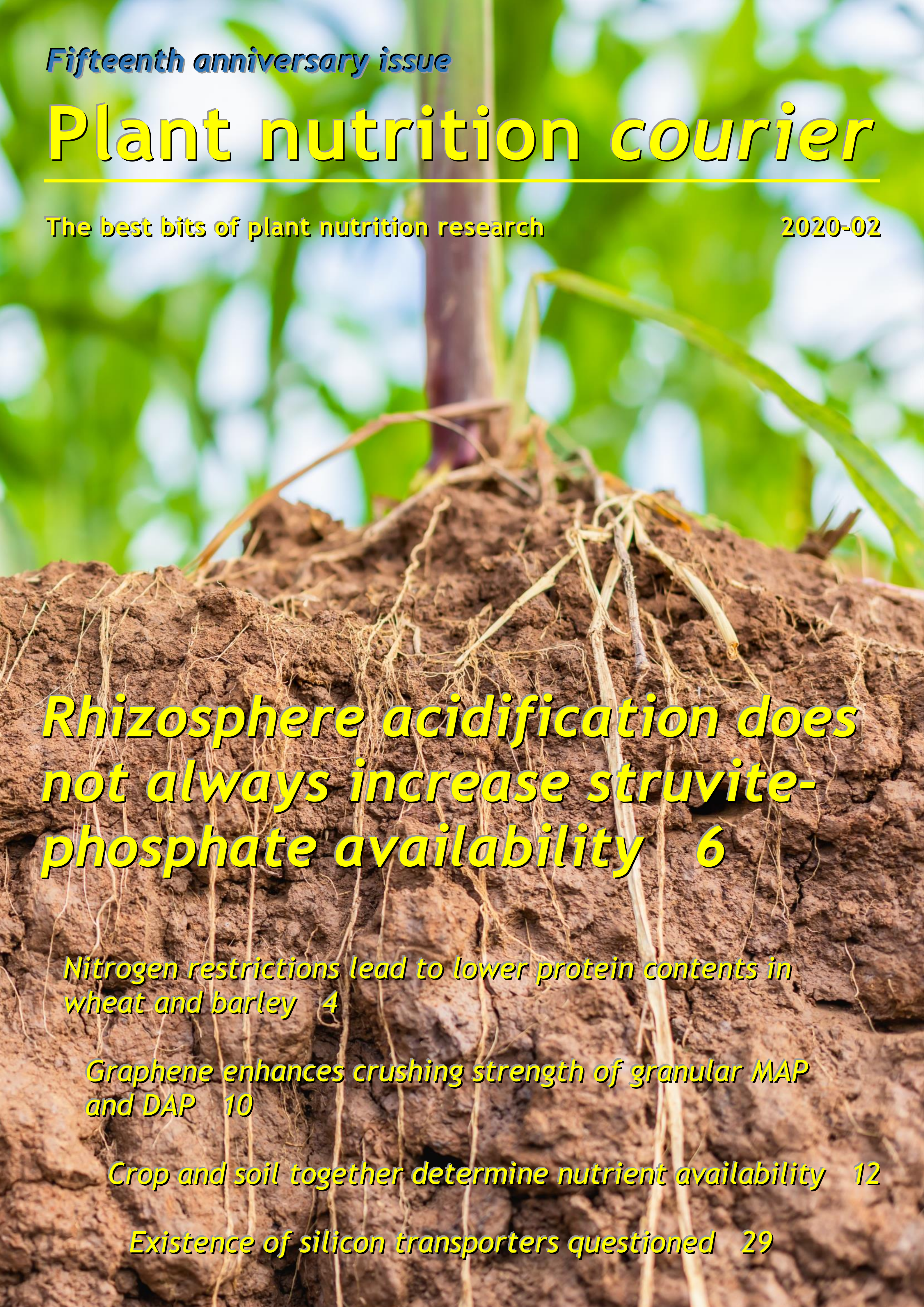

Fifteenth anniversary issue

Plant nutrition courier

The best bits of plant nutrition research 2020-02

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15 years of news about plant nutrition research and beneficial nutrients

It is March 2005. In this month the first issue of the digital newsletter Beneficial nutrients news is published. Six years this special interest newsletter publishes news and reviews on so-called beneficial nutrients, such as silicon, selenium, iodine and nickel.
From 2011, news about beneficial nutrients is a regular part of the digital bimonthly magazine Plant nutrition *courier*, which was previously a supplement of Beneficial nutrients news.

Beneficial nutrients news started with a four pages counting issue. Regular issues of the Plant nutrition *courier* have now at least 32 pages. We hope to provide you with the best bits of plant nutrition research for many years to come.

