthetic iron-use efficiency provides a means for screening elite barley genotypes that adapt to iron deficiency with unknown mechanism **Akihiro Saito, Japan**
12:30-13:30	Lunch, poster viewing and speakers corner (Theme 8-10)	

	24 August, Thursday	
13:30-14:30	Parallel sessions	
	Theme 8: Nutrient cycling, ecosystems and climate change – Tivoli Congress Hall Chair: **Ken Giller, The Netherlands**	**Theme 10: Novel technologies for fertilizers and fertilization – Carstensen Auditorium** Chair: **Pai Pedas, Denmark**
13:30-13:45	Why do smallholder farmers in Papua New Guinea, Fiji, Kiribati, The Philippines and Central West Africa not spend resources on management of soil fertility? **Michael Webb, Australia**	The influence of tensides on ZnIDHA 2.0 adhesion to the leaf surface of wheat canola and corn **Anika Mrozek-Niećko, Poland**
13:45-14:00	Nutrient status and vegetative growth in mature smallholder oil palm plantations **Lotte S. Woittiez, The Netherlands**	Zinc doped layered double hydroxides: A new source for zinc fertilization **Sandra López-Rayo, Spain**
14:00-14:15	Fertilizer recommendation method for sustainable cassava intensification **Mirasol Pampolino, Philippines**	Zinc distribution and localization in primed maize seeds and its translocation during early seedling development **Imran Muhammad, Denmark**
14:15-15:30	Coffee break, poster viewing and speakers corner (Theme 8-10)	

	24 August, Thursday
15:30-17:00	**Closing session – Tivoli Congress Hall** Chair: **Jan K. Schjoerring, Denmark** **15:30-16:15** Africa - The plant nutritionists paradise **Ken Giller, The Netherlands** **16:15-16:40** Presentation of poster prizes **16:40-16:55** Introduction to the 19th IPNC 2021 **16:55-17:00** Goodbye

	Boron satellite meeting, 19 August, Saturday Location: Copenhagen Plant Science Centre
9:00 - 9:05	Welcome by **Jan K. Schjoerring, Denmark**

	Session I – Biological functions and transport of boron
9:05 -10:30	Chair: **Jan K. Schjoerring, Denmark** **9:05-9:35** Recent advances in boron sensing and regulation of transport **Toru Fujiwara, Japan** **9:35-9:55** Beyond the wall: Boron, hormones and meristems in maize **Paula McSteen, USA** **9:55-10:15** Critical roles of boron in root growth and uptake of nutrients **Ismail Cakmak, Turkey** **10:15:-10:30** Hormonal regulation of boron stress response: defining key networks controlling root growth inhibition **Maria Reguera, Spain**
10:30-11:00	Coffee break and poster viewing
11:00-12:30	Chair: **Patrick Bienert, Germany** **11:00-11:15** A phenotypic comparison between boron deficiency and RGII disruption responses in Arabidopsis **Isidro Abreu, Spain** **11:15-11:30** Mechanisms of early responses of Arabidopsis roots to boron deprivation **Masaru Kobayashi, Japan** **11:30-11:45** Boron deprivation affects the expression of the Arabidopsis root meristem regulator WOX5 **Christoph Spitzer, Germany** **11:45-12:00** Influence of boron and aluminium on polar auxin transport in root tips **Min Yu, China** **12:00-12:15** The role of boron in vegetative and reproductive development in maize **Michaela Matthes, USA** **12:15-12:30** Development and utilization of cytosolic boric acid sensors for boron-transport studies **Junpei Takano, Japan**
12:30-13:30	Lunch and poster viewing

	Boron satellite meeting, 19 August, Saturday Location: Copenhagen Plant Science Centre
	Session II – Boron in crops, soil and fertilizers
13:30-14:50	Chair: **Patrick Brown, USA** **13:30-14:00** Developing more effective boron fertilizers **Mike McLaughlin, Australia** **14:00-14:10** Evaluation of efficacy of boron metalosate foliar supplement for maximising the yield and quality of pomegranate (*Punica granatum*) **Chickadibburahalli Subbarayappa, India** **14:10-14:20** Boron dynamics in volcanic ash-derived soils **Maria Fernanda Terraza Pira, USA** **14:20-14:30** Efficiency of boron fortified sulphur granules in enhancing yield, uptake and quality of chillies in swell-shrink soils of India **Virendra Goswami, India** **14:30-14:40** Long-term effects of boron fertiliser and weed control on foliar nutrition and growth of eight radiata pine genotypes grown at two contrasting sites in New Zealand **Jianming Xue, New Zealand** **14:40-14:50** Effect of foliar spray of boron metalosate on yield and quality of grapes (*Vitis vinifera*) **Chickadibburahalli Subbarayappa, India**
14:50-15:30	Coffee break and poster viewing

