Plant nutrition courier

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Intumescence injury in greenhouse-grown Russet Burbank may be a calcium related disorder that can be alleviated by calcium supplementation. Atlantic growing under low calcium circumstances has no defects. *Photograph: Department of Horticulture, University of Wisconsin-Madison.*

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Maize cultivars respond differently to banded nutrients

Maize cultivars adapt their root growth differently to nutrient-rich patches. Little is known about possible differences between cultivars of other field-grown crops and about the practical implications of this phenomenon.

Maize cultivars adapt their root growth differently to nutrient-rich patches. Chinese researchers have found this in a split-root experiment with maize hybrids that are exposed to localised nitrogen and phosphorus. Whereas one hybrid was more responsive to nitrogen-rich patches, another responded more to localised phosphorus. The study – published in the Chinese-language *Journal of Plant Nutrition and Fertilizer* – has been conducted by Shenyang Agricultural University and the Key Laboratory of Plant-Soil Interactions, China Agricultural University. The English abstract has no information about the soil type used. With reference to the heterogeneous distribution of nutrients, the researchers state that it is important to understand how roots respond to local nitrogen and phosphorus to help breeding nitrogen- and phosphorus-efficient maize cultivars. Previously other Chinese researchers found that maize genotypes responded differently to local nitrate supply (see article).
A related study led by Jianbo Shen (China Agricultural University) is conducted with two contrasting maize cultivars growing in rhizoboxes filled with calcareous loamy soil. One maize cultivar is bred in the 1950s, when barely any phosphorus fertiliser was used in China. The other is a modern hybrid bred in the 2000s, dating from an era with excessive amounts of applied phosphorus fertiliser. The plants are grown at a relatively low phosphorus level; the nutrient is supplied at different ratios of inorganic phosphorus (monopotassium phosphate) and organic phosphorus (sodium phytate). One of the experiments in this study had rhizoboxes in which phosphorus was applied in patches. The researchers observed that maize genotypes with different phosphorus foraging strategies responded differently to a heterogeneously supply and limited availability of this nutrient. The study sheds light on the differential optimal phosphorus supply patterns or phosphorus forms for different maize genotypes to improve phosphorus efficiency, the researchers say in their research report in the journal *Plant and Soil*. They further concluded that a mixture of different maize genotypes with diverse root traits may increase the stability of maize production in various phosphorus environments, just like in grasslands. The past years Shen and his team have conducted a long range of studies on the response of maize to band-applied nitrogen and/or phosphorus fertilisers (see e.g. article, article, article, article and article).

Editorial

Cultivar differences in response to fertiliser banding largely overlooked

Maize profits from band application of ammonium plus phosphate. Ammonium uptake induces proton release and causes rhizosphere acidification, which results in an enhanced uptake of phosphate. Nothing new, but Chinese researchers repeatedly report that maize cultivars respond differently to localised nutrients. Scientists suggest to utilise such genetic differences to breed maize cultivars with improved phosphorus use efficiency.

Insight into this phenomenon is not only necessary for maize breeders, but also for the everyday practice of maize growers. However, varietal differences in response to banded fertiliser are largely overlooked in field experiments and grower advices. And thus maize growers cannot take advantage of the phenomenon that some cultivars are better adapted to banded nutrients than others. A pressing question in this context is whether cultivars of other row crops also differ in their response to heterogeneously available nutrients.
Researchers usually report the varieties used in experiments with banded fertilisers. Information about cultivar-specific behaviour with regard to fertiliser banding is missing in the vast majority of research reports. This lack of attention to different responses to fertiliser banding raises the question whether results of fertiliser experiments are biased, or not.

Cover crops enhance phosphate uptake most on soils low in phosphorus

Cover crops benefit the phosphorus nutrition of main crops in different ways. Lupins, for instance, are good in mining (sparingly) soluble phosphorus pools. Grasses and legumes – and to a lesser extend also lupins – increase main crop phosphorus uptake via a positive impact on soil microorganisms like arbuscular mycorrhizal fungi. Cruciferous cover crops have a relatively high concentration of phosphorus in their shoots. The most pronounced benefits of cover crops on the phosphorus uptake of main crops are found on soils low in phosphorus and with reduced tillage or no-till, according to scientists at universities in Australia and Germany. They conducted an extensive meta-analysis that is published in the form of an open access article in *Plant and Soil*. In many cases, cover crop biomass determines the magnitude of the beneficial effects on the phosphorus uptake by the subsequent crop. The researchers therefore recommend appropriate cover crop management.

Cover crops increase annual evapotranspiration

Cover crops affect the water balance by increasing annual evapotranspiration by canopy transpiration. Researchers at the French National Institute for Agricultural Research (INRA) conclude this from a meta-analysis of 28 studies. Based on this analysis they quantified the mean drainage reduction with cover crops at 27 mm, compared to that of bare soil. The meta-analysis is published in *Agronomy for Sustainable Development*. With water drainage the researchers mean water that is unavailable to plant roots and likely to recharge groundwater; therefore they only used data of water measured at a depth of 90 cm below ground level. The researchers were unable to determine the key factors that explained the variability in reduced drainage. They say this is mainly due to the low number of published studies usable for the meta-analysis and the strong interactions between soil, climate, cover crop species and cropping systems. The researchers didn't account for the long-term effect of cover crops on the water holding capacity of soil.

Potassium reduces frost-induced grain sterility

Australian farmers in the central Wheat belt are more often confronted with frost during and after flowering of their wheat and barley crops than before. Western Australian researchers have examined a possible contribution of potassium chloride to the alleviation of frost damage in wheat in two years spanning field experiments. They found that an improved potassium status of wheat can increase grain set and yield during moderate frosts, but not during severe frosts. The field experiments have been conducted at frost-prone sites, with a low soil potassium status – a widespread condition in Western Australia. The study is published in the journal *Plant and Soil*.

Foliar-applied selenium counteracts mycotoxin stress

Foliar-applied selenium reduces phytotoxic effects of the mycotoxin zearalenone in young wheat, oat and barley plants. The fungal metabolite – produced by some *Fusarium* and *Gibberella* species – causes oxidative stress that is counteracted by a low dose of selenium ions in the form of sodium selenate (Na_2SeO_4). The protective effect of selenium is found by Polish investigators and published in an open access article in the *Journal of the Science of Food and Agriculture*. In a previously published study they found that selenium protected germinating wheat grains to some extend to oxidative stress caused by zearalenone. Some years ago, researchers at several Turkish universities reported a protective role of selenium (Se^{4+}) against aflatoxin B_1-induced DNA damage in faba bean and maize (see article).

Zinc enters sunflower leaves via trichomes and cuticle

Trichomes represent an important pathway for foliar-applied zinc sulphate to enter sunflower leaves. The cuticle pathway is also important, but the stomatal pathway is not likely to be important for the entrance of foliar-applied zinc sulphate into sunflower leaves. Australian scientists reported this in a paper in the journal *Annals of Botany*.

Silicon ameliorates magnesium deficiency

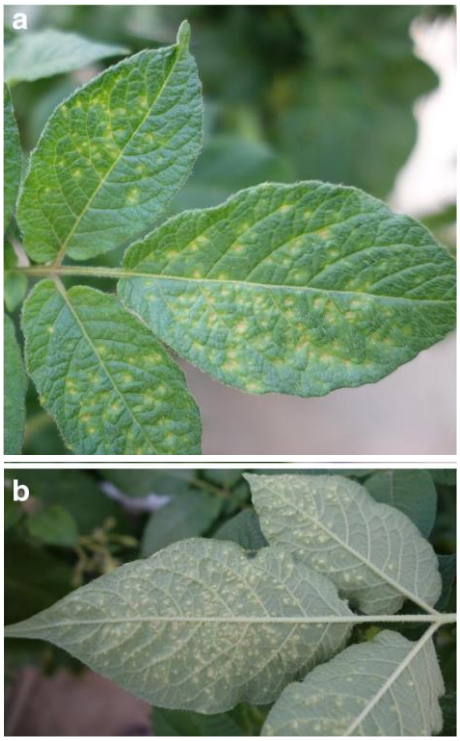
Silicon supplementation ameliorates magnesium deficiency in young maize plants. The plants maintain their growth and increase significantly the levels of chlorophyll and soluble sugars, compared to magnesium-deficient plants that don't receive silicon. Researchers at the fertiliser company Roullier and at the German Leibniz-Institute of Plant Genetics and Crop Plant Research have found this in an experiment with greenhouse-cultivated plants growing on a magnesium-deficient substrate. As silicon source they used monosilicic acid ($Si(OH)_4$) that was freshly prepared by passing sodium silicate solution through a column filled with cation-exchange resins. The researchers further observed that silicon supplementation resulted in an increase of stress-related plant metabolites and of specific plant hormones, so that the plants were more vital than magnesium-deficient congeners that didn't receive silicon. Results of this experiment are published in the *International Journal of Molecular Sciences*. According to the researchers, this research is the first study into effects of silicon application to magnesium-deprived plants. The past two years, researchers at Roullier were involved in studies on silicon effects in barley (article and article), rapeseed (article and article) and tomato (article).

Nitrogen affects insect defence by silicon

Silicon reduces true armyworm feeding damage in maize. Biologists at Western University (Canada) have found this in bioassays with larvae of the true armyworm (*Pseudeletia unipuncta*) feeding on maize, supplied or not with silicon. Silicon application led to increased larvae mortality, likely because early instars with poorly developed mandibles could not feed effectively. Nitrogen application reduced the effectiveness of the silicon defence. Larvae fed on plants treated with both silicon and nitrogen survived better than larvae fed on plants treated with silicon only. Details of this study are published in *Entomologia Experimentalis et Applicata*.

Calcium prevents intumescences in greenhouse-grown Russet Burbank

Greenhouse-grown potato plants can develop intumescences on their leaves. A similar disorder is known from greenhouse-cultured vegetables and ornamentals. Potato researchers Jiwan Palta and Justin Schabow are investigating whether measures applied by greenhouse ornamental growers or vegetable growers are also useful in growing potatoes in the glass-house. Results of their first experiment indicate that intumescence injury may be a calcium related disorder that can be alleviated by calcium supplementation. The two University of Wisconsin-Madison researchers conducted their experiment with two cultivars: Atlantic and Russet Burbank. Both cultivars are grown in a climate-controlled greenhouse, on a 1:1:1 potting mixture of sphagnum peat moss, vermiculite and perlite, and supplied with liquid fertiliser with or without calcium chloride. Atlantic growing under low calcium circumstances showed no defects, while Russet Burbank leaves had lots of intumescences when growing under the same low calcium regime. The researchers observed that calcium supplementation prevented or mitigated intumescence development in Russet Burbank. In line with results from studies with other crops they recommend to lower the relative air humidity and to provide supplemental UV radiation. They reported about their work in an article that is published in the *American Journal of Potato Research*. They had already shared their experiences at an annual conference of the American Society for Horticultural Science (see abstract).



Intumescence injury on adaxial (a) and abaxial (b) leaflet surfaces of potato cultivar Russet Burbank, 10 weeks after planting. The greenhouse-grown plants are given 1 mM Ca^{2+}.
Photographs: Department of Horticulture, University of Wisconsin-Madison.

Research into effects of silicon on phosphorus use efficiency

Researchers at São Paulo State University are investigating whether it is possible to decrease phosphorus fertiliser rates with the help of silicon application and to maintain potato tuber yields at the same level. They therefore investigate whether silicon supplementation affects phosphorus use efficiency. A greenhouse experiment with the potato cultivar Agata planted in soil didn't yield any effects of silicon application on phosphorus use efficiency. This experiment – conducted in fall 2013 – is recently published in the *Journal of Plant Nutrition* (see abstract). Previously researchers of the same Brazilian research group reported that in-furrow application of silicon along with triple superphosphate didn't result in higher tuber yield or differences in tuber grade, compared to phosphate fertiliser only. In still another experiment, however, they found positive effects of soil and foliar application of silicon in drought-stressed potato (see article in *Agronomy Journal*).

Leaf flavonoid content useful indicator for latent nitrogen deficiency

Belgian researchers detect nitrogen deficiency in potato before symptoms are visible by the naked eye. They do so by remote sensing with a tool that detects increased flavonoid contents instead of a reduction in chlorophyll contents. The past years they examined chlorophyll fluorescence tools to assess the nitrogen content of potato crops, with the objective to determine fluorescence indicator thresholds to help farmers in the decision whether in-season application of nitrogen is required. *Read more on page 10 of this issue*.

Publications about potato nutrition research

General

Seed potato minituber production in an aeroponic system under tropical conditions: electrical conductivity and plant density. Journal of Plant Nutrition 41(2018)17:2200-2209

Mapping, sensing, sampling and analytics

Critical dilution curves for nitrogen, phosphorus, and potassium in potato group Andigenum. Agronomy Journal 111(2019)1:419-427

Possibility of recommending potassium application rates based on a rapid detection of the potato petiole K status with a portable K ion meter. American Journal of Potato Research 96(2019)1:48-54

Delineating soil management zones using a proximal soil sensing system in two commercial potato fields in New Brunswick, Canada. Canadian Journal of Soil Science 98(2018)4:724-737

Comparison of optical indicators for potato crop nitrogen status assessment including novel approaches based on leaf fluorescence and flavonoid content. Journal of Plant Nutrition 41(2018)20:2705-2728

Publications about potato nutrition research

Application technology

Efficiency of P fertigation for drip-irrigated potato grown on calcareous sandy soils. Potato Research 62(2019)1:97-108

Green manure / cover crops

Field evaluation of potato N needs following forage legumes. American Journal of Potato Research 96(2019)1:62-68
The impact of cover crops and foliar application of micronutrients on accumulation of macronutrients in potato tubers at technological maturity stage. European Journal of Horticultural Science 83(2018)6:345-355

Nitrification and urease inhibitors / Specific release

Russet potato yield, quality, and nitrogen uptake with enhanced efficiency fertilizers. Agronomy Journal 111(2019)1:200-209
Nitrogen source and rate effects on irrigated potato in tropical sandy soils. Agronomy Journal 111(2019)1:378-389

Nitrogen

Russet potato yield, quality, and nitrogen uptake with enhanced efficiency fertilizers. Agronomy Journal 111(2019)1:200-209
Nitrogen source and rate effects on irrigated potato in tropical sandy soils. Agronomy Journal 111(2019)1:378-389
Nitrogen fertility and cultivar effects on potato agronomic properties and acrylamide-forming potential. Agronomy Journal 111(2019)1:408-418
Critical dilution curves for nitrogen, phosphorus, and potassium in potato group Andigenum. Agronomy Journal 111(2019)1:419-427
Field evaluation of potato N needs following forage legumes. American Journal of Potato Research 96(2019)1:62-68
The impact of cover crops and foliar application of micronutrients on accumulation of macronutrients in potato tubers at technological maturity stage. European Journal of Horticultural Science 83(2018)6:345-355
Potato in response to nitrogen nutrition regime and nitrogen fertilization. Field Crops Research 231(2019):115-121
Nitrogen fertilization effects on the leaf chemical concentrations in Russet Burbank potato. Field Crops Research 232(2019):40-48
Impact of integrated management of nitrogen fertilizers on yield and nutritional quality of potato. Journal of Plant Nutrition 41(2018)19:2482-2494
Comparison of optical indicators for potato crop nitrogen status assessment including novel approaches based on leaf fluorescence and flavonoid content. Journal of Plant Nutrition 41(2018)20:2705-2728

Phosphorus

Critical dilution curves for nitrogen, phosphorus, and potassium in potato group Andigenum. Agronomy Journal 111(2019)1:419-427
The impact of cover crops and foliar application of micronutrients on accumulation of macronutrients in potato tubers at technological maturity stage. European Journal of Horticultural Science 83(2018)6:345-355
Phosphorus and silicon effects on growth, yield, and phosphorus forms in potato plants. Journal of Plant Nutrition 42(2019)3:218-233
Efficiency of P fertigation for drip-irrigated potato grown on calcareous sandy soils. Potato Research 62(2019)1:97-108

Potassium

Critical dilution curves for nitrogen, phosphorus, and potassium in potato group Andigenum. Agronomy Journal 111(2019)1:419-427
Possibility of recommending potassium application rates based on a rapid detection of the potato petiole K status with a portable K ion meter. American Journal of Potato Research 96(2019)1:48-54
The impact of cover crops and foliar application of micronutrients on accumulation of macronutrients in potato tubers at technological maturity stage. European Journal of Horticultural Science 83(2018)6:345-355

Calcium

Intumescence injury in the leaves of Russet Burbank potato plants is mitigated by calcium nutrition. American Journal of Potato Research 96(2019)1:6-12
The impact of cover crops and foliar application of micronutrients on accumulation of macronutrients in potato tubers at technological maturity stage. European Journal of Horticultural Science 83(2018)6:345-355

Silicon

Does the application of silicon and Moringa seed extract reduce heavy metals toxicity in potato tubers treated with phosphate fertilizers? Environmental Science and Pollution Research 25(2018)17:16776-16787
Phosphorus and silicon effects on growth, yield, and phosphorus forms in potato plants. Journal of Plant Nutrition 42(2019)3:218-233
Growth of potato genotypes under different silicon concentrations. Advances in Horticultural Science 32(2018)2:289-295
Determination of optimal acidity and concentration of nano and micro sodium silicate on efficiency of foliar application of potato plantlets. Pizhūhishhā-yi zirāī-i Īrān 16(2018)2:355-368

Mycorrhiza etc.

Soil extract from an alfalfa (*Medicago sativa* L.) field improves potato rhizosphere enzyme activity and microbial quantity in a pot experiment. European Journal of Horticultural Science 83(2018)6:356-363

Silicic acid prevents soil acidification after drip fertigation with ammonium nitrate

Apple trees that are weekly fertigated with ammonium nitrate profit from addition of silicic acid (H_4SiO_4) to the fertigation solution. The silicon-treated trees are less affected by internal bark necrotic disorder, have stronger growth and yield more apples. Fruit nutrition researcher Paweł Wójcik from the Research Institute of Horticulture (Skierniewice, Poland) has found this in a three years spanning field experiment with 'Red Delicious' apple trees on sandy loam. Wójcik attributes the effects of silicic acid application to a reduction of soil acidification beneath the drippers, which resulted in a reduced root uptake of manganese and aluminium. Details of this study are reported in the journal *Scientia Horticulturae*. In a related study, Wójcik found indications that liming should be applied annually at a dose enabling the neutralization of fertigation-induced soil acidification to 'Delicious' group apple orchards fertigated with ammonium nitrate and planted on coarse-textured soil. In this study he examined the effects of different liming strategies after drip fertigation with ammonium nitrate. Results of this study have been published in the *Journal of Elementology*.

Foliar-applied phosphorus affects post-storage apple quality

Foliar applied phosphorus enhances blush colouration of apple fruits, but may also lead to increased greasiness and sooty blotch after long term storage. Researchers the AAFC Summerland Research and Development Centre reported these undesirable side effects in the *Canadian Journal of Plant Science* (article abstract). The Canadian researchers have found this in an investigation into possible effects of phosphorus foliar fertilisation four and two weeks before harvest of the apple cultivar Ambrosia.