Gert van den Berg

Cover of the first issue of Beneficial nutrients news

Beneficial nutrients news

Volume 1 • Issue 1
January 2005

Digital newsletter about silicon and other beneficial elements

Newsletter about beneficial nutrients

Silicon enhances the growth of some crops. The nutrient can also give some protection against diseases like powdery mildew. Moreover silicon can enhance resistance to abiotic stress, for instance drought stress and aluminium and manganese toxicity. Benefits of the nutrient are strikingly evident in adverse situations. It is remarkable that the knowledge about such a beneficial nutrient is so fragmented.

Focus on silicon
In short articles and newsflashes the digital bimonthly **Beneficial nutrients news** will provide you with information about the use of silicon in agriculture and horticulture.
Beneficial nutrients news focuses on silicon in plant nutrition and crop protection. **Beneficial nutrients news** will bring you up-to-date. Freelance journalist Gert van den Berg produces the newsletter.

Other beneficial nutrients
Beneficial nutrients news also reports about other beneficial nutrients. In this issue, attention is paid to effects of selenium on potato yield, tuber size and photooxidative stress tolerance. A list of publications completes the short review.


Gert van den Berg

Inducing bacterial disease resistance

Scientists from the University of Hannover (Germany) find silicon enhances resistance and tolerance to *Ralstonia solanacearum*, the causal agent of a bacterial disease of a 200 host species, including potato, tobacco, tomato and also ornamentals like pelargonium. In exploring experiments with the silicon non-accumulator plant tomato on hydroponics, positive results are achieved after adding monosilicic acid to the nutrient solution. The glasshouse experiments are continued with tomato on peat substrate. According to Kerstin Wydra from Institute of Plant Diseases and Plant Protection, results from these experiments are better than outcomes from experiments with tomato on hydroponics. An article about this research is in press (see preview abstract).
As a follow up Kerstin Wydra conducts glasshouse experiments in tomato (Thailand) and field experiments with potato and tomato (Ethiopia). Also trials with silicon as nutrient for ornamentals infected with bacterial diseases are planned.
At the moment Wydra and colleagues study which biochemical changes in tomato are caused by silicon nutrition.

Fungal diseases
Earlier scientists have found indications for induced resistance to fungal diseases after silicon application in cucumber, pea, rice and wheat. In most crops however, enhanced fungal disease resistance is believed to be a result of silicon accumulation in cell walls.

Efficiency of water use by maize

A treatment with silicic acid improves water use efficiency of maize, according to researchers from China Agricultural University. In lab experiments, silicon reduces transpiration rate through stomata. Chunqin Zou from Department of Plant Nutrition concludes from these experiments that silicon influences stomata movement.

Other crops
Furthermore, plants treated with silicic acid have a lower flow rate than untreated maize plants. The project is extended with other test crops: sunflower and aerobic rice. A part of the maize research is already published in Journal of plant nutrition 27(2004)8:1457-1470

Selectivity by silicon

The position of a silicon atom in the structure of a pesticide is important for its fungicidal activity, suspects Mikio Tsuda from Sankyo Agro Co (Japan). Results from a study with simeconazole indicate a contribution of the silicon atom to the antifungal activity of the pesticide in rice. Silicon may also contribute to the pesticide's selectivity.

Beneficial nutrients news 1 January 2005

Nitrogen restrictions lead to lower protein contents in wheat and barley

Cereal grains have reduced crude protein contents due to stricter nitrogen regulations, reduced aerial deposition and probably also rising CO_2 levels. Danish researchers conclude this from an analysis of wheat and barley trials. The lower crude protein content needs farmers to add protein sources to fodder.

Increased levels of atmospheric carbon dioxide likely reduce nitrogen and protein contents of cereal grains. This can be deduced from an analysis of a large number of Danish fertiliser trials with winter wheat and spring barley. The fertiliser trials were carried out by the Danish Agricultural Advisory Service on farmers' fields using contemporary varieties and fertiliser recommendations. The analysis is published in the *European Journal of Agronomy*. Reason for this analysis is the significant drop in protein content in Danish wheat and barley grains from 1990 to 2015. Possible effects of elevated CO_2-levels on grain protein contents are 'hidden' in the overall effect of plant breeding on the response of crops to nitrogen fertilisation and are difficult to separate. Incidentally, effects of the rising CO_2 levels are yet small.