	Boron satellite meeting, 19 August, Saturday Location: Copenhagen Plant Science Centre
	Session III – Genetics, physiology and molecular biology of boron efficiency and tolerance
15:30-17:30	Chair: **Ismail Cakmak** **15:30-16:00** Boron in boreal forest trees and forestry **Tarja Lehto, Finland** **16:00-16:15** Genotype differences from phenotypic to molecular levels in *Brassica napus* in response to boron deficiency **Fangsen Xu, China** **16:15-16:30** Identification of mechanisms contributing to boron efficiency in *Brassica napus* and Arabidopsis **Gerd Patrick Bienert, Germany** **16:30-16:40** Shoot based mechanisms are involved in boron toxicity tolerance in rice **Monika Wimmer, Germany** **16:40-16:50** Differential alternative splicing genes in response to low boron in *Brassica napus* **Lei Shi, China** **16:50-17:00** Boron toxicity responses in plant model species *Brachypodium distachyon* **Esref Erdogan, Turkey** **17:00-17:30** Boron in plant biology: Current knowledge and remaining uncertainties **Patrick Brown, USA**
17:30-19:30	Poster viewing and get-together reception
19:30	Busses leave for the Tivoli Congress Center

	Manganese satellite meeting, 20 August, Sunday Location: Copenhagen Plant Science Centre
9:00-9:05	Welcome by **Søren Husted, Denmark**

	Session I – Manganese transport and homeostasis
9:05-10:25	Chair: **Søren Husted, Denmark** **9:05-9:35** Uptake, distribution and detoxification of manganese in rice **Jian Feng Ma, Japan** **9:35-10:00** Metal transport functions of the Metal Tolerance Protein MTP8 during embryogenesis and germination **Nicolaus von Wirén, Germany** **10:00-10:25** The iron-regulated transporter 1 (IRT1) plays an essential role in uptake, translocation and grain-loading of manganese in barley **Pai Pedas, Denmark**
10:25-10:45	Coffee break and poster viewing
10:45-12:00	Chair: **Jan K. Schjoerring, Denmark** **10:45-11:10** Manganese detoxification and translocation by CDF transporters **Edgar Peiter, Germany** **11:10-11:35** The role of MNX/PAM71-family transporters in manganese homeostasis **Marion Eisenhut, Germany** **11:35-12:00** IRT1 cooperates with NRAMP1 for manganese acquisition by Arabidopsis root **Catherine Curie, France**
12:00-13:00	Lunch and poster viewing

	Session II – Manganese functionality, efficiency and toxicity
13:00-14:45	Chair: **Karl Herman Muehling** **13:00-13:25** The importance of manganese in photosynthesis – Perspectives for improving manganese efficiency in plants **Sidsel Birkelund Schmidt, Denmark**

	13:25-13:45 Combined transcriptome and proteome analysis of maize leaves in response to latent manganese deficiency under high light **Lizhi Long, China** **13:45-14:05** Manganese accumulation in plant foliage: From hypertolerance to toxicity stress **Denise Fernando, Australia** **14:05-14:25** Symptom development and synchrotron-based imaging identify mechanisms of manganese toxicity and tolerance in crop plants **Pax Blamey, Australia**
14:25-15:15	Coffee break and poster viewing

	Session III – Manganese fertilization
15:15-17:00	Chair: **Edgar Peiter, Germany** **15:15-15:40** Effect of stabilized ammonium fertilizers on soil manganese availability and concentration of wheat plants **Karl Herman Muehling, Germany** **15:40-16:00** Novel control-release fertilizers based on layered double hydroxides for manganese nutrition **Sandra López-Rayo, Denmark** **16:00-16:20** Effects of manganese and zinc on disease development of root rot and biomass production in red clover (*Trifolium pratense* L.) **Eva Stoltz, Sweden** **16:20-17:00** Effective strategies to diagnose and correct manganese deficiency in cereals **Søren Husted, Denmark**
17:00-19:00	Poster viewing and get-together reception
19:00	Busses leave for the Tivoli Congress Centre

Silicon mediates ion uptake, transport and homeostasis in plants under mineral stress