Urea helps plant activator to protect cucumber against bacterial disease

Benzothiadiazole treatment and a low dose of urea in the nutrient solution alleviates angular leaf spot disease in cucumber. Researchers at the University of Łódź observed this effect in an experiment with hydroponically-grown cucumbers. The cucumber plants are inoculated with the pathogenic bacterium *Pseudomonas syringae* pv. *Lachrymans*, the cause of this disease. The Polish researchers conclude that treatment with the plant activator benzothiadiazole prior to infection, combined with a low dose of urea, may have a positive influence on the nitrogen management, leading to the inhibition of disease symptom progress. They further conclude that the benzothiadiazole treatment modifies nitrogen metabolism toward efficient ammonium (NH_4^+) management. Results of this study are presented in the journal *Scientia Horticulturae*.

Poinsettia cuttings benefit from chelated calcium

Foliar application of calcium chelate (Ca-EDTA) improves the postharvest durability of unrooted cuttings from poinsettia. Researchers at Clemson University have found this in an experiment with poinsettia (*Euphorbia pulcherrima*) stock plants that weekly received a calcium spray. They published their study in *Horttechnology*. They observed in this study a greater impact of Ca-EDTA on leaf mechanical strength than with calcium chloride sprays in a previous study with cuttings of poinsettia and zonal geranium (*Pelargonium* × *hortorum*).

Tipburn in lisianthus is a matter of calcium distribution

Tipburn caused by local calcium deficiency is a serious problem in several lisianthus cultivars. Researchers at the Chiba University (Japan) are investigating plant traits related to this disorder. They recently found that the occurrence of tipburn is caused mainly by the inability of the plant to translocate adequate amounts of calcium to the tips of the upper leaves. Calcium acquirement competence, however, was not significantly associated with tipburn severity and incidence in lisianthus cultivars, according to the researchers in a paper published in *Scientia Horticulturae*. In a related study they observed that high air humidity conditions did not always increase tipburn severity in lisianthus cultivars (see paper in *Agronomy*).

Nitrogen recommendations app for ornamentals

The current version of the Plant Nitrogen Recommendations application can only be recommended for a selection of the range of ornamental plants. Researchers at the Department of Horticulture and Landscape Architecture at Oklahoma State University have found this in experiments with four floricultural crops. They report about the app in the *Journal of Plant nutrition*. The app contains a database of SPAD, atLEAF and Leaf N concentration values for various horticultural crops. These nitrogen values can be used as a reference for growers to determine plant nitrogen status based on chlorophyll sensor or foliar analysis values. The past years the researchers evaluated the use of optical sensors to monitor the nitrogen status in a range of ornamentals.

Foliar-applied calcium improves freezing tolerance of forsythia

Five sprays of calcium nitrate from June onwards with four-week intervals increases freezing tolerance of *Forsythia x intermedia* significantly. Nursery crop researchers at the Research Institute of Horticulture (Skierniewice, Poland) have found this in an experiment with the frost-resistant standard cultivar 'Spectabilis' and two newer, more susceptible cultivars. They reported this effect of calcium nitrate application in the *Journal of Plant Nutrition*. The researchers have planned follow-up experiments to determine the effectiveness of commercially calcium fertilisers to improve the cold tolerance of woody plants.

Handheld tool for detection of latent phosphorus deficiency

The photosynthesis process offers a unique marker to detect latent phosphorus deficiency in early growth stages. Danish plant scientists discovered this fingerprint of phosphorus deficiency and offer a portable tool to monitor crops.

The P-tester attached to a leaf clip and ready for measurement.
Picture: University of Copenhagen Department of Plant and Environmental Sciences

The young barley plants look green and healthy. Nothing betrays that they are already deficient in phosphorus for several weeks. But Danish plant scientists know how to detect phosphorus deficiency in this early growth stage. At the University of Copenhagen Department of Plant and Environmental Sciences they discovered a connection between plants with phosphorus deficiency and their fluorescence pattern: when a plant moves from darkness to light, it fluoresces to get rid of some of the energy of light until photosynthesis runs at full speed. This fluorescence pattern is affected by the plant's lack of phosphorus. The Danish researchers use a chlorophyll fluorescence meter to measure this fluorescence pattern in leaves that are dark adapted for at least 25 minutes prior to performing this measurement.

The measurement is based on chlorophyll *a* fluorescence, which reflects the efficiency of the electron transfer in photosynthesis. Since phosphorus is used in the composition of the energy molecule adenosine triphosphate (ATP), the formation of this molecule is reduced at low phosphorus availability. This ultimately inhibits the cascade of processes involved in the electron transfer from photosystem II to photosystem I, which is an important part of photosynthesis. The system is very sensitive and dynamic, and by analysing the plant's unique fluorescence pattern, the researchers have developed a mathematical model that can estimate the actual phosphorus content of each plant. Based on this model, a handheld fluorescence meter has been developed, so that the measurements can be made and interpreted directly in the field. This is done by sending the measurements directly to a smartphone and via a newly developed app the fluorescence spectra are analysed and presented in an easily understandable graphic interpretation. Results of this joint project with the Danish company Foss Analytics indicate that the method could be used for almost all crops without calibration.

Device

The model behind the handheld device is developed primarily based on barley plants, says Jens Frydenvang, but it has been successfully tested in a wider variety of plants. Together with his colleagues at the University of Copenhagen Department of Plant and Environmental Sciences he is now conducting field trials in spring barley and potatoes. They are also performing a series of high temperature and light intensity experiments in climate chambers in order to understand the impacts of these parameters on the chlorophyll *a* fluorescence spectra. With his research into sensitive detection of phosphorus deficiency using chlorophyll *a* fluorescence, Frydenvang paved the way for the commercial exploitation of the unique fingerprint of phosphorus deficiency. His colleague Andreas Carstensen further explored the impacts of phosphorus deficiency on the photosynthetic machinery, to diagnose the phosphorus status of a crop (see paper and paper). Frydenvang, Carstensen and their colleague Søren Husted are the founders of the University of Copenhagen spin-off company SpectraCrop that brings the handheld tool on the market. P-tester – as the tool is branded – can also measure the photosynthetic efficiency and the plant vitality-index. The price of a P-tester is € 5,000 excluding shipment. SpectraCrop is still in a phase of 'beta-testing' and asks the early adopters to share as much as possible of both data and metadata from their measurements to improve both the model and the associated app. Both method and a specialised fluorometer are covered by a series of patent applications (see AU2013401489, CA2921262, CN105556287, EP3049792, US20160245751, WO2015043623). These patent applications also cover other plants nutrients, particularly sulphur, copper and manganese.

A decade ago another spin-off company named NutriNostica launched the NN-Easy55 chlorophyll fluorometer, adapted to detect latent manganese deficiency. Although the P-tester and the NN-Easy 55 both measure chlorophyll *a* fluorescence spectra, there are currently no plans to combine the two tools.

Tractor-mounted tool to detect latent nitrogen deficiency

Belgian researchers detect nitrogen deficiency in potato before symptoms are visible by the naked eye. They do so by remote sensing with a tool that detects increased flavonoid contents instead of a reduction in chlorophyll contents.

A tractor with a front-mounted fluorometer linked to the rear-attached fertiliser spreader - that is what researchers at the Walloon Agricultural Research Center have in mind. In this way the Belgian researchers want to adjust the second nitrogen dressing in potato to the actual demand of the crop in real time. The fluorometer they are thinking off must measure the flavonoid content of the leaf epidermis. Field experiments with two potato cultivars demonstrated that the flavonoid content of the epidermis is a reliable and sensitive indicator of a crop's nitrogen status. Plants suffering from nitrogen deficiency show a significant increase of the flavonoid content, prior to a decrease of the chlorophyll content, say precision farming specialists Jean-Pierre Goffart and Feriel Ben Abdallah from the Gembloux-based research centre. Goffart concludes from the three-years spanning potato field experiment that the flavonoid content is a more promising indicator of the nitrogen status of a crop than the chlorophyll content. Moreover, the flavonoid content is not influenced by the water content of the canopy, he says, whereas chlorophyll readings do depend on the water content of a crop's foliage. A zero nitrogen zone or an over-fertilised zone is needed to properly interpret the flavonoid measurements.
The past years the researchers examined chlorophyll fluorescence tools to assess the nitrogen content of potato crops, with the objective to determine fluorescence indicator thresholds to help farmers in the decision whether in-season application of nitrogen is required. Goffart and his colleagues compared in-season plant readings of four handheld devices to test which approach offered the best results: two fluorometers (Dualex and Multiplex), a radiometer (Cropscan) and a chlorophyll meter (Yara N tester). A part of this work is published in the *Journal of Plant Nutrition*.

Continuous measurements
The current generation of fluorometers can only make point measurements. Goffart and his colleagues hope they can develop a tool that will be suitable for continuous measurements. They do this job with the French company Force-A, the manufacturer of the portable Dualex and Multiplex fluorometers. The objective is a fluorometer to mount on the front of a tractor and that steers a rear-attached fertiliser spreader. The flavonoid signal is too weak to measure it by a drone-mounted fluorometer.
The flavonoid approach is reminiscent of the tractor-mounted Yara N-Sensor that measures the crop's light reflectance at specific wave bands related to chlorophyll content and biomass. A more or less similar approach is developed by the Danish researcher Anton Thomsen during his work at the Aarhus University Department of Agroecology (Denmark). Thomson and his colleagues found that weekly measurements of the ratio vegetation index (RVI) and the leaf area index (LAI) are sufficient to detect nitrogen deficiency in potato crops.
The Belgian researchers have just started experiments in winter wheat to examine whether the leaf flavonoid content is a suitable measure for the rate of the widely practiced third nitrogen dressing. With these experiments they follow French researchers, who have previously established a relationship between the leaf flavonoid content and the nitrogen status of wheat.

Low-cost tool for on-site diagnosing of a crop's phosphorus status

A mortar and pestle, a garlic press, a glass vial, a sachet with a phosphate reagent, a handheld colorimeter and distilled water - that are the ingredients for a diagnostic tool to determine on-site a crop's phosphorus status. With these inexpensive implements and materials it is possible to measure the phosphorus concentration in extracts from fresh crop leaves within three to five minutes, according to a team of researchers at Japanese universities and the Philippine International Rice Research Institute. The researchers examined the usefulness of this technique for lowland rice, in order to offer agronomists and extension specialist a simple and low-cost diagnosing tool. They found that the phosphorus concentration in fresh leaves was closely correlated with the phosphorus concentration of oven-dried leaves measured with the standard molybdenum-blue method in the laboratory. Although not as accurate as the laboratory method, the new method can easily detect phosphorus deficiency of rice in the field (and possibly other cereal crops) without requiring costly, off-site equipment, according to the researchers. They present their method in a short article in the *Journal of Plant Nutrition and Soil Science*.

Reactive extrusion extends phosphate release profile of APP fertilisers

Ammonium polyphosphate hydrolyses in soil to plant-available orthophosphate. Chemical engineers at the Sichuan University have found a way to make the phosphate release profile of ammonium polyphosphate (APP) fertilisers more synchronous to the phosphorus demand of crops. For this purpose they prepared APP by reactive extrusion of a mixture of monoammonium phosphate and urea in a co-rotation twinscrew extruder. Increasing the screw rotation speed enhances the slow-release properties of the APP extrudate, the researchers reported in the journal *Chemical Engineering & Processing: Process Intensification*. In a second paper published in the *Chemical Engineering Journal* they report about process mechanisms and kinetics.
The Chinese scientists found that an improved phosphorus delivery profile does not depend on the molecular weight of the ammonium polyphosphate units; instead the multiformity of the phosphorus species is more significant. They therefore conclude that obtaining a higher molecular weight need not be the goal of the APP fertiliser production process, because APP with a broad molecular weight distribution is more effective. The molecular weight distribution of the APP oligomers/polymers can be characterized by the polydispersity index (PDI). This indicator is defined as the ratio of *weight-average* molecular weight to *number-average* molecular weight.

Granular potassium chloride as carrier for micronutrients

Granular potassium chloride can act as carrier for nutrients. Australian fertiliser experts have prepared experimental formulations by compacting boron with muriate of potash. Whitehurst and Associates Inc. has coated potassium chloride granules with manganese, boron and/or other nutrients.

Granular NP-fertilisers based on ammonium nitrate and/or monoammonium phosphate are known for decades as boron carriers. These fertilisers are, for instance, widely used in maize on sandy soils in Belgium and The Netherlands. Researchers at the Fertiliser Technology Research Centre of the University of Adelaide (Australia) use granular potassium chloride as boron carrier. They compacted a commercial-grade potassium chloride fertiliser with borate minerals differing in water-solubility to obtain fertilisers with different boron release patterns. With this approach they intend to reduce the risk of boron leaching and toxicity to seedlings and to synchronise boron availability and crop demand. The borates used are borax, ulexite and colemanite. The researchers had already shared their work at a symposium. Recently they reported this study in an open access article in the *Soil Science Society of America Journal*. A method to compact potassium chloride fertiliser (muriate of potash) feed material with one or more micronutrients has been patented by The Mosaic Company (see e.g. patent publication US20130031943). The University of Adelaide and The Mosaic Company (which funded this research in part) established the Fertiliser Technology Research Centre in 2007. The Australian researchers compared different boron-enriched potassium chloride formulations with regard to boron uptake by rapeseed (canola).

Nutrient coating

Whitehurst and Associates Inc. also uses potassium chloride as carrier for micronutrients. The New Bern-based (USA) company has prepared a manganese-carrying formulation by treating potassium chloride granules with a proprietary water-soluble boron-supplying binding composition and then adding manganese sulphate monohydrate ($MnSO_4.H_2O$) powder. The resulting fertiliser is a composition of 0-0-49 with 2.9% S, 5.03% Mn and 0.41% B. An experiment with greenhouse-grown soybean shows a proof of concept that the coated fertiliser can supply manganese to soybeans. However, the low boron concentration in the binder did not affect soil or plant boron, according to researchers at the Virginia Tech Department of Crop and Soil Environmental Sciences who tested the experimental fertiliser. Furthermore the positive results found in the greenhouse trials are not replicated under field conditions. The absence of any effect under field conditions is due to environmental conditions, such as precipitation and leaching, according to Virginia Tech PhD candidate Abigail Baxter. She has also tested potassium chloride fertilisers coated with phosphorus, sulphur and the sugar acid chelate glucoheptonate. These formulations increased plant tissue boron concentrations to some extent, but did not enhance phosphorus or sulphur concentrations. Abigail Baxter reported these results in her thesis. Whitehurst and Associates Inc. has also prepared granular urea fertilisers coated with micronutrients and other additives to reduce ammonia volatilisation.

Fertiliser raw material from phosphate slag

Scientists at the Shanghai Polytechnic University have prepared ultrafine iron phosphate micro-powder from phosphate slag. This purified and modified iron phosphate micro-powder has high dispersibility and can be used as slow release fertiliser, according to the Chinese researchers at the last year held International Conference on Novel Functional Materials (see paper).

Surfactants improve leaf coverage with Zn IDHA

The Polish specialty fertiliser company PPC ADOB has compared effects of three surfactants on the performance of its biodegradable Zn IDHA 2.0 foliar fertiliser. A greenhouse experiment with wheat, maize and rapeseed showed that the maximum covered leaf area was greatly dependent on type of plants and surfactant. A trisiloxane surfactant (super-spreader) reduces the contact angle of the droplets and improved leaf coverage best, compared to a polyglucoside and an alcohol EO (ethylene oxide) surfactant. ADOB researchers further observed that the micro-scale roughness of the leaf surface significantly affected the coverage area in wheat and rapeseed (maize was not examined). Ridges and hollows on rapeseed leaves are distributed uniformly over the entire leaf surface, so that fertiliser droplets are able to spread relatively evenly in all directions. Narrow grooves parallel to the main vein on the surface of wheat leaves produce a strong capillary effect. These grooves were found to reduce the distribution of droplets in the perpendicular direction to the main vein. Reducing the droplet spread possibilities to one direction results in a smaller fertiliser coverage area on wheat leaves than on rapeseed leaves, according to the Polish researches. Details of this greenhouse experiment are published in the journal *Plant and Soil*. In an additional experiment the researchers examined the influence of surfactants on zinc accumulation in the grains of greenhouse-grown bread wheat plants. Grain analyses showed that foliar application of Zn IDHA 2.0 with addition of a polyglucoside surfactant was highly effective in improving the zinc concentration in wheat grains. Results of this experiment have been presented at the International Plant Nutrition Colloquium (see Proceedings Book XVIII IPNC p. 848-849).

Cell membrane as foliar fertiliser carrier

Plasma membrane vesicles (microsomes) obtained from broccoli leaves are suited as delivery system for zinc sulphate foliar fertilisers. Scientists at the University of Murcia (Spain) conclude this from experiments with broccoli protoplasts and hydroponically-grown broccoli and pak choi test plants. The researchers noted a high zinc encapsulation efficiency and high delivery of this micronutrient into broccoli protoplasts and the hydroponically-grown vegetable plants. Results of this study are published in the journal *Colloids and Surfaces B: Biointerfaces*.

New biodegradable iron chelates for calcareous soils

The biodegradable chelating agent [S,S]-EDDS is an environmentally-friendly alternative to traditional synthetic chelating agents such as EDTA or o,o-EDDHA for crops in calcareous soils. A research group around agricultural chemist Juan Jose Lucena (Universidad Autónoma de Madrid) concludes this from a pot experiment with iron-deficient soybean plants growing in calcareous soil. Application of [S,S]-EDDS-Fe in a calcareous soil increased the iron concentration in soybean plants to the same extent as EDTA-Fe. When [S,S]-EDDS-Fe was applied in a double dosage, a similar effectiveness to that of o,o-EDDHA-Fe was obtained, the researchers report in the journal *Science of The Total Environment*. They further observed that [S,S]-EDDS-Fe improved the iron translocation from soil to leaves, compared with the two other iron chelates tested. Another advantage mentioned by the researchers is the lower reactivity of the [S,S]-EDDS-Fe with calcium, as compared to that for EDTA-Fe. The Spanish researchers also noted that the application of [S,S]-EDDS-Fe increased the uptake of zinc to a greater extent than the two other chelates.

Siderophores as iron carriers

Chemists at the University Autónoma of Madrid and two Portuguese universities have also examined two other biodegradable chelates as iron sources, in this case with hydroponically-grown cucumber as test crop. The used chelators are azotochelin and N-dihydroxy-N,N'-diisopropylhexanediamide (DPH). Azotochelin is a bis(catecholamide) siderophore produced by the nitrogen-fixing soil bacterium *Azotobacter vinelandii*. DPH is a biological and physicochemical model of the siderophore rhodotorulic acid, which is produced by *Rhodotorula pilimane* and related yeasts. Both biodegradable iron chelates are able to supply iron to plants to correct iron chlorosis and to maintain a good nutritional status of the plants, according to the researchers in a paper published in the open access *Emirates Journal of Food and Agriculture*. Both biodegradable iron chelates were as efficient as Fe(III)-EDTA and Fe(III)-EDDHA chelates in treating cucumber plants growing at pH 7.5 in hydroponics and having visible symptoms of iron chlorosis. In a related study with pot-grown soybean in calcareous soil they observed that azotochelin and DPH showed good results in amending iron induced chlorosis. Both chelators should be regarded as good green-candidates for iron plant nutrition in calcareous soils, the researchers conclude from this study (see article in *Science of The Total Environment*). Both studies are follow-ups to a previously published investigation into the potential of DPH as iron chelate in hydroponic cultures; this study was published in the *Journal of the Iranian Chemical Society*.