Simulations carried out by researchers at the University of Copenhagen Department of Plant and Environmental Sciences indicate that the changed palette of varieties explained only 15-20 % of the crude protein drop in winter wheat, but 40-60 % of this drop in spring barley. The outcomes of this simulation study indicate that the increasingly stringent nitrogen regulations may have as side effect a selective pressure for varieties that can produce reasonable yields at low nitrogen availability. All in all the changes in fertiliser regulations accompanied by a drop in aerial deposition of nitrogen explained between 50 and 70% of the decline in crude protein content in winter wheat. Warmer and wetter weather accounted for around 20 % of the change for both crops, the researchers report in the online available August 2020 issue of the *European Journal of Agronomy*. On the more clayey soils, reduced mineralisation influenced the protein content, the researchers say. This effect was probably underestimated in the simulation study. The lower grain protein content has economic consequences, as farmers compensate by adding an increasing amount of soybean and other protein sources to fodder. Farmers generally blame environmental restrictions for the low protein contents, particularly reduced nitrogen fertiliser norms. New varieties that produce more dry matter at lower nitrogen levels were also suggested to have reduced protein content. The just published analysis confirms these suspicions.

High potassium rate reduces shading stress in wheat

A high rate of potassium chloride protects wheat against grain yield reduction caused by shading stress. Chinese scientists report this stress-ameliorating effect of potassium chloride in the open access journal *Frontiers in Plant Science*. They found potassium chloride to improve both photosynthesis and translocation of photosynthates. The researchers studied the shading stress-ameliorating effect in a pot experiment with winter wheat growing in sandy loam soil. The past 50 years, wheat yields in the Huang-Huai Plain have been substantially reduced as result of the decreasing total solar radiation and sunshine hours, the researchers mention as reason for this study.

Nitrification inhibitor reduces greenhouse gas emission from injected slurry and digestate

Injection of slurry or digestate below maize seeds improves nitrogen use efficiency, but also increases nitrous oxide (N_2O) emissions. Addition of a nitrification inhibitor (DMPP) to the slurry or digestate significantly reduces the emission of this greenhouse gas. Researchers at the University of Applied Sciences Osnabrück evaluated DMPP addition to slurry and digestate in a soil-column incubation experiment. This laboratory experiment is carried out with PVC pipes as incubation vessels that are filled with field-moist loamy sand. The study is published in the *Journal of Plant Nutrition and Soil Science*.

Searching for nutrient profiles for early tuber yield prognoses

The maximum nitrogen concentration in growing potato tubers is the key yield driver and determines the final tuber yield. Poznan University of Life Sciences researchers conclude this in a paper in *Agronomy Journal*. The Polish researchers base their conclusions on field experiments carried out in 2007 and 2008 and published in Spring 2020. They are elaborating data from field experiments carried out from 2006 to 2014 to find an indicator in the potato nutritional status at the onset of tuberisation that can be used as yield prediction tool. The past years they have published al lot of papers (see article, article, article, article, article, article, article and article). A comprehensive analysis of the data is still lacking.

Publications about potato nutrition research

Mapping, sensing, sampling and analytics

The in-season nitrogen concentration in the potato tuber as the yield driver. Agronomy Journal 112(2020)2:1287-1308

Potato nutritional status at the onset of tuberisation – a yield prediction tool. Plant, Soil and Environment 66(2020)2:86-92

The unexploited potential of nutrient analysis in potato tissues at the onset of tuberization for tuber yield prediction. Agronomy 10(2020)1:103

Nitrogen profile of potato during the growing season - the tuber yield prediction. Journal of Elementology 24(2019)4:1309-1322

The in-season variability in the calcium concentration in potato organs and its relationship with the tuber yield. Journal of Elementology 25(2020)1:107-124

Testing critical phosphorus dilution curves for potato cropped in tropical Oxisols of southeastern Brazil. European Journal of Agronomy 115(2020):126020

Organic fertilisers and industrial wastes (selection)

Potato response to struvite compared with conventional phosphorus fertilizer in Eastern Canada. Agronomy Journal 112(2020)2:1360-1376

Green manure / cover crops

Optimizing soil nitrogen balance in a potato cropping system through legume intercropping. Nutrient Cycling in Agroecosystems 117(2020)1:43-59

Biochar

Nutrient uptake and growth of potato: Arbuscular mycorrhiza symbiosis interacts with quality and quantity of amended biochars. Journal of Plant Nutrition and Soil Science 183(2020)2:220-232

Specific release

Nitrogen source and rate effects on residual soil nitrate and overwinter NO_3-N losses for irrigated potatoes on sandy soils. Canadian Journal of Soil Science 100(2020)1:44-57

Nitrogen

Response of potato to nitrogen and phosphorus fertilizers at Assosa, western Ethiopia. Agronomy Journal 112(2020)2:1227-1237