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INTRODUCTION

Silicon is the only known mineral element that effectively alleviates multiple environmental stress in many plant species. Over the past decade rapid progress has been made in understanding the mechanisms through which Si mediates mineral excess and/or toxicity stress. It has been demonstrated that Si mediates uptake and transport of mineral elements at excess by regulating expression of various transporter genes (e.g. Kim et al., 2014; Akcay and Erkan, 2016; Che et al., 2016); however, the role of Si in nutrient uptake and transport under nutrient deficiency conditions is still insufficiently understood. In this presentation, I will talk about Si influence on (a) root P-starvation responses for rhizosphere mobilization and uptake of Pi in wheat (*Triticum aestivum*) and (b) acquisition and long-distance transport of Fe in cucumber (*Cucumis sativus*) under low Fe conditions; our recent unpublished work on (c) Si-regulated expression of the transporters involved in Na homeostasis in maize (*Zea mays*) subjected to NaCl stress will also be discussed.

RESULTS AND DISCUSSION

(a) Silicon-mediated P acquisition in wheat

In addition to amelioration of the main soil constrains (H^+ and Al^{3+} rhizotoxicity) for root growth in acid soil by increasing soil pH, Si fertilization significantly increased root exudation rate of citrate and malate for mobilization of Pi in the rhizosphere (Kostic et al., 2017) through up-regulated related anion efflux transporter genes *TaMATE1* and *TaALMT1* in wheat roots. Furthermore, Si also increased exudation rate of the organic anions by roots grown under Al-free and low P conditions. Silicon-increased shoot P concentration to an adequate level (in the range of P-fertilized plants) can also be attributed to the higher expression levels of *TaPHT1;1* and *TaPHT1;*2 transporter genes for Pi uptake compared to both lime-treated (increased soil pH) and P-fertilized wheat plants (Kostic et al., 2017).

(b) Silicon-mediated Fe acquisition and long-distance transport of Fe in cucumber

At the root level, Si increased Fe pools in the root apoplast of cucumber, in parallel with increased accumulation of Fe-mobilizing compounds (organic acids and phenolics) in the root tissue by up-regulating expression of key genes related to their biosynthesis (Pavlovic et al., 2013; Bityutskii et al., 2014). In Fe-deficient cucumber plants, Si up-regulated expression of the Fe-deficiency responsive genes involved in the Strategy 1-based Fe uptake, *CsHA1, CsFRO2* (also known as *CsFRO1)* and *IRT1* (Pavlovic et al., 2013). Furthermore, Si facilitated root-to-shoot movement of Fe complexed by citrate via xylem, by increased concentration of the Fe-chelators, and more directly through the formation of Si-Fe complex in the xylem sap (Pavlovic et al., 2013; Stevic et al., 2016).

At the shoot level, we showed for the first time that Si induces Fe mobilization in older (sink) leaves and increases its retranslocation to younger (source) leaves (Pavlovic et al., 2016). Silicon increased the accumulation of Fe chelator nicotianamine (NA) by up-regulating expression of *CsNAS1* gene responsible for its biosynthesis, which in turn enhances chelation of Fe for NA-mediated Fe transport via phloem. Also, Si up-regulated expression of *CsYSL1* transporter genes responsible for loading of Fe-NA in the source leaves and phloem unloading of Fe in the sink leaves.

(c) Silicon-mediated Na homeostasis in maize

Here we show for the first time that Si significantly decreased Na accumulation in the root apex and cortex of maize plants exposed to mild NaCl stress (40 mM) through up-regulation of the expression of efflux Na^+ transporter gene *ZmSOS1* and down-regulation of the expression of influx transporter gene *ZmHKT1;1*. However, Si also markedly increased the Na concentrations in the xylem sap (and concomitantly in the leaf tissues) by up-regulating ZmSOS1 involved in xylem loading of Na^+. Albeit higher Na accumulation was recorded within the leaf tissue, we clearly demonstrated higher vacuolar to chloroplast sequestration ratio in Si-fed plants which was further supported by higher expression of tonoplast transporter gene *ZmNHX5* for vacuolar Na^+ transport. We also show for the first time that Si significantly increased shoot-to-root Na recirculation via phloem; Si-mediated phloem transport was further confirmed by up-regulated expression of leaf ZmHKT1;1 responsible for Na^+ loading into the phloem.

CONCLUSIONS

The role of Si in modulation of nutrient and other mineral element utilization appears to be more indirect by transcriptional regulation of genes responsible for both root acquisition and tissue homeostasis. Further understanding of how exactly Si regulates the expression of transporter genes will help to improve crop productivity, yield quality and food safety.

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