Publications about new, experimental and potential fertiliser formulations

Chelates

Azotochelin and N-dihydroxy-N,N'-diisopropylhexanediamide as Fe sources to cucumber plants in hydroponic cultures. Emirates Journal of Food and Agriculture 30(2018)1:65-76

Calcareous soil interactions of the iron(III) chelates of DPH and Azotochelin and its application on amending iron chlorosis in soybean (*Glycine* max). Science of The Total Environment 647(2019):1586-1593

[S,S]-EDDS/Fe: A new chelate for the environmentally sustainable correction of iron chlorosis in calcareous soil. Science of The Total Environment 647(2018):1508-1517

Nano-fertilisers

Controlled synthesis of struvite nanowires in synthetic wastewater. ACS Sustainable Chemistry & Engineering 7(2019)2:2035-2043

Nanoclay polymer composites loaded with urea and nitrification inhibitors for controlling nitrification in soil. Archives of Agronomy and Soil Science 65(2019)4:478-491

The use of biovesicles to improve the efficiency of Zn foliar fertilization. Colloids and Surfaces B: Biointerfaces 173(2019):899-905

Nitrification and urease inhibitors

Nanoclay polymer composites loaded with urea and nitrification inhibitors for controlling nitrification in soil. Archives of Agronomy and Soil Science 65(2019)4:478-491

Novel dual-action plant fertilizer and urease inhibitor: Urea·catechol cocrystal. Characterization and environmental reactivity. ACS Sustainable Chemistry & Engineering 7(2019)2:2852-2859

^{15}N-urea efficiency in maize as influenced by humic substances and urease inhibitors treatments. Communications in Soil Science and Plant Analysis 50(2019)2:198-208

A minireview on what we have learned about urease inhibitors of agricultural interest since mid-2000s. Journal of Advanced Research 13(2018):29-37

Schiff bases and their metal complexes as urease inhibitors – A brief review. Journal of Advanced Research 13(2018):113-126

Specific release

Zinc release from Zn-Mg-Fe(III)-LDH intercalated with nitrate, phosphate and carbonate: The effects of low molecular weight organic acids. Applied Clay Science 170(2019):135-142

Periclase-induced generation of flowerlike clay-based layered double hydroxides: A highly efficient phosphate scavenger and solid-phase fertilizer. Chemical Engineering Journal 359(2019):902-913

Evolution of the polydispersity of ammonium polyphosphate in a reactive extrusion process: Polycondensation mechanism and kinetics. Chemical Engineering Journal 359(2019):1453-1462

Publications about new, experimental and potential fertiliser formulations

Reactive extrusion of ammonium polyphosphate in a twin-screw extruder: polydispersity improvement. Chemical Engineering and Processing - Process Intensification 133(2018):58-65
Zeolite reinforced carboxymethyl cellulose-Na^+-*g*-*cl*-poly(AAm) hydrogel composites with pH responsive phosphate release behaviour. Journal of Applied Polymer Science 136(2019)15:47332
pH-triggered release of boron and thiamethoxam from boric acid crosslinked carboxymethyl cellulose hydrogel based formulations. Polymer-Plastics Technology and Materials 58(2019)1:83-96
Slow and fast-release boron sources in potash fertilizers: spatial variability, nutrient dissolution and plant uptake. Soil Science Society of America Journal 82(2018)6:1437-1448

Nitrogen

Nanoclay polymer composites loaded with urea and nitrification inhibitors for controlling nitrification in soil. Archives of Agronomy and Soil Science 65(2019)4:478-491
Novel dual-action plant fertilizer and urease inhibitor: Urea·catechol cocrystal. Characterization and environmental reactivity. ACS Sustainable Chemistry & Engineering 7(2019)2:2852-2859
Evolution of the polydispersity of ammonium polyphosphate in a reactive extrusion process: Polycondensation mechanism and kinetics. Chemical Engineering Journal 359(2019):1453-1462
Reactive extrusion of ammonium polyphosphate in a twin-screw extruder: polydispersity improvement. Chemical Engineering and Processing - Process Intensification 133(2018):58-65
^{15}N-urea efficiency in maize as influenced by humic substances and urease inhibitors treatments. Communications in Soil Science and Plant Analysis 50(2019)2:198-208
Aminochelates in plant nutrition: a review. Journal of Plant Nutrition 42(2019)1:67-78

Phosphorus

Controlled synthesis of struvite nanowires in synthetic wastewater. ACS Sustainable Chemistry & Engineering 7(2019)2:2035-2043
Periclase-induced generation of flowerlike clay-based layered double hydroxides: A highly efficient phosphate scavenger and solid-phase fertilizer. Chemical Engineering Journal 359(2019):902-913
Evolution of the polydispersity of ammonium polyphosphate in a reactive extrusion process: Polycondensation mechanism and kinetics. Chemical Engineering Journal 359(2019):1453-1462
Reactive extrusion of ammonium polyphosphate in a twin-screw extruder: polydispersity improvement. Chemical Engineering and Processing - Process Intensification 133(2018):58-65
Zeolite reinforced carboxymethyl cellulose-Na^+-*g*-*cl*-poly(AAm) hydrogel composites with pH responsive phosphate release behaviour. Journal of Applied Polymer Science 136(2019)15:47332

Boron

Novel coated fertilizers as multi-nutrient sources for soybeans and tomatoes. Thesis
Novel fertilizer as an alternative for supplying manganese and boron to soybeans. Communications in Soil Science and Plant Analysis 50(2019)1:65-76
pH-triggered release of boron and thiamethoxam from boric acid crosslinked carboxymethyl cellulose hydrogel based formulations. Polymer-Plastics Technology and Materials 58(2019)1:83-96
Slow and fast-release boron sources in potash fertilizers: spatial variability, nutrient dissolution and plant uptake. Soil Science Society of America Journal 82(2018)6:1437-1448

Iron

Azotochelin and N-dihydroxy-N,N'-diisopropylhexanediamide as Fe sources to cucumber plants in hydroponic cultures. Emirates Journal of Food and Agriculture 30(2018)1:65-76
Calcareous soil interactions of the iron(III) chelates of DPH and Azotochelin and its application on amending iron chlorosis in soybean (*Glycine* max). Science of The Total Environment 647(2019):1586-1593
[*S*,*S*]-EDDS/Fe: A new chelate for the environmentally sustainable correction of iron chlorosis in calcareous soil. Science of The Total Environment 647(2018):1508-1517

Manganese

Novel coated fertilizers as multi-nutrient sources for soybeans and tomatoes. Thesis
Novel fertilizer as an alternative for supplying manganese and boron to soybeans. Communications in Soil Science and Plant Analysis 50(2019)1:65-76

Zinc

Zinc release from Zn-Mg-Fe(III)-LDH intercalated with nitrate, phosphate and carbonate: The effects of low molecular weight organic acids. Applied Clay Science 170(2019):135-142
The use of biovesicles to improve the efficiency of Zn foliar fertilization. Colloids and Surfaces B: Biointerfaces 173(2019):899-905

New and old urease inhibitors scrutinised

It remains to be demonstrated that the active ingredient in Nutrisphere-N functions as a soil urease inhibitor at the concentrations likely to be found in the vicinity of a urea granule. With this firm statement, soil scientist R. Jay Goos concludes his short paper about a soil incubation experiment with this maleic-itaconic copolymer based fertiliser additive. The North Dakota State University researcher responds with his experiment to a previously published experiment conducted by a team around the Italian chemist Stefano Ciurli. These University of Bologna researchers reported that the maleic-itaconic copolymer can inactivate purified urease at a pH of 5.0 in the absence of soil (see paper). In another study, Goos observed that Agrotain Ultra slows urea hydrolysis, but that Nutrisphere-N and NZone had too little effect to be of practical interest; NZone has been replaced by NZone GL and NZone Max. This study will be published in the *Agronomy Journal*.

The *Journal of Advanced Research* published last year an open access special issue on ureases and urease inhibitors. Scientists from different disciplines presented in this issue a state-of-the-art of urease research (article), the agronomic efficiency of NBPT as urease inhibitor (article) and a review of recent advances in the search for urease inhibitors other than NBPT (article). A part of this work work was made possible by the Brazilian Network for the Development of Novel Urease Inhibitors. Brazilian investigators also discussed the development of urease inhibitors as antimicrobial agents against pathogenic bacteria (article), Polish scientists reviewed recent advances in the design of new urease inhibitors (article) and Brazilian researchers discussed Schiff bases and their metal complexes as urease inhibitors (article). The three latter reviews deal with the most relevant urease inhibitors of pharmacological interest.

Research into improved phosphoramide urease inhibitors

Urease inhibitors from the phosphoramide group must have at least one O atom bound to the central P atom. Only with this O-P bond, the molecules can efficiently and rapidly bind to the dinickel center of the urease enzyme. This requirement is fulfilled in the case of the urease inhibitors PPD and NBPTO. However, for NBPT, the preliminary loss of an amide group is necessary. A research team led by the Italian chemist Stefano Ciurli has found this in detailed studies into the precise mode of action of phosphoramide urease inhibitors. Although NBPTO outperforms NBPT in speed of urease inhibition, the latter works much better under practical conditions. This superiority of NBPT is caused by its higher stability in terms of hydrolysis and longer persistence in the environment. With their work, Ciurli and his colleagues at the University of Bologna aim to pave the way to improving and developing more efficient derivatives of phosphoramides as general urease inhibitors for agricultural and medical applications. Their study is published in the *Journal of Agricultural and Food Chemistry*.

Urea fertiliser with inherent urease inhibitor properties

Urea can be milled with the urease inhibitor catechol to form a cocrystal with inherent urease inhibitor properties. Scientists at Lehigh University (USA) and the University of Bologna (Italy) use this mechanochemical approach to synthesize novel urea fertilisers with a reduced risk of ammonia volatilisation. The experimental fertiliser has still to be tested in the field. The preparation process is reported in a just published article in the journal *ACS Sustainable Chemistry & Engineering*. The researchers have also recently synthesised ionic cocrystals of urea with potassium chloride and zinc chloride by mechanochemical and solution methods. The researchers obtained two polymorphic modifications of urea ionic cocrystals that are very efficient as urease inhibitor. They published the preparation process of these cocrystals in *Chemical Communications*. Work of Lehigh University researchers is also subject of a patent application (WO2019040427). This recently published application covers adducts of urea and an inorganic salt obtained via a solventless mechanochemical process. Previously the US-based company Koch Agronomic Services LLC has patented reaction products including adducts of the urease inhibitor NBPT, urea and formaldehyde (see e.g. the patent publication US9725372).

Nitrification inhibitors compared

Thiosulphates are weak nitrification inhibitors. However, liquid fertilisers like urea ammonium nitrate that are blended with ammonium thiosulphate at rates appropriate for the correction of sulphur deficiency may slow nitrification to a certain extent, especially when applied in concentrated bands. Soil scientist R. Jay Goos concludes this from a laboratory incubation experiment with different nitrification inhibitors. The North Dakota State University researcher further observed that the nitrapyrin formulation N-Serve was more effective than the microencapsulated nitrapyrin formulation Instinct. The nitrification inhibitor Nutrisphere-N performed less well than both nitrapyrin formulations and as dicyandiamide as well. Goos reported his findings in the journal *Communications in Soil Science and Plant Analysis*.

Publications about plant nutrition research

General

General
Physics and hydraulics of the rhizosphere network. Journal of Plant Nutrition and Soil Science 182(2019)1:5-8
Plant nutrition and soil fertility: synergies for acquiring global green growth and sustainable development. Plant and Soil 434(2019)1-2:1-6
Long-term fertilisation strategies and form affect nutrient budgets and soil test values, soil carbon retention and crop yield resilience. Plant and Soil 434(2019)1-2:47-64

Arable crops - cereals and grasses
Fertilisation practice changes rhizosphere microbial community structure in the agroecosystem. Annals of Applied Biology 174(2019)2:123-132

Arable crops - potato and sugar beet
Seed potato minituber production in an aeroponic system under tropical conditions: electrical conductivity and plant density. Journal of Plant Nutrition 41(2018)17:2200-2209

Fruit and vegetable crops
Variable fall climate influences nutrient resorption and reserve storage in young peach trees. Frontiers in Plant Science 9(2018):1819
Biostimulation effects of rosemary essential oil on growth and nutrient uptake of tomato seedlings. Scientia Horticulturae 243(2019):472-476
The increase in electrical conductivity of nutrient solution enhances compositional and sensory properties of tomato fruit cv. Patrón. Scientia Horticulturae 244(2019):388-398
Seawater potential use in soilless culture: A review. Scientia Horticulturae 249(2019):199-207

Ornamentals and turf
Controlling salt flushing using a salinity index obtained by soil dielectric sensors improves the physiological status and quality of potted hydrangea plant. Scientia Horticulturae 247(2019):335-343
Seawater potential use in soilless culture: A review. Scientia Horticulturae 249(2019):199-207

Miscellaneous crops
Biostimulants enhance growth and drought tolerance in *Arabidopsis thaliana* and exhibit chemical priming action. Annals of Applied Biology 174(2019)2:153-165

Biofortification

Arable crops - cereals and grasses
Wheat grain selenium content as affected by year and tillage system in a rainfed Mediterranean Vertisol. Field Crops Research 233(2019):41-48
Grain Zn concentrations and yield of Zn-biofortified versus Zn-efficient rice genotypes under contrasting growth conditions. Field Crops Research 234(2019):26-32
Effects of different application methods of selenite and selenate on selenium distribution within wheat. Journal of Plant Nutrition 41(2018)20:2729-2740

Arable crops - other crops
Potential of cassava clones enriched with ß-carotene and lycopene for zinc biofortification under different soil Zn conditions. Journal of the Science of Food and Agriculture 99(2019)2:666-674

Fruit and vegetable crops
Biofortification of onion bulb with selenium at different levels of sulfate. Journal of Plant Nutrition 42(2019)3:269-277

Climate change

Arable crops - cereals and grasses
Positive effects of free air CO_2 enrichment on N remobilization and post-anthesis N uptake in winter wheat. Field Crops Research 234(2019):107-118
Potassium application alleviates grain sterility and increases yield of wheat (*Triticum aestivum*) in frost-prone Mediterranean-type climate. Plant and Soil 434(2019)1-2:203-216
Effect of predicted climate change on growth and yield performance of wheat under varied nitrogen and zinc supply. Plant and Soil 434(2019)1-2:231-244

Publications about plant nutrition research

Fruit and vegetable crops
The role of nitrogen in photosynthetic acclimation to elevated [CO_2] in tomatoes. Plant and Soil 434(2019)1-2:397-411
Heat shock, high CO_2 and nitrogen fertilization effects in pepper plants submitted to elevated temperatures. Scientia Horticulturae 244(2019):322-329

Greenhouse gas emission

General
Interactive effects of ammonium application rates and temperature on nitrous oxide emission from tropical agricultural soil. Soil Science and Plant Nutrition 64(2018)6:767-773

Arable crops - cereals and grasses
Enhanced-efficiency fertilizer impacts on yield-scaled nitrous oxide emissions in maize. Soil Science Society of America Journal 82(2018)6:1469-1481

Arable crops - other crops
Nitrous oxide emissions after incorporation of winter oilseed rape (*Brassica napus* L.) residues under two different tillage treatments. Journal of Plant Nutrition and Soil Science 182(2019)1:48-59

Grassland and forage
Soil nitrous oxide emissions from grassland: Potential inhibitor effect of hippuric acid. Journal of Plant Nutrition and Soil Science 182(2019)1:40-47

Fruit and vegetable crops
Annual nitric and nitrous oxide emissions response to biochar amendment from an intensive greenhouse vegetable system in southeast China. Scientia Horticulturae 246(2019):879-886

Mapping, sensing, sampling and analytics

General
Fast abiotic sorption of selenates (SeO_4^{2-}) in soils: pitfalls of batch sorption data acquired by inductively coupled plasma quadrupole mass spectrometry (ICP-QMS). Archives of Agronomy and Soil Science 65(2019)4:566-580
Placement of ion-exchange membranes for monitoring nutrient release from flooded soils. Canadian Journal of Soil Science 98(2018)4:709-715
Trace metal contamination during grinding of plant samples. Communications in Soil Science and Plant Analysis 50(2019)1:102-107
Synchrotron-based x-ray fluorescence microscopy as a technique for imaging of elements in plants. Plant Physiology 178(2018)2:507-523
Imaging and functional characterization of crop root systems using spectroscopic electrical impedance measurements. Plant and Soil 435(2019)1-2:201-22
Development of field mobile soil nitrate sensor technology to facilitate precision fertilizer management. Precision Agriculture 20(2019)1:40-55
Effects of sample pretreatment and particle size on the determination of nitrogen in soil by portable LIBS and potential use on robotic-borne remote Martian and agricultural soil analysis systems. RSC Advances 8(2018)64:36886-36894
Developing near- and mid-infrared spectroscopy analysis methods for rapid assessment of soil quality in Illinois. Soil Science Society of America Journal 82(2018)6:1415-1427

Arable crops - cereals and grasses
Barley, oat, rye and wheat
Relationship between rainfall-adjusted nitrogen nutrition index and yield of wheat in Western Australia. Journal of Plant Nutrition 41(2018)20:2637-2643
Plant-microbe competition: does injection of isotopes of C and N into the rhizosphere effectively characterise plant use of soil N? New Phytologist 221(2019)2:796-806
Chlorophyll *a* fluorescence analysis can detect phosphorus deficiency under field conditions and is an effective tool to prevent grain yield reductions in spring barley (*Hordeum vulgare* L.). Plant and Soil 434(2019)1-2:79-91
Farmer attitudes to the use of sensors and automation in fertilizer decision-making: nitrogen fertilization in the Australian grains sector. Precision Agriculture 20(2019)1:157-175
Fine-tuning of wheat (*Triticum aestivum*, L.) variable nitrogen rate by combining crop sensing and management zones approaches in southern Brazil. Precision Agriculture 20(2019)1:56-77

Maize
Assessment of in-season soil nitrogen tests for corn planted into winter annual cover crops. Soil Science Society of America Journal 82(2018)6:1428-1436

Publications about plant nutrition research

Evaluation of Adapt-N and realistic yield expectation approaches for maize nitrogen management in North Carolina. Soil Science Society of America Journal 82(2018)6:1449-1458
Critical sulfur dilution curve and sulfur nutrition index in maize. Agronomy Journal 111(2019)1:448-456