The in-season nitrogen concentration in the potato tuber as the yield driver. Agronomy Journal 112(2020)2:1287-1308

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Nitrogen profile of potato during the growing season - the tuber yield prediction. Journal of Elementology 24(2019)4:1309-1322

Effects of nitrogen fertilization on the leaf chemical composition of two potato cultivars under controlled conditions. American Journal of Potato Research 97(2020)2:175-184

Identification of QTLs associated with nitrogen use efficiency and related traits in a diploid potato population. American Journal of Potato Research 97(2020)2:185-201

Nitrogen source and rate effects on residual soil nitrate and overwinter NO_3-N losses for irrigated potatoes on sandy soils. Canadian Journal of Soil Science 100(2020)1:44-57

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Nutrient uptake and growth of potato: Arbuscular mycorrhiza symbiosis interacts with quality and quantity of amended biochars. Journal of Plant Nutrition and Soil Science 183(2020)2:220-232

Potassium

Nutrient uptake and growth of potato: Arbuscular mycorrhiza symbiosis interacts with quality and quantity of amended biochars. Journal of Plant Nutrition and Soil Science 183(2020)2:220-232

Calcium

The in-season variability in the calcium concentration in potato organs and its relationship with the tuber yield. Journal of Elementology 25(2020)1:107-124

Mycorrhiza etc.

Nutrient uptake and growth of potato: Arbuscular mycorrhiza symbiosis interacts with quality and quantity of amended biochars. Journal of Plant Nutrition and Soil Science 183(2020)2:220-232

Rhizosphere acidification does not always increase struvite-phosphate availability

Acidification of the rhizosphere enhances the availability of struvite-phosphate to the roots. However, the rhizosphere-pH must not drop too far to prevent formation of aluminium phosphate. Struvite source and form also affect the plant-availability of phosphorus.

Struvite has left its childhood. The dewatered magnesium ammonium phosphate mineral is increasingly praised as sustainable phosphorus fertiliser. The phosphate release kinetics of this coarse sea salt looking fertiliser is estimated and valued differently. Ostara Nutrient Recovery Technologies company proudly promotes its Crystal Green branded granular struvite fertiliser as the “only root-activated fertiliser that continually supplies phosphorus, nitrogen, and magnesium all season long”. However, not everyone is charmed by the slow phosphate release in neutral and alkaline soils. Researchers are therefore looking into options to accelerate the solubilisation of struvite. Different approaches have already investigated, including manipulation of the soil pH.

Rhizosphere acidification is one of these options studied. Researchers at the German Forschungszentrum Jülich Institute of Bio- and Geosciences IBG-2 Plant Sciences used for this purpose ammonium sulphate. They fertigated maize and lupin plants growing in nutrient-poor acidic sand (pH 4.8) with nitrogen applied either as ammonium sulphate or as calcium nitrate and potassium nitrate. Ammonium sulphate does increase phosphorus uptake from struvite via acidification of a plant’s rhizosphere, according to the researchers. Lupin plants had a higher phosphorus uptake efficiency as compared to maize plants and this might be due to additional rhizosphere acidification by lupin root exudates. The researchers reported their observations in an open access article in the *Journal of Plant Nutrition and soil Science*.

Phosphate precipitation

French researchers have conducted a similar study, with struvite and triple superphosphate as phosphorus sources and Italian ryegrass as test crop. Nitrogen was applied as ammonium sulphate or as calcium nitrate. The Haplic Luvisol soil (pH 7.8) used in this study has a history of arable farming, with organic and mineral fertilisation based on soil tests and crop requirements. Although supplying ammonium sulphate instead of calcium nitrate resulted in rhizosphere acidification, this did not result in higher phosphate uptake, the researchers report. They partially attribute the lack of an increase in the uptake of phosphorus to the increase of the soluble aluminium concentration in the rhizosphere. This subsequently controlled the phosphate availability by precipitating this nutrient under the form of an amorphous aluminium phosphate (variscite-like) phase. The absence of phosphorus deficiency may have also contributed to the lack of an increased phosphorus uptake, the researchers mention in an article in the ►

► open access journal *Sustainability*. They suggest to test a partial substitution of nitrate-nitrogen by ammonium-nitrogen in order to acidify rhizosphere without reaching pH values at which aluminium is soluble (pH < 5.5).