Rice
Suitability of extractant for soil available silicon and silicon response to upland paddy grown on alkaline soils of central India. Journal of Plant Nutrition 41(2018)18:2298-2308
A simple, low-cost technique for in situ measurement of leaf P concentration in field-grown rice. Journal of Plant Nutrition and Soil Science 182(2019)1:28-30

Sugarcane
Evaluation of soil extractants for silicon availability for sugarcane. Journal of Plant Nutrition 41(2018)17:2241-2255

Arable crops - potato and sugar beet
Critical dilution curves for nitrogen, phosphorus, and potassium in potato group Andigenum. Agronomy Journal 111(2019)1:419-427
Possibility of recommending potassium application rates based on a rapid detection of the potato petiole K status with a portable K ion meter. American Journal of Potato Research 96(2019)1:48-54
Delineating soil management zones using a proximal soil sensing system in two commercial potato fields in New Brunswick, Canada. Canadian Journal of Soil Science 98(2018)4:724-737
Comparison of optical indicators for potato crop nitrogen status assessment including novel approaches based on leaf fluorescence and flavonoid content. Journal of Plant Nutrition 41(2018)20:2705-2728

Arable crops - other crops
Establishing indicator leaf and its threshold values for need based nitrogen management using chlorophyll meter and leaf color chart in Bt cotton. Journal of Plant Nutrition 42(2019)2:186-201

Fruit and vegetable crops
Determination suitable sample method of rose apple (*Syzygium jambos* L.) for evaluation of plant nutrient status. Journal of Plant Nutrition 41(2018)20:2741-2748
Testing foliar nutritional changes in space and over time in greenhouse tomato. Journal of Plant Nutrition 42(2019)4:333-343
Growth, N uptake and N critical dilution curve in broccoli cultivars grown under Mediterranean conditions. Scientia Horticulturae 244(2019):109-121

Ornamentals
Evaluation of a mobile phone plant nitrogen recommendation application in the greenhouse. Journal of Plant Nutrition 41(2018)20:2615-2625
Controlling salt flushing using a salinity index obtained by soil dielectric sensors improves the physiological status and quality of potted hydrangea plant. Scientia Horticulturae 247(2019):335-343
Metabolic nitrogen and carbohydrate pools as potential quality indicators of supply chains for ornamental young plants. Scientia Horticulturae 247(2019):449-462

Ammonia and urea fabrication processes

General
Operating envelope of Haber–Bosch process design for power-to-ammonia. RSC Advances 8(201861:34926-34936

Granulation

General
A comparison of drum granulation of biochars. Powder Technology 343(2019)723-732

Application technology

Arable crops - cereals and grasses
Barley, oat, rye and wheat
Effects of different application methods of selenite and selenate on selenium distribution within wheat. Journal of Plant Nutrition 41(2018)20:2729-2740
Evaluating grain sorghum hybrids for tolerance to iron chlorosis. Journal of Plant Nutrition 42(2019)4:401-409

Publications about plant nutrition research

Maize
Managing fertiliser placement locations and source types to improve rice yield and the use efficiency of nitrogen and phosphorus. Field Crops Research 231(2019):10-17

Rice
Selenium forms and methods of application differentially modulate plant growth, photosynthesis, stress tolerance, selenium content and speciation in *Oryza sativa* L. Ecotoxicology and Environmental Safety 169(2019):911-917

Arable crops - legumes
Row-applied iron chelate for correcting iron deficiency chlorosis in dry bean. Agronomy Journal 111(2019)1:362-367
Improving corn yields and NUE. With late N applications using high- clearance equipment. The Fluid Journal 28(2019)1:5-8

Arable crops - potato and sugar beet
Efficiency of P fertigation for drip-irrigated potato grown on calcareous sandy soils. Potato Research 62(2019)1:97-108

Arable crops - other crops
Effects of seed-placed hog manure-recovered struvite on canola seedling emergence. Agronomy Journal 111(2019)1:390-396

Fruit and vegetable crops
Effects of alternate partial root-zone irrigation on the utilization and movement of nitrates in soil by tomato plants. Scientia Horticulturae 243(2019):41-47
Response of 'Red Delicious' apple trees drip-fertigated with ammonium nitrate to application of silicic acid. Scientia Horticulturae 249(2019):15-21

Foliar fertilisation

General
The use of biovesicles to improve the efficiency of Zn foliar fertilization. Colloids and Surfaces B: Biointerfaces 173(2019):899-905
Mathematical modeling of diffusion of a hydrophilic ionic fertilizer in plant cuticles: surfactant and hygroscopic effects. Frontiers in Plant Science 9(2018):1888

Arable crops - cereals and grasses
Selenium forms and methods of application differentially modulate plant growth, photosynthesis, stress tolerance, selenium content and speciation in *Oryza sativa* L. Ecotoxicology and Environmental Safety 169(2019):911-917
Effects of different application methods of selenite and selenate on selenium distribution within wheat. Journal of Plant Nutrition 41(2018)20:2729-2740
Effect of surfactants and leaf surface morphology on the evaporation time and coverage area of ZnIDHA droplets. Plant and Soil 434(2019)1-2:93-105
Statement of foliar fertilization impact on yield, composition, and oxidative biomarkers in rice. Journal of Agricultural and Food Chemistry 67(2019)2:597-605

Arable crops - potato and sugar beet
Foliar application of Fe resonates to the belowground rhizosphere microbiome in Andean landrace potatoes. Applied Soil Ecology 131(2018):89-98
Exploring candidate genes and rhizosphere microbiome in relation to iron cycling in Andean potatoes. PhD thesis

Arable crops - other crops
Absorption of foliar-applied Zn in sunflower (*Helianthus annuus*): importance of the cuticle, stomata and trichomes. Annals of Botany 123(2019)1:57-68
Effect of surfactants and leaf surface morphology on the evaporation time and coverage area of ZnIDHA droplets. Plant and Soil 434(2019)1-2:93-105

Fruit and vegetable crops
Postharvest quality implications of preharvest treatments applied to enhance Ambrosia™ apple red blush colour at harvest. Canadian Journal of Plant Science 99(2019)1:40-49
Foliar applied zinc and the performance of pecan trees. Journal of Plant Nutrition 42(2019)5:512-516
Foliar nutrient applications to 'Wonderful' pomegranate (*Punica granatum* L.). I. Effects on fruit mineral nutrient concentrations and internal quality. Scientia Horticulturae 244(2019):421-427

Publications about plant nutrition research

Cooperative effects of pre-harvest calcium and gibberellic acid on tissue calcium content, quality attributes, and in relation to postharvest disorders of late-maturing sweet cherry. Scientia Horticulturae 246(2019):123-128
Effects of prebloom sprays of tryptophan and zinc on calcium nutrition, yielding and fruit quality of 'Elstar' apple trees. Scientia Horticulturae 246(2019):212-216

Ornamentals
Quantifying the effects of chelated calcium and salicylic acid on the postharvest quality of poinsettia cuttings. Horttechnology 29(2019)1:30-34
Effect of calcium nitrate foliar spray on the calcium content, growth and freezing tolerance of *Forsythia x Intermedia* cultivars. Journal of Plant Nutrition 41(2018)20:2606-2614

Chelates

General
Chemistry of Polymeric Metal Chelates. Springer. ISBN: 9783319560229 and eISBN: 9783319560243
Aminochelates in plant nutrition: a review. Journal of Plant Nutrition 42(2019)1:67-78

Arable crops - cereals and grasses
Evaluating grain sorghum hybrids for tolerance to iron chlorosis. Journal of Plant Nutrition 42(2019)4:401-409
Effect of surfactants and leaf surface morphology on the evaporation time and coverage area of ZnIDHA droplets. Plant and Soil 434(2019)1-2:93-105

Arable crops - legumes
Row-applied iron chelate for correcting iron deficiency chlorosis in dry bean. Agronomy Journal 111(2019)1:362-367
Iron and humic acid accumulation on soybean roots fertilized with leonardite iron humates under calcareous conditions. Journal of Agricultural and Food Chemistry 66(2018)51:13386-13396
Calcareous soil interactions of the iron(III) chelates of DPH and Azotochelin and its application on amending iron chlorosis in soybean (*Glycine* max). Science of The Total Environment 647(2019):1586-1593
[*S,S*]-EDDS/Fe: A new chelate for the environmentally sustainable correction of iron chlorosis in calcareous soil. Science of The Total Environment 647(2018):1508-1517

Arable crops - other crops
Effect of surfactants and leaf surface morphology on the evaporation time and coverage area of ZnIDHA droplets. Plant and Soil 434(2019)1-2:93-105

Fruit and vegetable crops
Azotochelin and N-dihydroxy-N,N'-diisopropylhexanediamide as Fe sources to cucumber plants in hydroponic cultures. Emirates Journal of Food and Agriculture 30(2018)1:65-76
Effect of seed and foliar application of nano-zinc oxide, zinc chelate, and zinc sulphate rates on yield and growth of pinto bean (*Phaseolus vulgaris*) cultivars. Journal of Plant Nutrition 41(2018)18:2401-2412

Ornamentals
Quantifying the effects of chelated calcium and salicylic acid on the postharvest quality of poinsettia cuttings. Horttechnology 29(2019)1:30-34

Organic fertilisers and industrial wastes (selection)

General
Transient struvite formation during stoichiometric (1:1) NH_4^+ and PO_4^{3-} adsorption/reaction on magnesium oxide (MgO) particles. ACS Sustain Chemistry & Engineering 7(2019)1:1545-1556
Controlled synthesis of struvite nanowires in synthetic wastewater. ACS Sustainable Chemistry & Engineering 7(2019)2:2035-2043
Fertilising effect of sewage sludge ash inoculated with the phosphate-solubilising fungus *Penicillium bilaiae* under semi-field conditions. Biology and Fertility of Soils 55(2019)1:43-51
Sugarcane vinasse and microalgal biomass in the production of pectin particles as an alternative soil fertilizer. Carbohydrate Polymers 203(2019):322-330

Arable crops - cereals and grasses
Barley, oat, rye and wheat
Mineral NPK and manure fertilisation affecting the yield stability of winter wheat: Results from a long-term field experiment. European Journal of Agronomy 102(2019):14-22

Publications about plant nutrition research

Arable crops - legumes
The effect of pH on morphological and physiological root traits of *Lupinus angustifolius* treated with struvite as a recycled phosphorus source. Plant and Soil 434(2019)1-2:65-78

Arable crops - other crops
Effects of seed-placed hog manure-recovered struvite on canola seedling emergence. Agronomy Journal 111(2019)1:390-396

Fruit and vegetable crops
Human urine as a fertilizer in the cultivation of snap beans (*Phaseolus vulgaris*) and turnips (*Brassica rapa*). Journal of Agricultural and Food Chemistry 67(2019)1:50-62
Phosphates recycled from semi-liquid manure and digestate are suitable alternative fertilizers for ornamentals. Scientia Horticulturae 243(2019):440-450

Ornamentals
Phosphates recycled from semi-liquid manure and digestate are suitable alternative fertilizers for ornamentals. Scientia Horticulturae 243(2019):440-450

Green manure / cover crops

General
Cover crops reduce water drainage in temperate climates: A meta-analysis. Agronomy for Sustainable Development 39(20191:3
A UK survey of the use and management of cover crops. Annals of Applied Biology 174(2019)2:179-189
Hidden miners – the roles of cover crops and soil microorganisms in phosphorus cycling through agroecosystems. Plant and Soil 434(2019)1-2:7-45
Cover crops and corn residue removal: impacts on soil hydraulic properties and their relationships with carbon. Soil Science Society of America Journal 83(2019)1:221-231
Cover crops and tillage influence on nitrogen dynamics in plant-soil-water pools. Soil Science Society of America Journal 82(2018)6:1572-1582

Arable crops - cereals and grasses
Cover crop effects on net ecosystem carbon balance in grain and silage maize. Agronomy Journal 111(2019)1:30-38
Cover crops and returning residue impact on soil organic carbon, bulk density, penetration resistance, water retention, infiltration, and soybean yield. Agronomy Journal 111(2019)1:99-108
Manipulating cover crop growth by adjusting sowing time and cereal inter-row spacing to enhance residual nitrogen effects. Field Crops Research 234(2019):15-25
The combination of *Arachis pintoi* green manure and natural phosphate improves maize growth, soil microbial community structure and enzymatic activities. Plant and Soil 435(2019)1-2:175-185
Corn nitrogen management following daikon radish and forage oat cover crops. Soil Science Society of America Journal 83(2019)1:181-189

Arable crops - legumes
Cover crops and returning residue impact on soil organic carbon, bulk density, penetration resistance, water retention, infiltration, and soybean yield. Agronomy Journal 111(2019)1:99-108

Arable crops - potato and sugar beet
Field evaluation of potato N needs following forage legumes. American Journal of Potato Research 96(2019)1:62-68
The impact of cover crops and foliar application of micronutrients on accumulation of macronutrients in potato tubers at technological maturity stage. European Journal of Horticultural Science 83(2018)6:345-355

Fruit and vegetable crops
Optimization of nitrogen nutrition of cauliflower intercropped with clover and in rotation with lettuce. Scientia Horticulturae 246(2019):734-740

Miscellaneous crops
Integration and potential nitrogen contributions of green manure inter-row legumes in coppiced tree cropping systems. European Journal of Agronomy 103(2019):47-53

Biochar

General
A comparison of drum granulation of biochars. Powder Technology 343(2019)723-732

Publications about plant nutrition research

Biochar is a potential source of silicon fertilizer: An overview. Biochar from Biomass and Waste: Fundamentals and Applications. Chapter 12. Page 225-238

Fruit and vegetable crops
Activated charcoal reduces pasture herbicide injury in vegetable crops. Crop Protection 117(2019):1-6
Annual nitric and nitrous oxide emissions response to biochar amendment from an intensive greenhouse vegetable system in southeast China. Scientia Horticulturae 246(2019):879-886

Humic acids

Arable crops - cereals and grasses
^{15}N-urea efficiency in maize as influenced by humic substances and urease inhibitors treatments. Communications in Soil Science and Plant Analysis 50(2019)2:198-208

Arable crops - legumes
Iron and humic acid accumulation on soybean roots fertilized with leonardite iron humates under calcareous conditions. Journal of Agricultural and Food Chemistry 66(2018)51:13386-13396

Nano-fertilisers

General
Controlled synthesis of struvite nanowires in synthetic wastewater. ACS Sustainable Chemistry & Engineering 7(2019)2:2035-2043
Nanoclay polymer composites loaded with urea and nitrification inhibitors for controlling nitrification in soil. Archives of Agronomy and Soil Science 65(2019)4:478-491
Nanoclay polymer composites loaded with urea and nitrification inhibitors for controlling nitrification in soil. Archives of Agronomy and Soil Science 65(2019)4:478-491
The use of biovesicles to improve the efficiency of Zn foliar fertilization. Colloids and Surfaces B: Biointerfaces 173(2019):899-905

Fruit and vegetable crops
Effect of seed and foliar application of nano-zinc oxide, zinc chelate, and zinc sulphate rates on yield and growth of pinto bean (*Phaseolus vulgaris*) cultivars. Journal of Plant Nutrition 41(2018)18:2401-2412
Effects of graphene oxide and zinc oxide nanoparticles on growth, chlorophyll, carotenoids, proline contents and diseases of carrot. Scientia Horticulturae 249(2019):374-382

Nitrification and urease inhibitors

General
Nanoclay polymer composites loaded with urea and nitrification inhibitors for controlling nitrification in soil. Archives of Agronomy and Soil Science 65(2019)4:478-491
Novel dual-action plant fertilizer and urease inhibitor: Urea·catechol cocrystal. Characterization and environmental reactivity. ACS Sustainable Chemistry & Engineering 7(2019)2:2852-2859
Insights into urease inhibition by N-(n-Butyl) phosphoric triamide through an integrated structural and kinetic approach. Journal of Agricultural and Food Chemistry 67(2019)8:2127-2138
Evaluation of Nutrisphere-N as an inhibitor of urease in soils with pH values near five. Soil Science Society of America Journal 82(2018)6:1568-1571
Editorial: Special Issue: Biotechnological and medical relevance of ureases. Journal of Advanced Research 13(2018):1-2
Ureases: Historical aspects, catalytic, and non-catalytic properties – A review. Journal of Advanced Research 13(2018):3-17
Agronomic efficiency of NBPT as a urease inhibitor: A review. Journal of Advanced Research 13(2018):19-27
A minireview on what we have learned about urease inhibitors of agricultural interest since mid-2000s. Journal of Advanced Research 13(2018):29-37
A review on the development of urease inhibitors as antimicrobial agents against pathogenic bacteria. Journal of Advanced Research 13(2018):69-100
Schiff bases and their metal complexes as urease inhibitors – A brief review. Journal of Advanced Research 13(2018):113-126

Arable crops - cereals and grasses
Maize
^{15}N-urea efficiency in maize as influenced by humic substances and urease inhibitors treatments. Communications in Soil Science and Plant Analysis 50(2019)2:198-208

Publications about plant nutrition research

Rice
Medium-term effects of different types of N fertilizer on yield, apparent N recovery, and soil chemical properties of a double rice cropping system. Field Crops Research 234(2019):87-94

Arable crops - potato and sugar beet
Russet potato yield, quality, and nitrogen uptake with enhanced efficiency fertilizers. Agronomy Journal 111(2019)1:200-209
Nitrogen source and rate effects on irrigated potato in tropical sandy soils. Agronomy Journal 111(2019)1:378-389

Specific release

General
Zinc release from Zn-Mg-Fe(III)-LDH intercalated with nitrate, phosphate and carbonate: The effects of low molecular weight organic acids. Applied Clay Science 170(2019):135-142
Periclase-induced generation of flowerlike clay-based layered double hydroxides: A highly efficient phosphate scavenger and solid-phase fertilizer. Chemical Engineering Journal 359(2019):902-913
Evolution of the polydispersity of ammonium polyphosphate in a reactive extrusion process: Polycondensation mechanism and kinetics. Chemical Engineering Journal 359(2019):1453-1462
Reactive extrusion of ammonium polyphosphate in a twin-screw extruder: polydispersity improvement. Chemical Engineering and Processing - Process Intensification 133(2018):58-65
Zeolite reinforced carboxymethyl cellulose-Na^+-*g*-*cl*-poly(AAm) hydrogel composites with pH responsive phosphate release behaviour. Journal of Applied Polymer Science 136(2019)15:47332
pH-triggered release of boron and thiamethoxam from boric acid crosslinked carboxymethyl cellulose hydrogel based formulations. Polymer-Plastics Technology and Materials 58(2019)1:83-96
Slow and fast-release boron sources in potash fertilizers: spatial variability, nutrient dissolution and plant uptake. Soil Science Society of America Journal 82(2018)6:1437-1448

Arable crops - cereals and grasses
Maize
Reduction in nitrogen fertilizer applications by the use of polymer-coated urea: effect on maize yields and environmental impacts of nitrogen losses. Journal of the Science of Food and Agriculture 99(2019)5:2259-2266

Rice
Evaluation of agronomic and economic performance of controlled and slow-release nitrogen fertilizers in two rice cropping systems. Agronomy Journal 111(2019)1:210-216
Controlled-release fertilizer enhances rice grain yield and N recovery efficiency in continuous non-flooding plastic film mulching cultivation system. Field Crops Research 231(2019):122-129
Medium-term effects of different types of N fertilizer on yield, apparent N recovery, and soil chemical properties of a double rice cropping system. Field Crops Research 234(2019):87-94

Arable crops - potato and sugar beet
Russet potato yield, quality, and nitrogen uptake with enhanced efficiency fertilizers. Agronomy Journal 111(2019)1:200-209

Arable crops - other crops
Effects of seed-placed hog manure-recovered struvite on canola seedling emergence. Agronomy Journal 111(2019)1:390-396

Ornamentals
Growth response of *Hydrangea macrophylla* and *Ilex crenata* cultivars to low-phosphorus controlled-release fertilizers. Scientia Horticulturae 246(2019):578-588

Nitrogen

General
Nanoclay polymer composites loaded with urea and nitrification inhibitors for controlling nitrification in soil. Archives of Agronomy and Soil Science 65(2019)4:478-491
Fast abiotic sorption of selenates (SeO_4^{2-}) in soils: pitfalls of batch sorption data acquired by inductively coupled plasma quadrupole mass spectrometry (ICP-QMS). Archives of Agronomy and Soil Science 65(2019)4:566-580
Novel dual-action plant fertilizer and urease inhibitor: Urea·catechol cocrystal. Characterization and environmental reactivity. ACS Sustainable Chemistry & Engineering 7(2019)2:2852-2859

Publications about plant nutrition research

Nitrogen gas fixation and conversion to ammonium using microbial electrolysis cells. ACS Sustainable Chemistry & Engineering 7(2019)3:3511-3519
Evolution of the polydispersity of ammonium polyphosphate in a reactive extrusion process: Polycondensation mechanism and kinetics. Chemical Engineering Journal 359(2019):1453-1462
Reactive extrusion of ammonium polyphosphate in a twin-screw extruder: polydispersity improvement. Chemical Engineering and Processing - Process Intensification 133(2018):58-65
Simulating soil fertility management effects on crop yield and soil nitrogen dynamics in field trials under organic farming in Europe. Field Crops Research 233(2019):1-11
Agronomic efficiency of NBPT as a urease inhibitor: A review. Journal of Advanced Research 13(2018):19-27
A minireview on what we have learned about urease inhibitors of agricultural interest since mid-2000s. Journal of Advanced Research 13(2018):29-37
Development of field mobile soil nitrate sensor technology to facilitate precision fertilizer management. Precision Agriculture 20(2019)1:40-55
Effects of sample pretreatment and particle size on the determination of nitrogen in soil by portable LIBS and potential use on robotic-borne remote Martian and agricultural soil analysis systems. RSC Advances 8(2018)64:36886-36894
Interactive effects of ammonium application rates and temperature on nitrous oxide emission from tropical agricultural soil. Soil Science and Plant Nutrition 64(2018)6:767-773
Evaluation of Nutrisphere-N as an inhibitor of urease in soils with pH values near five. Soil Science Society of America Journal 82(2018)6:1568-1571
Cover crops and tillage influence on nitrogen dynamics in plant-soil-water pools. Soil Science Society of America Journal 82(2018)6:1572-1582

Arable crops - cereals and grasses
Barley, oat, rye and wheat
Mineral NPK and manure fertilisation affecting the yield stability of winter wheat: Results from a long-term field experiment. European Journal of Agronomy 102(2019):14-22
The effect of nitrogen timing and rate on radiation interception, grain yield and grain quality in autumn sown oats. Field Crops Research 231(2019):130-140
Positive effects of free air CO_2 enrichment on N remobilization and post-anthesis N uptake in winter wheat. Field Crops Research 234(2019):107-118
Manipulating cover crop growth by adjusting sowing time and cereal inter-row spacing to enhance residual nitrogen effects. Field Crops Research 234(2019):15-25
Relationship between rainfall-adjusted nitrogen nutrition index and yield of wheat in Western Australia. Journal of Plant Nutrition 41(2018)20:2637-2643
Influence of nitrogen fertilization on yield and phenolic compounds in wheat grains (*Triticum aestivum* L. ssp. *aestivum*). Journal of Plant Nutrition and Soil Science 182(2019)1:111-118
Plant–microbe competition: does injection of isotopes of C and N into the rhizosphere effectively characterise plant use of soil N? New Phytologist 221(2019)2:796-806
Quantification of the contribution of nitrogen fertilization and crop harvesting to soil acidification in a wheat-maize double cropping system. Plant and Soil 434(2019)1–2:167–184
Effect of predicted climate change on growth and yield performance of wheat under varied nitrogen and zinc supply. Plant and Soil 434(2019)1–2:231–244
Fine-tuning of wheat (*Triticum aestivum*, L.) variable nitrogen rate by combining crop sensing and management zones approaches in southern Brazil. Precision Agriculture 20(2019)1:56–77
Farmer attitudes to the use of sensors and automation in fertilizer decision-making: nitrogen fertilization in the Australian grains sector. Precision Agriculture 20(2019)1:157–175

Maize
^{15}N-urea efficiency in maize as influenced by humic substances and urease inhibitors treatments. Communications in Soil Science and Plant Analysis 50(2019)2:198-208
Managing fertiliser placement locations and source types to improve rice yield and the use efficiency of nitrogen and phosphorus. Field Crops Research 231(2019):10-17
Plastic film mulching combined with nutrient management to improve water use efficiency, production of rain-fed maize and economic returns in semi-arid regions. Field Crops Research 231(2019):30-39
Nitrogen economy of early and late-sown maize crops. Field Crops Research 231(2019):40-50
Late harvest improves yield and nitrogen utilization efficiency of summer maize. Field Crops Research 232(2019):88-94
Reduction in nitrogen fertilizer applications by the use of polymer-coated urea: effect on maize yields and environmental impacts of nitrogen losses. Journal of the Science of Food and Agriculture 99(2019)5:2259-2266
Quantification of the contribution of nitrogen fertilization and crop harvesting to soil acidification in a wheat-maize double cropping system. Plant and Soil 434(2019)1–2:167–184
Effect of different forms of N fertilizers on the hyperaccumulator *Solanum nigrum* L. and maize in intercropping mode under Cd stress. RSC Advances 8(2018)70:40210-40218

Publications about plant nutrition research

Assessment of in-season soil nitrogen tests for corn planted into winter annual cover crops. Soil Science Society of America Journal 82(2018)6:1428-1436
Evaluation of Adapt-N and realistic yield expectation approaches for maize nitrogen management in North Carolina. Soil Science Society of America Journal 82(2018)6:1449-1458
Enhanced-efficiency fertilizer impacts on yield-scaled nitrous oxide emissions in maize. Soil Science Society of America Journal 82(2018)6:1469-1481
Corn nitrogen management following daikon radish and forage oat cover crops. Soil Science Society of America Journal 83(2019)1:181-189

Rice
Evaluation of agronomic and economic performance of controlled and slow-release nitrogen fertilizers in two rice cropping systems. Agronomy Journal 111(2019)1:210-216
Controlled-release fertilizer enhances rice grain yield and N recovery efficiency in continuous non-flooding plastic film mulching cultivation system. Field Crops Research 231(2019):122-129
Ground cover rice production system reduces water consumption and nitrogen loss and increases water and nitrogen use efficiencies. Field Crops Research 233(2019):70-79
Late-season nitrogen applications improve grain yield and fertilizer-use efficiency of dry direct-seeded rice in the tropics. Field Crops Research 233(2019):114-120
Medium-term effects of different types of N fertilizer on yield, apparent N recovery, and soil chemical properties of a double rice cropping system. Field Crops Research 234(2019):87-94

Arable crops - legumes
Soybean
Improving corn yields and NUE. With late N applications using high- clearance equipment. The Fluid Journal 28(2019)1:5-8
Nitrogen management for soybeans a must. Economics and environment are two essentials. The Fluid Journal 28(2019)1:14-16

Arable crops - potato and sugar beet
Russet potato yield, quality, and nitrogen uptake with enhanced efficiency fertilizers. Agronomy Journal 111(2019)1:200-209
Nitrogen source and rate effects on irrigated potato in tropical sandy soils. Agronomy Journal 111(2019)1:378-389
Nitrogen fertility and cultivar effects on potato agronomic properties and acrylamide-forming potential. Agronomy Journal 111(2019)1:408-418
Critical dilution curves for nitrogen, phosphorus, and potassium in potato group Andigenum. Agronomy Journal 111(2019)1:419-427
Field evaluation of potato N needs following forage legumes. American Journal of Potato Research 96(2019)1:62-68
The impact of cover crops and foliar application of micronutrients on accumulation of macronutrients in potato tubers at technological maturity stage. European Journal of Horticultural Science 83(2018)6:345-355
Potato in response to nitrogen nutrition regime and nitrogen fertilization. Field Crops Research 231(2019):115-121
Nitrogen fertilization effects on the leaf chemical concentrations in Russet Burbank potato. Field Crops Research 232(2019):40-48
Impact of integrated management of nitrogen fertilizers on yield and nutritional quality of potato. Journal of Plant Nutrition 41(2018)19:2482-2494
Comparison of optical indicators for potato crop nitrogen status assessment including novel approaches based on leaf fluorescence and flavonoid content. Journal of Plant Nutrition 41(2018)20:2705-2728

Arable crops - other crops
Brassica
Nitrous oxide emissions after incorporation of winter oilseed rape (*Brassica napus* L.) residues under two different tillage treatments. Journal of Plant Nutrition and Soil Science 182(2019)1:48-59

Cichorium
Soil fertility requirements of root chicory (*Cichorium intybus* var. *sativum*): a review. Journal of Plant Nutrition 41(2018)20:2644-2659

Cotton
Establishing indicator leaf and its threshold values for need based nitrogen management using chlorophyll meter and leaf color chart in Bt cotton. Journal of Plant Nutrition 42(2019)2:186-201

Grassland and forage
Soil nitrous oxide emissions from grassland: Potential inhibitor effect of hippuric acid. Journal of Plant Nutrition and Soil Science 182(2019)1:40-47

Fruit and vegetable crops
General
Annual nitric and nitrous oxide emissions response to biochar amendment from an intensive greenhouse vegetable system in southeast China. Scientia Horticulturae 246(2019):879-886

Publications about plant nutrition research

Brassica and other leaf vegetables

Effects of bentonite application and urea fertilization time on growth, development and nitrate accumulation in spinach (*Spinacia oleraceae* L.). Communications in Soil Science and Plant Analysis 50(2019)1:1-9

Seasonal changes in growth, nitrogen nutrition, and yield of hydroponic lettuce. HortScience 54(2019)1:76-85

Growth, N uptake and N critical dilution curve in broccoli cultivars grown under Mediterranean conditions. Scientia Horticulturae 244(2019):109-121

Optimization of nitrogen nutrition of cauliflower intercropped with clover and in rotation with lettuce. Scientia Horticulturae 246(2019):734-740

NaSH: Phytotoxin or biostimulant in N assimilation in *Brassica oleracea* L. 'Bronco' plants? Scientia Horticulturae 249(2019):471-477

Cucumber, eggplant, melon, pepper and tomato

The role of nitrogen in photosynthetic acclimation to elevated [CO_2] in tomatoes. Plant and Soil 434(2019)1-2:397-411

Effects of alternate partial root-zone irrigation on the utilization and movement of nitrates in soil by tomato plants. Scientia Horticulturae 243(2019):41-47

Heat shock, high CO_2 and nitrogen fertilization effects in pepper plants submitted to elevated temperatures. Scientia Horticulturae 244(2019):322-329

Benzothiadiazole and nitrogen source modify the nitrogen metabolism in cucumber infected with *Pseudomonas syringae* pv. *lachrymans*. Scientia Horticulturae 246(2019):289-297

Fruit trees and grape

Significance of proper nitrogen fertilization for olive productivity in intensive cultivation. Scientia Horticulturae 246(2019):710-717

Nitrogen management influenced root length intensity of young olive trees. Scientia Horticulturae 246(2019):726-733

Citrus fruit yield response to nitrogen and potassium fertilization depends on nutrient-water management system. Scientia Horticulturae 249(2019):329-333

Response of 'Red Delicious' apple trees drip-fertigated with ammonium nitrate to application of silicic acid. Scientia Horticulturae 249(2019):15-21

Ornamentals and turf

Nitrogen fertilization and irrigation frequency affect hydrangea growth and nutrient uptake in two container types. HortScience 54(2019)1:167-174

Evaluation of a mobile phone plant nitrogen recommendation application in the greenhouse. Journal of Plant Nutrition 41(2018)20:2615-2625

Response of potted anthurium (*Anthurium andreanum* Lind.) to the K^+: Ca^{+2}: Mg^{+2} balance in the nutrient solution. Journal of Plant Nutrition 42(2019)4:351-361

Metabolic nitrogen and carbohydrate pools as potential quality indicators of supply chains for ornamental young plants. Scientia Horticulturae 247(2019):449-462

Miscellaneous crops

Integration and potential nitrogen contributions of green manure inter-row legumes in coppiced tree cropping systems. European Journal of Agronomy 103(2019):47-53

Leaf endophytes mediate fertilizer effects on plant yield and traits in northern oat grass (*Trisetum spicatum*). Plant and Soil 434(2019)1-2:425-440

Identification of genomic regions regulating ammonium-dependent inhibition of primary root length in *Arabidopsis thaliana*. Soil Science and Plant Nutrition 64(2018)6:746-751

Shoot nitrate underlies a perception of nitrogen satiety to trigger local and systemic signaling cascades in *Arabidopsis thaliana*. Soil Science and Plant Nutrition 65(2019)1:56-64

Phosphorus

General

Transient struvite formation during stoichiometric (1:1) NH_4^+ and PO_4^{3-} adsorption/reaction on magnesium oxide (MgO) particles. ACS Sustain Chemistry & Engineering 7(2019)1:1545-1556

Fast abiotic sorption of selenates (SeO_4^{2-}) in soils: pitfalls of batch sorption data acquired by inductively coupled plasma quadrupole mass spectrometry (ICP-QMS). Archives of Agronomy and Soil Science 65(2019)4:566-580

Controlled synthesis of struvite nanowires in synthetic wastewater. ACS Sustainable Chemistry & Engineering 7(2019)2:2035-2043

Fertilising effect of sewage sludge ash inoculated with the phosphate-solubilising fungus *Penicillium bilaiae* under semi-field conditions. Biology and Fertility of Soils 55(2019)1:43-51

Placement of ion-exchange membranes for monitoring nutrient release from flooded soils. Canadian Journal of Soil Science 98(2018)4:709-715

Changes in soil phosphorus balance and phosphorus-use efficiency under long-term fertilization conducted on agriculturally used chernozem in Germany. Canadian Journal of Soil Science 98(2018)4:650-662

Publications about plant nutrition research

Periclase-induced generation of flowerlike clay-based layered double hydroxides: A highly efficient phosphate scavenger and solid-phase fertilizer. Chemical Engineering Journal 359(2019):902-913
Evolution of the polydispersity of ammonium polyphosphate in a reactive extrusion process: Polycondensation mechanism and kinetics. Chemical Engineering Journal 359(2019):1453-1462
Reactive extrusion of ammonium polyphosphate in a twin-screw extruder: polydispersity improvement. Chemical Engineering and Processing - Process Intensification 133(2018):58-65
Hidden miners – the roles of cover crops and soil microorganisms in phosphorus cycling through agroecosystems. Plant and Soil 434(2019)1-2:7-45
Zeolite reinforced carboxymethyl cellulose-Na^+-*g*-*cl*-poly(AAm) hydrogel composites with pH responsive phosphate release behaviour. Journal of Applied Polymer Science 136(2019)15:47332
Organic acid excretion from roots: a plant mechanism for enhancing phosphorus acquisition, enhancing aluminum tolerance, and recruiting beneficial rhizobacteria. Soil Science and Plant Nutrition 64(2018)6:697-704

Arable crops - cereals and grasses
Barley, oat, rye and wheat
Phosphorus-induced zinc deficiency in wheat pot-grown on noncalcareous and calcareous soils of different properties. Archives of Agronomy and Soil Science 65(2019)2:208-223
Mineral NPK and manure fertilisation affecting the yield stability of winter wheat: Results from a long-term field experiment. European Journal of Agronomy 102(2019):14-22
Shoot and root biomass, phosphorus and nitrogen uptake of spring wheat grown in low phosphorus and moisture content conditions in a pot experiment. Journal of Plant Nutrition 41(2018)17:273-2280
Chlorophyll *a* fluorescence analysis can detect phosphorus deficiency under field conditions and is an effective tool to prevent grain yield reductions in spring barley (*Hordeum vulgare* L.). Plant and Soil 434(2019)1-2:79-91
Zinc nutrition of wheat in response to application of phosphorus to a calcareous soil and an acid soil. Plant and Soil 434(2019)1-2:139-150

Maize
Managing fertiliser placement locations and source types to improve rice yield and the use efficiency of nitrogen and phosphorus. Field Crops Research 231(2019):10-17
Competition between *Zea mays* genotypes with different root morphological and physiological traits is dependent on phosphorus forms and supply patterns. Plant and Soil 434(2019)1-2:125-137
The combination of *Arachis pintoi* green manure and natural phosphate improves maize growth, soil microbial community structure and enzymatic activities. Plant and Soil 435(2019)1-2:175-185

Rice
Phosphorus uptake commences at the earliest stages of seedling development in rice. Journal of Experimental Botany 69(2018)21:5233-5240
Seeds with low phosphorus content: not so bad after all? Journal of Experimental Botany 69(2018)21:4993-4996
A simple, low-cost technique for in situ measurement of leaf P concentration in field-grown rice. Journal of Plant Nutrition and Soil Science 182(2019)1:28-30
Phosphorus uptake of rice plants is affected by phosphorus forms and physicochemical properties of tropical weathered soils. Plant and Soil 435(2019)1-2:27-38
Mild drying of sandy soil can physically limit the uptake of phosphorus by rainfed lowland rice in northeast Thailand. Soil Science and Plant Nutrition 64(2018)6:677-685

Arable crops - legumes
Peanut
Role of halotolerant phosphate-solubilising bacteria on growth promotion of peanut (*Arachis hypogaea*) under saline soil. Annals of Botany 174(2019)1:20-30

Soybean
A reduced phosphorus application rate using a mycorrhizal plant as the preceding crop maintains soybean seeds' nutritional quality. Journal of Agricultural and Food Chemistry 67(2019)1:32-42

Lupin
The effect of pH on morphological and physiological root traits of *Lupinus angustifolius* treated with struvite as a recycled phosphorus source. Plant and Soil 434(2019)1-2:65-78

Arable crops - potato and sugar beet
Critical dilution curves for nitrogen, phosphorus, and potassium in potato group Andigenum. Agronomy Journal 111(2019)1:419-427
The impact of cover crops and foliar application of micronutrients on accumulation of macronutrients in potato tubers at technological maturity stage. European Journal of Horticultural Science 83(2018)6:345-355

Publications about plant nutrition research

Phosphorus and silicon effects on growth, yield, and phosphorus forms in potato plants. Journal of Plant Nutrition 42(2019)3:218-233
Efficiency of P fertigation for drip-irrigated potato grown on calcareous sandy soils. Potato Research 62(2019)1:97-108

Arable crops - other crops
Effects of seed-placed hog manure-recovered struvite on canola seedling emergence. Agronomy Journal 111(2019)1:390-396
Soil fertility requirements of root chicory (*Cichorium intybus* var. *sativum*): a review. Journal of Plant Nutrition 41(2018)20:2644-2659

Fruit and vegetable crops
Postharvest quality implications of preharvest treatments applied to enhance Ambrosia™ apple red blush colour at harvest. Canadian Journal of Plant Science 99(2019)1:40-49
Mineral element composition of cabbage as affected by soil type and phosphorus and zinc fertilisation. Plant and Soil 434(2019)1-2:151-165
Phosphates recycled from semi-liquid manure and digestate are suitable alternative fertilizers for ornamentals. Scientia Horticulturae 243(2019):440-450
Foliar nutrient applications to 'Wonderful' pomegranate (*Punica granatum* L.). I. Effects on fruit mineral nutrient concentrations and internal quality. Scientia Horticulturae 244(2019):421-427
Use of phosphorus fertilization and mycorrhization as strategies for reducing copper toxicity in young grapevines. Scientia Horticulturae 248(2019):176-183

Ornamentals and turf
Influence of phosphorus in starter fertilizer on the establishment of tall fescue. HortScience 53(2018)12:1897-1906
Response of potted anthurium (*Anthurium andreanum* Lind.) to the K^{+}: Ca^{+2}: Mg^{+2} balance in the nutrient solution. Journal of Plant Nutrition 42(2019)4:351-361
Phosphates recycled from semi-liquid manure and digestate are suitable alternative fertilizers for ornamentals. Scientia Horticulturae 243(2019):440-450
Growth response of *Hydrangea macrophylla* and *Ilex crenata* cultivars to low-phosphorus controlled-release fertilizers. Scientia Horticulturae 246(2019):578-588

Miscellaneous crops
Leaf endophytes mediate fertilizer effects on plant yield and traits in northern oat grass (*Trisetum spicatum*). Plant and Soil 434(2019)1-2:425-440

Potassium

General
Placement of ion-exchange membranes for monitoring nutrient release from flooded soils. Canadian Journal of Soil Science 98(2018)4:709-715
Morpholine-based gemini surfactant: synthesis and its application for reverse froth flotation of carnallite ore in potassium fertilizer production. Journal of Agricultural and Food Chemistry 66(2018)50:13126-13132
Purification and rapid dissolution of potassium sulfate in aqueous solutions. RSC Advances 9(2019)4:2156-2161

Arable crops - cereals and grasses
Barley, oat, rye and wheat
Mineral NPK and manure fertilisation affecting the yield stability of winter wheat: Results from a long-term field experiment. European Journal of Agronomy 102(2019):14-22
Potassium application alleviates grain sterility and increases yield of wheat (*Triticum aestivum*) in frost-prone Mediterranean-type climate. Plant and Soil 434(2019)1-2:203-216

Arable crops - potato and sugar beet
Critical dilution curves for nitrogen, phosphorus, and potassium in potato group Andigenum. Agronomy Journal 111(2019)1:419-427
Possibility of recommending potassium application rates based on a rapid detection of the potato petiole K status with a portable K ion meter. American Journal of Potato Research 96(2019)1:48-54
The impact of cover crops and foliar application of micronutrients on accumulation of macronutrients in potato tubers at technological maturity stage. European Journal of Horticultural Science 83(2018)6:345-355

Arable crops - other crops
How potassium deficiency alters flower bud retention on cotton (*Gossypium hirsutum* L.). Archives of Agronomy and Soil Science 65(2019)4:521-536
Organic acids exuded from roots increase the available potassium content in the rhizosphere soil: A rhizobag experiment in *Nicotiana tabacum*. HortScience 54(2019)1:23-27
Soil fertility requirements of root chicory (*Cichorium intybus* var. *sativum*): a review. Journal of Plant Nutrition 41(2018)20:2644-2659

Publications about plant nutrition research

Fruit and vegetable crops
Citrus fruit yield response to nitrogen and potassium fertilization depends on nutrient-water management system. Scientia Horticulturae 249(2019):329-333

Ornamentals and turf
Response of potted anthurium (*Anthurium andreanum* Lind.) to the K^{+}: Ca^{+2}: Mg^{+2} balance in the nutrient solution. Journal of Plant Nutrition 42(2019)4:351-361

Calcium

General
Gypsum and carbon amendments influence leachate quality from two soils in Ohio, USA. Soil Science Society of America Journal 83(2019)1:212-220

Arable crops - legumes
Is pH the key reason why some *Lupinus* species are sensitive to calcareous soil? Plant and Soil 434(2019)1-2:185-201

Arable crops - potato and sugar beet
Intumescence injury in the leaves of Russet Burbank potato plants is mitigated by calcium nutrition. American Journal of Potato Research 96(2019)1:6-12
The impact of cover crops and foliar application of micronutrients on accumulation of macronutrients in potato tubers at technological maturity stage. European Journal of Horticultural Science 83(2018)6:345-355

Fruit and vegetable crops
Calcium and the physiology of sweet cherries: A review. Scientia Horticulturae 245(2019):107-115
Cooperative effects of pre-harvest calcium and gibberellic acid on tissue calcium content, quality attributes, and in relation to postharvest disorders of late-maturing sweet cherry. Scientia Horticulturae 246(2019):123-128
Effects of prebloom sprays of tryptophan and zinc on calcium nutrition, yielding and fruit quality of 'Elstar' apple trees. Scientia Horticulturae 246(2019):212-216
Amplification of gibberellins response in tomato modulates calcium metabolism and blossom end rot occurrence. Scientia Horticulturae 246(2019):498-505
Multiple season-long sprays of ethephon or NAA combined with calcium chloride on Honeycrisp: II. Effect on fruit mineral concentrations and incidence of bitter pit. Scientia Horticulturae 247(2019):96-100
Preharvest spraying calcium ameliorated aroma weakening and kept higher aroma-related genes expression level in postharvest 'Nanguo' pears after long-term refrigerated storage. Scientia Horticulturae 247(2019):287-295
Effects of calcium and growth regulators on sweet cherry (*Prunus avium* L.) quality and sensory attributes at harvest. Scientia Horticulturae 248(2019):231-240
Blossom end-rot in tomato (*Solanum lycopersicum* L.): A multi-disciplinary overview of inducing factors and control strategies. Scientia Horticulturae 249(2019):49-58
Physiological changes of sweet and hot peppers in vegetative and reproductive growth stages treated by Ca and H_2O_2 under unforeseen heat stresses. Scientia Horticulturae 249(2019):306-313

Ornamentals
Quantifying the effects of chelated calcium and salicylic acid on the postharvest quality of poinsettia cuttings. Horttechnology 29(2019)1:30-34
Effect of calcium nitrate foliar spray on the calcium content, growth and freezing tolerance of *Forsythia x Intermedia* cultivars. Journal of Plant Nutrition 41(2018)20:2606-2614
Relevance of tipburn incidence to the competence for Ca acquirement and Ca distributivity in lisianthus [*Eustoma grandiflorum* (Raf.) Shinn.] cultivars. Scientia Horticulturae 246(2019):805-811

Lime / pH

General
What effect does liming have on silicon availability in agricultural soils? Geoderma 337(2019):375-383
Gypsum and carbon amendments influence leachate quality from two soils in Ohio, USA. Soil Science Society of America Journal 83(2019)1:212-220

Arable crops - cereals and grasses
Quantification of the contribution of nitrogen fertilization and crop harvesting to soil acidification in a wheat-maize double cropping system. Plant and Soil 434(2019)1-2:167-184

Publications about plant nutrition research

Arable crops - legumes
Is pH the key reason why some *Lupinus* species are sensitive to calcareous soil? Plant and Soil 434(2019)1-2:185-201

Ornamentals
Lime rate affects substrate pH and container-grown birch trees. Communications in Soil Science and Plant Analysis 50(2019)1:93-101

Magnesium

Arable crops - cereals and grasses
The ameliorative effect of silicon on maize plants grown in Mg-deficient conditions. International Journal of Molecular Sciences 20(2019)4:969

Fruit and vegetable crops
Nano-magnesium oxide: a novel bactericide against copper-tolerant *Xanthomonas perforans* causing tomato bacterial spot. Phytopathology 109(2019)1:52-62
Foliar nutrient applications to 'Wonderful' pomegranate (*Punica granatum* L.). I. Effects on fruit mineral nutrient concentrations and internal quality. Scientia Horticulturae 244(2019):421-427

Miscellaneous crops
MgO-induced defence against bacterial wilt disease in *Arabidopsis thaliana*. Plant Pathology 68(2019)2:323-333

Sulphur

General
Fast abiotic sorption of selenates (SeO_4^{2-}) in soils: pitfalls of batch sorption data acquired by inductively coupled plasma quadrupole mass spectrometry (ICP-QMS). Archives of Agronomy and Soil Science 65(2019)4:566-580

Arable crops - cereals and grasses
Critical sulfur dilution curve and sulfur nutrition index in maize. Agronomy Journal 111(2019)1:448-456

Arable crops - legumes
Does *Lupinus angustifolius* L. need sulfur fertilization under central European conditions? Journal of Plant Nutrition and Soil Science 182(2019)1:31-39

Arable crops - other crops
Soil fertility requirements of root chicory (*Cichorium intybus* var. *sativum*): a review. Journal of Plant Nutrition 41(2018)20:2644-2659

Grassland and forage
Grassland species are more efficient in acquisition of S from the atmosphere when pedospheric S availability decreases. Plant and Soil 435(2019)1-2:69-80

Boron

General
pH-triggered release of boron and thiamethoxam from boric acid crosslinked carboxymethyl cellulose hydrogel based formulations. Polymer-Plastics Technology and Materials 58(2019)1:83-96
Slow and fast-release boron sources in potash fertilizers: spatial variability, nutrient dissolution and plant uptake. Soil Science Society of America Journal 82(2018)6:1437-1448

Arable crops - cereals and grasses
Seed priming with micronutrients for improving the quality and yield of hybrid maize. Gesunde Pflanzen 71(2019)1:37-44

Arable crops - legumes
Novel coated fertilizers as multi-nutrient sources for soybeans and tomatoes. Thesis
Novel fertilizer as an alternative for supplying manganese and boron to soybeans. Communications in Soil Science and Plant Analysis 50(2019)1:65-76

Publications about plant nutrition research

Fruit and vegetable crops
Antifungal effect of boron compounds against three *Rhizoctonia solani* AG-4 subgroups causing root and crown rot. Gesunde Pflanzen 71(2019)1:61-71
Metabolic changes in roots of trifoliate orange [*Poncirus trifoliate* (L.) Raf.] as induced by different treatments of boron deficiency and resupply. Plant and Soil 434(2019)1-2:217-229

Cobalt

Arable crops - legumes
Cobalt chloride enhances crop duration, increases production, and productivity of chickpea. Journal of Plant Nutrition 42(2019)1:40-57

Copper

Fruit and vegetable crops
The application of copper nanoparticles and potassium silicate stimulate the tolerance to *Clavibacter michiganensis* in tomato plants. Scientia Horticulturae 245(2019):82-89
Use of phosphorus fertilization and mycorrhization as strategies for reducing copper toxicity in young grapevines. Scientia Horticulturae 248(2019):176-183

Iron

General
Placement of ion-exchange membranes for monitoring nutrient release from flooded soils. Canadian Journal of Soil Science 98(2018)4:709-715

Arable crops - cereals and grasses
Sorghum
Evaluating grain sorghum hybrids for tolerance to iron chlorosis. Journal of Plant Nutrition 42(2019)4:401-409

Arable crops - legumes
Row-applied iron chelate for correcting iron deficiency chlorosis in dry bean. Agronomy Journal 111(2019)1:362-367
Iron and humic acid accumulation on soybean roots fertilized with leonardite iron humates under calcareous conditions. Journal of Agricultural and Food Chemistry 66(2018)51:13386-13396
Calcareous soil interactions of the iron(III) chelates of DPH and Azotochelin and its application on amending iron chlorosis in soybean (*Glycine* max). Science of The Total Environment 647(2019):1586-1593
[*S,S*]-EDDS/Fe: A new chelate for the environmentally sustainable correction of iron chlorosis in calcareous soil. Science of The Total Environment 647(2018):1508-1517

Fruit and vegetable crops
Azotochelin and N-dihydroxy-N,N'-diisopropylhexanediamide as Fe sources to cucumber plants in hydroponic cultures. Emirates Journal of Food and Agriculture 30(2018)1:65-76
Silicon ameliorates iron deficiency of cucumber in a pH-dependent manner. Journal of Plant Physiology 231(2018):364-373
Sensitivity of sweet pepper plants (*Capsicum annuum* L.) to iron excess. European Journal of Horticultural Science 83(2018)6:382-387
Bacillus subtilis STU6 ameliorates iron deficiency in tomato by enhancement of polyamine-mediated iron remobilization. Journal of Agricultural and Food Chemistry 67(2019)1:320-330

Manganese

General
Placement of ion-exchange membranes for monitoring nutrient release from flooded soils. Canadian Journal of Soil Science 98(2018)4:709-715

Arable crops - cereals and grasses
Barley, oat, rye and wheat
Physiological mechanisms for antagonistic interaction of manganese and aluminum in barley. Journal of Plant Nutrition 42(2019)5:466-476

Maize
Seed priming with micronutrients for improving the quality and yield of hybrid maize. Gesunde Pflanzen 71(2019)1:37-44

Publications about plant nutrition research

Arable crops - legumes
Novel coated fertilizers as multi-nutrient sources for soybeans and tomatoes. Thesis
Novel fertilizer as an alternative for supplying manganese and boron to soybeans. Communications in Soil Science and Plant Analysis 50(2019)1:65-76

Sodium

Arable crops - cereals and grasses
Sodium fluxes and silicon at the root plasma membrane: a paradigm shift? Journal of Experimental Botany 69(2018)7:1433-1436
Membrane fluxes, bypass flows, and sodium stress in rice: the influence of silicon. Journal of Experimental Botany 69(2018)7:1679-1692

Zinc

General
Zinc release from Zn-Mg-Fe(III)-LDH intercalated with nitrate, phosphate and carbonate: The effects of low molecular weight organic acids. Applied Clay Science 170(2019):135-142
The use of biovesicles to improve the efficiency of Zn foliar fertilization. Colloids and Surfaces B: Biointerfaces 173(2019):899-905

Arable crops - cereals and grasses
Barley, oat, rye and wheat
Phosphorus-induced zinc deficiency in wheat pot-grown on noncalcareous and calcareous soils of different properties. Archives of Agronomy and Soil Science 65(2019)2:208-223
Effect of surfactants and leaf surface morphology on the evaporation time and coverage area of ZnIDHA droplets. Plant and Soil 434(2019)1-2:93-105
Zinc nutrition of wheat in response to application of phosphorus to a calcareous soil and an acid soil. Plant and Soil 434(2019)1-2:139-150
Effect of predicted climate change on growth and yield performance of wheat under varied nitrogen and zinc supply. Plant and Soil 434(2019)1-2:231-244

Maize
Seed priming with micronutrients for improving the quality and yield of hybrid maize. Gesunde Pflanzen 71(2019)1:37-44
Effect of surfactants and leaf surface morphology on the evaporation time and coverage area of ZnIDHA droplets. Plant and Soil 434(2019)1-2:93-105

Rice
Grain Zn concentrations and yield of Zn-biofortified versus Zn-efficient rice genotypes under contrasting growth conditions. Field Crops Research 234(2019):26-32

Arable crops - legumes
Arbuscular mycorrhiza *Rhizophagus irregularis* and silicon modulate growth, proline biosynthesis and yield in *Cajanus cajan* L. Millsp. (pigeonpea) genotypes under cadmium and zinc stress. Journal of Plant Growth Regulation 37(2018):1:46-63
Mycorrhizal inoculations and silicon fortifications improve rhizobial symbiosis, antioxidant defense, trehalose turnover in pigeon pea genotypes under cadmium and zinc stress. Plant Growth Regulation 86(2018)1:105-119

Arable crops - other crops
Absorption of foliar-applied Zn in sunflower (*Helianthus annuus*): importance of the cuticle, stomata and trichomes. Annals of Botany 123(2019)1:57-68
Potential of cassava clones enriched with ß-carotene and lycopene for zinc biofortification under different soil Zn conditions. Journal of the Science of Food and Agriculture 99(2019)2:666-674
Effect of surfactants and leaf surface morphology on the evaporation time and coverage area of ZnIDHA droplets. Plant and Soil 434(2019)1-2:93-105

Fruit and vegetable crops
Effect of seed and foliar application of nano-zinc oxide, zinc chelate, and zinc sulphate rates on yield and growth of pinto bean (*Phaseolus vulgaris*) cultivars. Journal of Plant Nutrition 41(2018)18:2401-2412
Foliar applied zinc and the performance of pecan trees. Journal of Plant Nutrition 42(2019)5:512-516
Preharvest zinc sulfate spray improves the storability of longan (*Dimocarpus longan* Lour.) fruits by protecting the cell wall components and antioxidants of pericarp. Journal of the Science of Food and Agriculture 99(2019)3:1098-1107

Publications about plant nutrition research

Mineral element composition of cabbage as affected by soil type and phosphorus and zinc fertilisation. Plant and Soil 434(2019)1-2:151-165
Zinc pulverization alleviates the adverse effect of water deficit on plant growth, yield and nutrient acquisition in grapevines (*Vitis vinifera* L.). Scientia Horticulturae 244(2019):61-67
Foliar nutrient applications to 'Wonderful' pomegranate (*Punica granatum* L.). I. Effects on fruit mineral nutrient concentrations and internal quality. Scientia Horticulturae 244(2019):421-427
Effects of prebloom sprays of tryptophan and zinc on calcium nutrition, yielding and fruit quality of 'Elstar' apple trees. Scientia Horticulturae 246(2019):212-216
Effects of graphene oxide and zinc oxide nanoparticles on growth, chlorophyll, carotenoids, proline contents and diseases of carrot. Scientia Horticulturae 249(2019):374-382

Aluminium

General
Organic acid excretion from roots: a plant mechanism for enhancing phosphorus acquisition, enhancing aluminum tolerance, and recruiting beneficial rhizobacteria. Soil Science and Plant Nutrition 64(2018)6:697-704
Aluminum toxicity in plant cells: Mechanisms of cell death and inhibition of cell elongation. Soil Science and Plant Nutrition 65(2019)1:41-55

Arable crops - cereals and grasses
Physiological mechanisms for antagonistic interaction of manganese and aluminum in barley. Journal of Plant Nutrition 42(2019)5:466-476

Miscellaneous crops
Co-deposition of silicon with rare earth elements (REEs) and aluminium in the fern *Dicranopteris linearis* from China. Plant and Soil 437(2019)1-2:427-437

Selenium

General
Fast abiotic sorption of selenates (SeO_4^{2-}) in soils: pitfalls of batch sorption data acquired by inductively coupled plasma quadrupole mass spectrometry (ICP-QMS). Archives of Agronomy and Soil Science 65(2019)4:566-580

Arable crops - cereals and grasses
Selenium forms and methods of application differentially modulate plant growth, photosynthesis, stress tolerance, selenium content and speciation in *Oryza sativa* L. Ecotoxicology and Environmental Safety 169(2019):911-917
Wheat grain selenium content as affected by year and tillage system in a rainfed Mediterranean Vertisol. Field Crops Research 233(2019):41-48
Effects of different application methods of selenite and selenate on selenium distribution within wheat. Journal of Plant Nutrition 41(2018)20:2729-2740
Foliar application of selenium for protection against the first stages of mycotoxin infection of crop plant leaves. Journal of the Science of Food and Agriculture 99(2019)1:482-485
Foliar spraying with silicon and selenium reduces cadmium uptake and mitigates cadmium toxicity in rice. Science of The Total Environment 631-632(2018):1100-1108

Fruit and vegetable crops
Biofortification of onion bulb with selenium at different levels of sulfate. Journal of Plant Nutrition 42(2019)3:269-277
Protective role of selenium on cucumber (*Cucumis sativus* L.) exposed to cadmium and lead stress during reproductive stage role of selenium on heavy metals stress. Journal of Plant Nutrition 42(2019)5:529-542
Effect of selenium enrichment on metabolism of tomato (*Solanum lycopersicum*) fruit during postharvest ripening. Journal of the Science of Food and Agriculture 99(2019)5:2463-2472

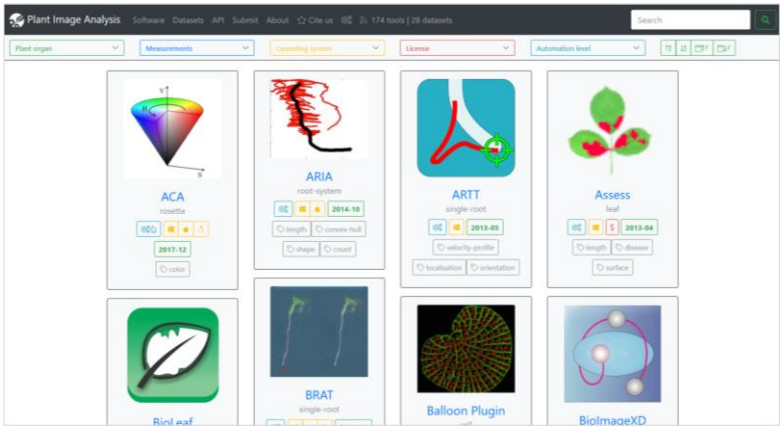
Rare earth elements

Miscellaneous crops
Co-deposition of silicon with rare earth elements (REEs) and aluminium in the fern *Dicranopteris linearis* from China. Plant and Soil 437(2019)1-2:427-437

Plant Image Analysis

A fertiliser planner or a diagnostic tool – the web has dozens of interesting websites. In this issue Plant Image Analysis.

Website	Plant Image Analysis
URL	http://www.plant-image-analysis.org
Languages	English
Description	An online database for plant image analysis software tools. The aim of this website is to help researchers having to analyse plant images to find the right tool for their research. The website has 174 tools and 28 datasets (viewed on 30-04-2019).
Offered by	Guillaume Lobet and Xiaoran Zhou



Publications about plant nutrition research

Rhizobia, mycorrhiza etc.

General

Fertilising effect of sewage sludge ash inoculated with the phosphate-solubilising fungus *Penicillium bilaiae* under semi-field conditions. Biology and Fertility of Soils 55(2019)1:43-51

The arbuscular mycorrhizal fungus *Rhizophagus irregularis* MUCL 43194 induces the gene expression of citrate synthase in the tricarboxylic acid cycle of the phosphate-solubilizing bacterium *Rahnella aquatilis* HX2. Mycorrhiza 29(2019)1:69-75

Organic acid excretion from roots: a plant mechanism for enhancing phosphorus acquisition, enhancing aluminum tolerance, and recruiting beneficial rhizobacteria. Soil Science and Plant Nutrition 64(2018)6:697-704

Arable crops - cereals and grasses

Barley, oat, rye and wheat

Plant-assisted selection: a promising alternative for *in vivo* identification of wheat (*Triticum turgidum L. subsp. Durum*) growth promoting bacteria. Plant and Soil 435(2019)1-2:367-384

Arable crops - legumes

Role of halotolerant phosphate-solubilising bacteria on growth promotion of peanut (*Arachis hypogaea*) under saline soil. Annals of Botany 174(2019)1:20-30

A reduced phosphorus application rate using a mycorrhizal plant as the preceding crop maintains soybean seeds' nutritional quality. Journal of Agricultural and Food Chemistry 67(2019)1:32-42

Arbuscular mycorrhiza *Rhizophagus irregularis* and silicon modulate growth, proline biosynthesis and yield in *Cajanus cajan* L. Millsp. (pigeonpea) genotypes under cadmium and zinc stress. Journal of Plant Growth Regulation 37(2018):1:46-63

Mycorrhizal inoculations and silicon fortifications improve rhizobial symbiosis, antioxidant defense, trehalose turnover in pigeon pea genotypes under cadmium and zinc stress. Plant Growth Regulation 86(2018)1:105-119

Arable crops - potato and sugar beet

Soil extract from an alfalfa (*Medicago sativa* L.) field improves potato rhizosphere enzyme activity and microbial quantity in a pot experiment. European Journal of Horticultural Science 83(2018)6:356-363

Fruit and vegetable crops

Silicon and the association with an arbuscular-mycorrhizal fungus (*Rhizophagus clarus*) mitigate the adverse effects of drought stress on strawberry. Agronomy 9(2019):41

Bacillus subtilis STU6 ameliorates iron deficiency in tomato by enhancement of polyamine-mediated iron remobilization. Journal of Agricultural and Food Chemistry 67(2019)1:320-330

Use of phosphorus fertilization and mycorrhization as strategies for reducing copper toxicity in young grapevines. Scientia Horticulturae 248(2019):176-183

Miscellaneous crops

Leaf endophytes mediate fertilizer effects on plant yield and traits in northern oat grass (*Trisetum spicatum*). Plant and Soil 434(2019)1-2:425-440

Silicon protects tobacco against parasitic plant

Silicon protects tobacco plants against European dodder, a parasitic plant species. Researchers at the Comenius University in Bratislava (Slovakia) have found this in an experiment with tobacco plants growing from silicon-primed seeds, watered with silicon or that are supplied with silicon via the leaf. The researchers observed that dodder was able to wrap around the treated plants, but did not penetrate the stems and died. they further found that silicon supplementation altered the growth and antioxidant enzymes activities of tobacco shoots. Silicon application method and the time of application affected the response of the tobacco plants. Results of this study are published in the online version of the journal *Plant Physiology and Biochemistry*.

Silicic acid prevents soil acidification after drip fertigation with AN

Apple trees fertigated with ammonium nitrate profit from silicic acid in the fertigation solution. Silicon-treated trees are less affected by internal bark necrotic disorder, have stronger growth and yield more apples. *Read more on page 8 of this issue*.

Silicon ameliorates magnesium deficiency

Silicon supplementation ameliorates magnesium deficiency in young maize plants. Researchers at the fertiliser company Roullier and at the German Leibniz-Institute of Plant Genetics and Crop Plant Research have found this in an experiment with greenhouse-cultivated plants growing on a magnesium-deficient substrate. *Read more on page 5 of this issue*.

Nitrogen affects insect defence by silicon

Silicon reduces true armyworm feeding damage in maize. Silicon application leads to an increase of the mortality of true armyworm larvae, compared with control plants. Larvae fed on plants treated with both silicon and nitrogen survive better than larvae fed on plants treated with silicon only. *Read more on page 5 of this issue*.

Silicon and phosphorus use efficiency in potato

Brazilian researchers are investigating whether it is possible to decrease phosphorus fertiliser rates with the help of silicon application and to maintain potato tuber yields at the same level. They therefore investigate whether silicon supplementation affects phosphorus use efficiency. Experiments yielded different results. *Read more on page 6 of this issue*.

Recent silicon publications

General

The controversies of silicon's role in plant biology. New Phytologist 221(2019)1:67-85
Silicon in Indian Agriculture. Westville Publishishing House. ISBN: 9789383491957
Role of silicon in mitigation of heavy metal stresses in crop plants. Plants 8(2019)3:71
Role of silicon in plant stress tolerance: opportunities to achieve a sustainable cropping system. 3 Biotech 9(2019):73

Arable crops - cereals and grasses

Wheat
Silicon decreases cadmium concentrations by modulating root endodermal suberin development in wheat plants. Journal of Hazardous Materials 364(2019):581-590
Silicon priming benefits germination, ion balance, and root structure in salt-stressed durum wheat (*Triticum durum* desf.). Journal of Plant Nutrition 41(2018)20:2560-2571

Barley
Silicon mitigates cold stress in barley plants via modifying the activity of apoplasmic enzymes and concentration of metabolites. Acta Physiologiae Plantarum 41(2019):29

Maize
Seed priming and soil incorporation with silicon influence growth and yield of maize under water-deficit stress. Archives of Agronomy and Soil Science 65(2019)2:197-207
Plant silicon effects on insect feeding dynamics are influenced by plant nitrogen availability. Entomologia Experimentalis et Applicata 167(2019)2:91-97
The ameliorative effect of silicon on maize plants grown in Mg-deficient conditions. International Journal of Molecular Sciences 20(2019)4:969

Rice
Long-term silicate fertilization increases the abundance of Actinobacterial population in paddy soils. Biology and Fertility of Soils 55(2019)2:109-120
Impacts of calcium silicate slag on the availability of silicon and trace contaminants in rice (*Oryza sativa* L.). Communications in Soil Science and Plant Analysis 50(2019)2:173-184
Bioavailability of silicon from different sources and its effect on the yield of rice in acidic, neutral, and alkaline soils of Karnataka, South India. Communications in Soil Science and Plant Analysis 50(2019)3:295-306
The effect of calcium silicate as foliar application on aerobic rice blast disease development. European Journal of Plant Pathology 153(2019)2:533-543
Suitability of extractant for soil available silicon and silicon response to upland paddy grown on alkaline soils of central India. Journal of Plant Nutrition 41(2018)18:2298-2308

Grass
Elevated carbon dioxide and warming impact silicon and phenolic-based defences differently in native and exotic grasses. Global Change Biology 24(2018)9:3886-3896

Recent silicon publications

	Climate warming and plant biomechanical defences: Silicon addition contributes to herbivore suppression in a pasture grass. Functional Ecology 33(2019)4:587-596
	Impact of grassland degradation on the distribution and bioavailability of soil silicon: Implications for the Si cycle in grasslands. Science of The Total Environment 657(2019):811-818
Sorghum	Silicon accumulation and its effect on agricultural traits and anthracnose incidence in lignocellulosic sorghum. Pesquisa Agropecuária Tropical 49(2019):e54201
Sugarcane	Evaluation of soil extractants for silicon availability for sugarcane. Journal of Plant Nutrition 41(2018)17:2241-2255
	Sugarcane yield response to calcium silicate on Florida mineral soils. Journal of Plant Nutrition 41(2018)19:2413-2424

Arable crops - other crops

Cotton	Silicon and salicylic acid in the physiology and yield of cotton. Journal of Plant Nutrition 42(2019)5:458-465
Potato	Phosphorus and silicon effects on growth, yield, and phosphorus forms in potato plants. Journal of Plant Nutrition 42(2019)3:218-233
Sunflower	Nutrition and production of *Helianthus annuus* in a function of application of leaf silicon. Journal of Plant Nutrition 42(2019)2:137-144

Fruit and vegetable crops

Apple	Application of sodium silicate retards apple softening by suppressing the activity of enzymes related to cell wall degradation. Journal of the Science of Food and Agriculture 99(2019)4:1828-1833
	Response of 'Red Delicious' apple trees drip-fertigated with ammonium nitrate to application of silicic acid. Scientia Horticulturae 249(2019):15-21
Cucumber	Silicon enhances the salt tolerance of cucumber through increasing polyamine accumulation and decreasing oxidative damage. Ecotoxicology and Environmental Safety 169(2019):8-17
Kale	Silicon leaf fertilization promotes biofortification and increases dry matter, ascorbate content, and decreases post-harvest leaf water loss of chard and kale. Communications in Soil Science and Plant Analysis 50(2019)2:164-172
Pepper	Silicon-induced salinity tolerance improves photosynthesis, leaf water status, membrane stability, and growth in pepper (*Capsicum annuum* L.). HortScience 53(2018)12:1820-1826
Spinach	Silicon (Si) biochar for the mitigation of arsenic (As) bioaccumulation in spinach (*Spinacia oleracean*) and improvement in the plant growth. Journal of Cleaner Production 189(2018):386-395
Strawberry	Silicon and the association with an arbuscular-mycorrhizal fungus (*Rhizophagus clarus*) mitigate the adverse effects of drought stress on strawberry. Agronomy 9(2019):41
Swiss chard	Silicon leaf fertilization promotes biofortification and increases dry matter, ascorbate content, and decreases post-harvest leaf water loss of chard and kale. Communications in Soil Science and Plant Analysis 50(2019)2:164-172
Tomato	The application of copper nanoparticles and potassium silicate stimulate the tolerance to *Clavibacter michiganensis* in tomato plants. Scientia Horticulturae 245(2019):82-89
	Transcriptome analysis reveals new insights into the bacterial wilt resistance mechanism mediated by silicon in tomato. International Journal of Molecular Sciences 20(2019)4:761

Miscellaneous crops

Chinese liquorice	Silicon promotes seedling growth and alters endogenous IAA, GA_3 and ABA concentrations in *Glycyrrhiza uralensis* under 100 mM NaCl stress. Journal of Horticultural Science and Biotechnology 94(2019)1:87-93
Horsetail (Equisetum)	Distributions of silica and biopolymer structural components in the spore elater of *Equisetum arvense*, an ancient silicifying plant. Frontiers in Plant Science 10(2019):210
Fern	Co-deposition of silicon with rare earth elements (REEs) and aluminium in the fern *Dicranopteris linearis* from China. Plant and Soil 437(2019)1–2:427–437

Soil and fertilisers

Biochar is a potential source of silicon fertilizer: An overview. Biochar from Biomass and Waste: Fundamentals and Applications. Chapter 12. Page 225-238

Chemical investigations of Si-rich organic and inorganic amendments and correlation analysis between different chemical composition and Si contents in amendments. Arabian Journal of Geosciences 12(2019):47

Using chemical experiments and plant uptake to prove the feasibility and stability of coal gasification fine slag as silicon fertilizer. Environmental Science and Pollution Research 26(2019)6:5925–5933

Si cycling and isotope fractionation: Implications on weathering and soil formation processes in a typical subtropical area. Geoderma 337(2019):479-490

What effect does liming have on silicon availability in agricultural soils? Geoderma 337(2019):375-383

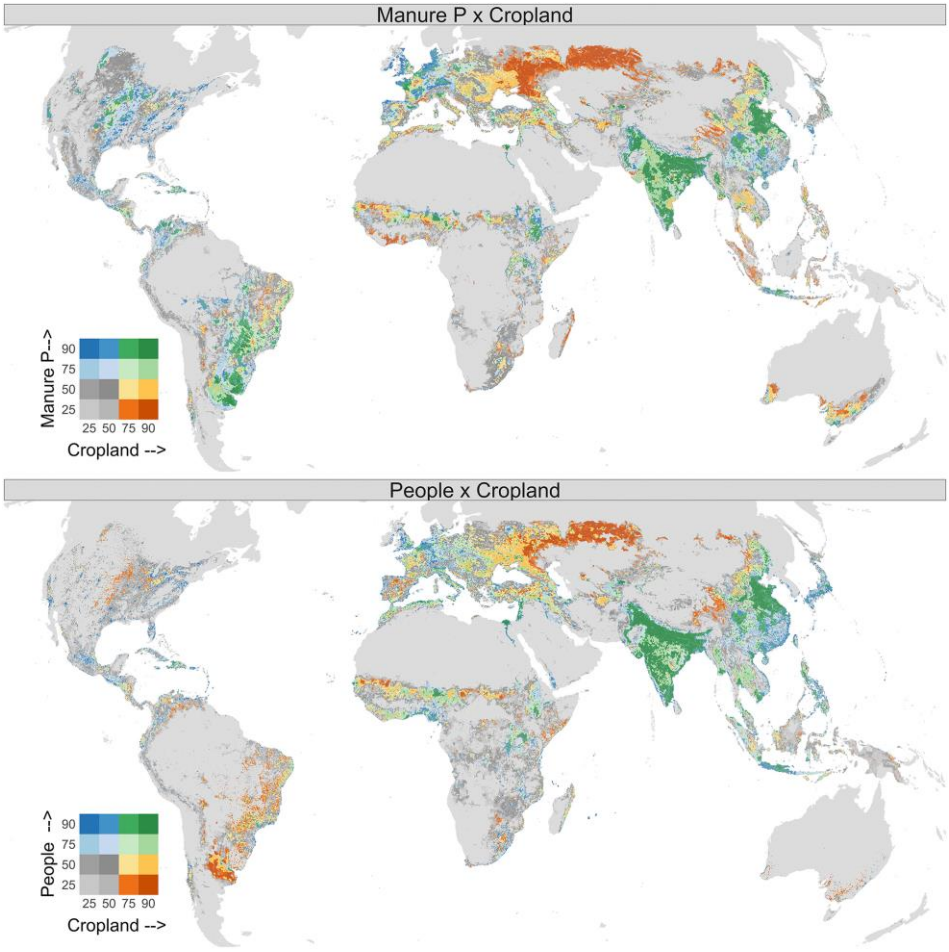
Release of plant-available silicon from various silicon-rich amendments into soil solutions and leachates. Journal of Soils and Sediments 19(2019)3:1272–1285

Impact of grassland degradation on the distribution and bioavailability of soil silicon: Implications for the Si cycle in grasslands. Science of The Total Environment 657(2019):811-818

Researchers map the world's manure-phosphorus flows

Scientists have mapped global hotspots of phosphorus-rich manure by combining recently developed datasets. The study is intended to encourage both recovery and recycling of this nutrient. The just published study disregards already started recovery projects.

The world's recoverable reserves of phosphate rocks are finite and unevenly distributed. Stevens Institute of Technology (Hoboken, New Jersey, USA) is spearheading an international effort to map the global flow of manure-phosphorus and jump-start efforts to recapture and recycle this nutrient. In the April 2019 issue of *Earth's Future*, the international research team map that process globally for the first time (see article). They identify regional 'hot spots' where there's both significant demand for fertilisers and significant potential for recapturing phosphorus from animal manure. "If we want to get serious about phosphorus recycling, these are the places where we're going to get the most bang for our buck," says David Vaccari, director of the Stevens Department of civil, environmental and ocean engineering. His team includes researchers from China, Australia, Canada, Sweden and The Netherlands. The team combined recently developed datasets to map global crop production alongside human and livestock population levels. They then divided the planet into a grid of 10-km wide blocks, allowing detailed local insights with an overview of global phosphorus flows.



Global distribution of manure-rich cultivated areas and populous cultivated areas.

Top: *Green shades exceed the global 75th percentiles for manure as kilograms of phosphorus per square kilometre and cropland extent as % grid cell area.*
Bottom: *Green shades exceed the global 75th percentiles for human population density as number per square kilometre and cropland extent as % grid cell area.*
Click here for high-resolution picture.

Manure-rich livestock operations

Some 72 percent of croplands with significant manure production nearby, and 68 percent of croplands with significant human populations nearby, are in regions that are heavily dependent on imported phosphorus, including large swathes of major emerging economies such as India and Brazil. The study also identifies significant surpluses of phosphorus-rich waste in much of Asia, Europe and the United States, suggesting that both developing and developed economies could benefit from increased recycling.

The results also show that at least five times as much phosphorus is contained in animal manure as human waste, suggesting that livestock operations are an abundant target for recycling efforts. Almost half of the world's farmlands – about 12 percent of the planet's landmass – are co-located with manure-rich livestock operations, suggesting that in many regions manure could be applied to fields directly, or processed using bio-digesters to extract phosphorus for efficient and economical transport to farms. First-author Steve Powers, a researcher at Washington State University who conceived of the study, and Vaccari are now trying to figure out exactly how much phosphorus can be recaptured from animal and human waste and identify other opportunities for more efficient phosphorus use. "If we can recycle more of this locally-available waste phosphorus back into agriculture, we might be able to keep it away from leak points while reducing our dependence on future fertiliser imports and mining," says Powers.

One-sided study

Many figures, useful suggestions, but yet one-sided: the study about manure-phosphorus flows disregards already started phosphorus recovery projects. Although the authors mention struvite and dry manure forms as options, they do not provide information about the many projects that have been initiated or commercialised. This raises the question whether the researchers contacted experts from the field of animal manure, fertilisers, or phosphorus recovery and recycling. Japanese researchers did exactly that job. They published earlier this year a useful handbook about both recovery and recycling of phosphorus, including the commercialisation of fertilisers based on so-called secondary phosphates.

Calendar of events

General interest

Agrishow	29-04 / 03-05 - 2019	Ribeirão Preto, Brazil
15th International Conference on the Biogeochemistry of Trace Elements (ICOBTE)	05-05 / 09-05 - 2019	Nanjing, China
► ISF World Seed Congress 2019	03-06 / 05-06 - 2019	Nice, France
Greensys 2019	16-06 / 20-06 - 2019	Angers, France
Nanotech 2019	17-06 / 19-06 - 2019	Boston, Massachusetts, USA
IX International Symposium on Irrigation of Horticultural Crops	17-06 / 20-06 - 2019	Matera, Italy
8th ISMOM (International Symposium on Interactions of Soil Minerals with Organic Components and Microorganisms)	23-06 / 28-06 - 2019	Seville, Spain
III International Symposium on Growing Media, Composting and Substrate Analysis	24-06 / 28-06 - 2019	Milan, Italy
► Advanced Fertilizer Technology and Lessons Learning	24-06 / 26-06 - 2019	Lugano, Switzerland
7th International Symposium on Metallomics	30-06 / 03-07 - 2019	Warsaw, Poland
IUPAC 2019 Paris France	05-07 / 12-07 - 2019	Paris, France
Rhizosphere 5	07-07 / 11-07 - 2019	Saskatoon, Canada
12th European Conference on Precision Agriculture	08-07 / 11-07 - 2019	Montpellier, France
Int. Conf. on Computer Technologies and Applications in Food and Agriculture	11-07 / 13-07 - 2019	Konya, Turkey
InfoAg 2019	23-07 / 25-07 - 2019	St. Louis, Missouri, USA
103rd Annual Meeting of the Potato Association of America	28-07 / 01-08 - 2019	Winnipeg, Manitoba, Canada
Plant Health 2019	03-08 / 07-08 - 2019	Cleveland, Ohio, USA
36th International Conference on Solution Chemistry	04-08 / 08-08 - 2019	Xining, China
258th ACS National Meeting & Exposition	25-08 / 29-08 - 2019	San Diego, California, USA
InfoAg International Conference & Exhibition	26-08 / 28-08 - 2019	Campinas, Brazil
Wageningen Soil Conference 2019	27-08 / 30-08 - 2019	Wageningen, The Netherlands
New Ag International China	23-09 / 25-09 - 2019	Chengdu, China
Comparing organic and conventional agricultural cropping systems - What can be learned from the DOK and other long-term trials?	06-10 / 10-10 - 2019	Ascona, Switzerland
► XI International workshop on sap flow	07-10 / 11-10 - 2019	Hyytiälä, Finland
8th Asian-Australasian Conference on Precision Agriculture	14-10 / 17-10 - 2019	Ludhiana, India
► ASA-CSSA-SSSA Annual Meeting	10-11 / 13-11 - 2019	San Antonio, Texas, USA
Soil Science 2019	25-11 / 26-11 - 2019	Singapore City, Singapore
Agritechnica	10-11 / 16-11 - 2019	Hannover, Germany
► 2019 Irrigation Show & Education Conference	02-12 / 06-12 - 2019	Las Vegas, Nevada, USA
► ICSC 2019 : International Conference on Solution Chemistry	04-12 / 05-12 - 2019	Tokyo, Japan
► Acres U.S.A. 2019 Eco-Ag Conference & Trade Show	09-12 / 12-12 - 2019	Minneapolis, Minnesota, USA
► European Geosciences Union General Assembly 2020	03-05 / 08-05 - 2020	Vienna, Austria
► 21st Triennial Conference of the European Association for the Potato Research	06-07 / 10-07 - 2020	Warsaw, Poland
► 12th International Biometals Symposium	July 2020	Grenoble, France
► ISAA 2020 - ISAA Agrochemical Network	21-07 / 24-07 - 2020	Bordeaux, France
► Eurosoil 2020	24-08 / 28-08 - 2020	Geneva, Switzerland
► ICSC 2019 : International Conference on Solution Chemistry	03-12 / 04-12 - 2020	Tokyo, Japan
Pacifichem 2020	15-12 / 20-12 - 2020	Honolulu, Hawaii, USA

Biostimulants

US Biostimulants Summit 2019	01-05 / 02-05 - 2019	St Louis, Missouri, USA
► Future of Agricultural Biosolutions	09-05-2019	Cawood, UK
Crops & Chemicals USA – Biostimulants	20-05 / 22-05 - 2019	Raleigh, North Carolina, USA
Agri Biostimulants 2019	05-06 / 06-06 - 2019	Rome, Italy
► AgriBusiness Global Biostimulant CommerceCon	22-07 / 23-07 - 2019	Atlantic City, New Jersey, USA
► 2019 China-Overseas Biopesticides & Biostimulants Business Exchange Congress (BioEx 2019)	22-08 / 23-08 - 2019	Hangzhou, Zhejiang, China
4th Partnerships in Biocontrol, Biostimulants & Microbiome: USA	04-11 / 05-11 - 2019	Raleigh-Durham, NC, USA
4th Biostimulants World Congress	18-11 / 21-11 - 2019	Barcelona, Spain

Plant nutrition and fertilisers general

32nd AFA International Fertilizers Technology Conference	30-04 / 02-05 - 2019	Muscat, Oman
Argus East Europe Fertilizer 2019	15-05 / 17-05 - 2019	Vienna, Austria
Delivering Balanced Crop Nutrition to Small-Scale Farmers	27-05 / 31-05 - 2019	Accra, Ghana
► New EU Fertilizer Regulation: Where do we go?	28-05-2019	Brussels, Belgium
Argus Added Value Fertilizers US	03-06 / 05-06 - 2019	Atlanta, Georgia, USA
2019 IFS Technical Conference	04-06 / 05-06 - 2019	Brussels, Belgium
4R Nutrient Stewardship Summit	10-06 / 11-06 - 2019	Cleveland, Ohio, USA
► 87th IFA Annual Conference	11-06 / 13-06 - 2019	Montreal, Quebec, Canada

► 2019 CNCIC Global Specialty Fertilizers Convention	14-06 / 15-06 - 2019	Beijing, China
94th Annual Southwestern Fertilizer Conference	21-07 / 25-07 - 2019	Nashville, Tennesee, USA
North American Fertilizer Transportation Conference	18-08 / 19-08 - 2019	Victoria, BC, Canada
Fertilizer Canada Annual Conference	19-08 / 21-08 - 2019	Victoria, BC, Canada
► Australian Fertilizer Industry Conference	04-09 / 06-09 - 2019	Gold Coast, Australia
► Argus FSU Fertilizer 2019 — Production, Trading and Logistics in the CIS and Baltics	04-09 / 06-09 - 2019	Minsk, Belarus
► Argus Added Value Fertilizers Africa	11-09 / 13-09 - 2019	Nairobi, Kenya
► TFI World Fertilizer Conference	23-09 / 25-09 - 2019	Chicago, Illinois, USA
Annual meeting of the German Society of Plant Nutrition 2017 "Plant Nutrition meets social expectations of sustainable plant production"	25-09 / 27-09 - 2019	Berlin, Germany
► Africa Fertilizer Agribusiness Conference	01-10 / 03-10 - 2019	Cape Town, South Africa
Argus Europe Fertilizer	16-10 / 18-10 - 2019	St Julian's, Malta
2019 IFA Crossroads Asia-Pacific Conference	22-10 / 24-10 - 2019	Sydney, Austrlia
2019 IFA Strategic Forum	19-11 / 20-11 - 2019	Paris, France
Fertilizer Outlook and Technology Conference	19-11 / 21-11 - 2019	Savannah, Georgia, USA
Smart Fertilization Day	29-11-2019	Wageningen, The Netherlands
► Specialty Fertilizer Global Summit 2019	05-12-2019	New Orleans, Louisiana, USA
2019 IFS Agronomic Conference	12-12 / 13-12 - 2019	Cambridge, UK
► Fertilizer Latino Americano 2020	20-01 / 22-01 - 2020	São Paulo, Brazil
► Argus Added Value Fertilizers Europe	February 2020	TBC
► 33rd Annual Fertilizer & Lime Research Centre Workshop	11-02 / 13-02 - 2020	Palmerston North, New Zealand
► TFI Annual Meeting	17-02 / 19-02 - 2020	Palm Springs, California, USA
► Argus Africa Fertilizer 2020	19-02 / 21-02 - 2020	Cape Town, South Africa
► Argus Asia Fertilizer	April 2020	Shanghai, China
► IX International Symposium on Mineral Nutrition of Fruit Crops	08-06 / 11-06 - 2020	Ma'ale HaHamish, Israel
Mapping, sensing, sampling and analytics		
5th Global Workshop on Proximal Soil Sensing	28-05 / 31-05 - 2019	Columbia, Missouri, USA
► CSI XLI: Colloqium Spectroscopicum Internationale XLI	09-06 / 14-06 - 2019	Mexico City, Mexico
16th International Symposium on Soil and Plant Analysis (ISSPA 2019)	17-06 / 20-06 - 2019	Wageningen, The Netherlands
III International Symposium on Growing Media, Composting and Substrate Analysis	24-06 / 28-06 - 2019	Milan, Italy
Euroanalysis 2019: XX Euroanalysis	01-09 / 05-09 - 2019	Istanbul, Turkey
► AOAC 133rd Annual Meeting & Exposition	06-09 / 12-09 - 2019	Denver, Colorado, USA
► IMA-2019: 11th International Conference on Instrumental Methods of Analysis	22-09 / 25-09 - 2019	Ioannina, Greece
► SciX 2019	13-10 / 18-10 - 2019	Palm Springs, California, USA
► Analytica 2020	31-03 / 03-04 - 2020	Munich, Germany
► HPLC 2021	20-06 / 24-06 - 2021	Düsseldorf, Germany
Foliar fertilisation		
► 26th Meeting working group foliar fertilisation (German)	13-12-2019	Wittenberg, Germany
Chelates / ligands / metal complexes		
► 44th International Conference on Coordination Chemistry (ICCC 2020)	05-07 / 10-07 - 2020	Rimini, Italy
Organic matter / organic fertilisers (compost / manure / green manure / industrial wastes / biochar, humic acids etc)		
1st Summit of the Organic Fertiliser and organo-mineral fertilising materials Industry in Europe (SOFIE)	05-06 / 06-06 - 2019	Brussels, Belgium
HUMIC Conference - IHSS Nordic-Baltic Chapter	05-06 / 08-06 - 2019	Riga, Latvia
► Pyroliq 2019: Pyrolysis and Liquefaction of Biomass and Wastes	16-06 / 20-06 - 2019	Cork, Ireland
► USBI Biochar 2019	30-06 / 03-07 - 2019	Fort Collins, Colorado, USA
North American Manure Expo 2019	31-07 / 01-08 - 2019	Fair Oaks, Indiana, USA
First Australia New Zealand Biochar Study Tour and third Conference	20-10 / 26-10 - 2019	Melbourne, Australia
Bio-Char II: Production, Characterization and Applications	15-09 / 20-09 - 2019	Cetraro, Italy
► IBI Biochar World Congress 2019	10-11 / 14-11 - 2019	Seoul, Korea
► European Biosolids & Organic Resources Conference & Exhibition	19-11 / 20-11 - 2018	Manchester, UK
ManuREsource 2019 - Int. conference on manure management and valorization	27-11 / 28-11 - 2019	Hasselt, Belgium
Specific release / nitrification and urease inhibitors		
► IFA/IFDC Training on Production of Slow-, Controlled-Release and Stabilized Fertilizers	24-06 / 26-06 - 2019	Frankfurt am Main, Gemany
46th Annual Meeting & Exposition of the Controlled Release Society	21-07 / 24-07 - 2019	Valencia, Spain

Nitrogen		
► Nitrogen North America	30-05-2019	Las Vegas, Nevada, USA
Argus NPK and Added Value Fertilizers Asia	26-06 / 28-08 - 2019	Ho Chi Minh, Vietnam
ICNF 2019: 21st International Conference on Nitrogen Fixation	27-06 / 28-06 - 2019	London, UK
2019 NUE Workshop	05-08 / 07-08 - 2019	Columbia, Missouri, USA
64th Annual Safety in Ammonia Plants and Related Facilities Symposium	08-09 / 12-09 - 2019	San Francisco, CA, USA
2019 ANNA Conference	08-09 / 13-09 - 2019	Vienna, Austria
► Middle East Nitrogen + Syngas 2019	27-10 / 29-10 - 2019	Muscat, Oman
► Nitrogen + Syngas 2020	17-02 / 19-02 - 2020	The Hague, The Netherlands
Phosphorus		
► 43rd Annual International Phosphate Fertilizer & Sulfuric Acid Technology Conference (Clearwater Conference)	07-06 / 08-06 - 2019	Clearwater Beach, Florida, USA
Argus NPK and Added Value Fertilizers Asia	26-06 / 28-08 - 2019	Ho Chi Ming, Vietnam
► Marketplace Phosphorrückgewinnung	27-06-2019	Sulzbach-Rosenberg, Germany
International Phosphorus Workshop 9	08-07 / 12-07 - 2019	Zürich, Switzerland
► Global Phosphate & Compound Fertilizer Industry Development Conference	28-08 / 29-08 - 2019	Beijing, China
► DPP-Forum 2019	26-09-2019	Frankfurt am Main, Germany
► PBSi 2019 - International Conference On Phosphorus, Boron and Silicon	02-12 / 04-12 - 2019	Rome, Italy
► Phosphates 2020	08-03 / 10-03 - 2020	Paris, France
► 4th European Sustainable Phosphorus Conference	15-06 / 17-06 - 2020	Vienna, Austria
Potassium		
Argus NPK and Added Value Fertilizers Asia	26-06 / 28-08 - 2019	Ho Chi Ming, Vietnam
13th IPI-CAU-ISASS International Symposium. Potash and Polyhalite: Potassium, Sulphur, Magnesium and Calcium for Efficient Balanced Plant Nutrition	06-11 / 08-11 - 2019	Kunming, China
Calcium and magnesium		
13th IPI-CAU-ISASS International Symposium. Potash and Polyhalite: Potassium, Sulphur, Magnesium and Calcium for Efficient Balanced Plant Nutrition	06-11 / 08-11 - 2019	Kunming, China
Magnesium		
13th IPI-CAU-ISASS International Symposium. Potash and Polyhalite: Potassium, Sulphur, Magnesium and Calcium for Efficient Balanced Plant Nutrition	06-11 / 08-11 - 2019	Kunming, China
Sulphur		
► 43rd Annual International Phosphate Fertilizer & Sulfuric Acid Technology Conference (Clearwater Conference)	07-06 / 08-06 - 2019	Clearwater Beach, Florida, USA
► Sulphur Products Summit: Insight on Ag and Industry	01-10 / 02-10 - 2019	Atlanta, Georgia, USA
Sulphur + Sulphuric Acid 2019	04-11 / 07-11 - 2019	Houston, Texas, USA
13th IPI-CAU-ISASS International Symposium. Potash and Polyhalite: Potassium, Sulphur, Magnesium and Calcium for Efficient Balanced Plant Nutrition	06-11 / 08-11 - 2019	Kunming, China
Boron		
Euroboron 8 - 8th European Conference on Boron Chemistry	24-06 / 27-06 - 2019	Montpellier, France
► PBSi 2019 - International Conference On Phosphorus, Boron and Silicon	02-12 / 04-12 - 2019	Rome, Italy
19th International Meeting on Boron Chemistry (IMEBORON XVII)	July 2020	Rennes, France
Zinc		
2019 International Zinc Conference	15-05 / 17-05 - 2019	Plovdiv, Bulgaria
Selenium		
► 6th Int. Conf. on Selenium in the Environment and Human Health (ICSEHH)	27-10 / 30-10 - 2019	Yangling/Xi'an, China
Silicon		
► PBSi 2019 - International Conference On Phosphorus, Boron and Silicon	02-12 / 04-12 - 2019	Rome, Italy
Mycorrhiza and other microorganisms improving a crop's nutritional status		
10th International Conference on Mycorrhizae	30-06 / 05-07 - 2019	Mérida, Mexico
miCROPe 2019	02-12 / 05-12 - 2019	Vienna, Austria

► New or additional information added

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Publisher	Landbouwkundige Uitgeverij G.C. van den Berg
Address	Van Maerlantstraat 5, 3906 EL Veenendaal, The Netherlands
Website	www.plantnutritioncourier.nl
Subscriptions	Small: € 125,00/year ex VAT (1 - 10 readers at one physical location of the organisation).
	Medium: € 375,00/year ex VAT (11 - 50 readers ate multiple physical locations of the organisation).
	Worldwide: € 825,00/year ex VAT (worldwide in-company subscription).
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