Struvite source and form does matter
Struvite and triple superphosphate were in these experiments applied in powdery form and thoroughly mixed through the growing medium. The experiments had no treatments with granular fertilisers as commonly used under field conditions. Previously several research groups reported that ground struvite showed a phosphorus release rate that was comparable to the phosphorus release of a water-soluble fertiliser. Ground struvite mixed through soil quickly dissolved and its agronomic effectiveness was similar to that of the water-soluble phosphorus fertiliser monoammonium phosphate, researchers at the Australian Fertiliser Technology Research Centre at the University of Adelaide reported. They further found that struvite preparation with magnesium oxide or magnesium hydroxide as magnesium source resulted in products containing excess of MgO or $Mg(OH)_2$. This base excess reduced the dissolution of granular struvite significantly. The researchers explained this by the higher pH and the higher magnesium concentrations at the granule:soil interface, which resulted in lower solubility of the struvite. The negative effect of excess base on the struvite dissolution rate is most pronounced in soils with a low pH buffering capacity, according to the researchers in their article about this research in *Plant and Soil*. ►

Organic matter-rich struvite from process water from potato processor Aviko Steenderen (The Netherlands) treated in wastewater treatment plant Waterstromen Olburgen. Different water treatment processes yield different forms struvite, ranging from crystals with few impurities to organic matter-rich struvite. The water treatment process determines which struvite is harvested and which applications of this material are possible.

Editorial

Struvite tested as if it is a potting soil fertiliser

Is struvite a suitable source of phosphate for arable crops and field-gown vegetables? It depends. All kinds of aspects are found to affect the dissolution and diffusion of this relatively low water-soluble phosphate fertiliser. Researchers have found that the struvite recovery method affects the effectiveness of this fertiliser, but also the presence of ‘impurities’, particle size, fertiliser placement, soil conditions, irrigation water pH, crop characteristics, length of growing season and nitrogen fertilisation. The past years a lot of these factors have been investigated, often with struvite in powdery form.

And that is exactly the point. Struvite performance is often examined in pot experiments, with field-grown crops as test plants. Farmers would fertilise these crops with liquid (starter) fertiliser formulations, for instance containing polyphosphate, or with granular phosphate fertilisers, such as monoammonium phosphate, diammonium phosphate, triple superphosphate, or an NPK fertiliser. Powdered struvite is by no means the form they would apply to their field crops. Judging by the frequent use of powdered struvite in experiments, it seems that many researchers are hardly aware of this discrepancy between powdery struvite that is thoroughly mixed through a growing medium and the commercial liquid or granular fertilisers used in the field. And so, these researchers report that struvite is at least equally effective as the highly water-soluble triple superphosphate.
Unfortunately, such studies are seldom followed by field experiments under real world conditions to verify whether these results hold up under field conditions.
What then? Although the worldwide web does have some interesting studies with granular struvite, more research into the performance of granulated struvite of various origins is urgently needed. ►

► Recently Brazil and British researchers confirmed that the struvite source does matter: chicken manure derived struvite (pellets) was more soluble than struvite recovered from pipelines used in swine manure wastewater processing (crystals) or struvite recovered from a large municipal wastewater treatment plant (Crystal Green, spherical granules). Their report in the open access journal *Sustainability* has no details about the size of the struvite 'grains'.

Nitrification inhibitor counteracts struvite-phosphate release

Conor Watson and his colleagues at Rhine-Waal University of Applied Sciences investigated whether addition of the nitrification inhibitor dicyandiamide affects phosphorus uptake from struvite. The German researchers observed a significantly reduced phosphate uptake in the first harvest of pot-grown ryegrass plants. They surmise that inhibited nitrification of struvite-ammonium had diminished struvite dissolution. This negative effect of dicyandiamide on the phosphate uptake was short-lived, probably due to the rapid degradation of dicyandiamide in the warm greenhouse used for the pot experiment. The researchers warn that dicyandiamide degradation is less rapidly in field conditions, which could potentially result in limited phosphate supply in early growth stages. The study is published in the journal *Soil Use and Management*. Background of this study was the question whether magnesium and phosphorus from struvite is as plant-available as from Epsom salt and triple superphosphate, respectively.
The researchers conclude from their pot trial that struvite produced from milk industry wastewater is as good as or better than commercially available phosphate or magnesium fertilisers in terms of ryegrass shoot biomass production and phosphate and magnesium uptake, regardless of its form (fresh, air-dried or heat-dried). They note that this observation should also be tested with granular struvite; in their greenhouse experiment they used powdery struvite and dicyandiamide that were mixed thoroughly with the substrate (a nutrient-poor mixture of quartz sand and the B horizon of a grassland silty loam).

Temporarily ammonium fixation by nitrification inhibitor

Ammonium uptake decreases rhizosphere pH due to release of hydrogen ions (H^+) by the roots. Use of a nitrification inhibitor delays nitrification, so that ammonium remains available for a longer period. Addition of a nitrification inhibitor also promotes ammonium fixation in soil, according to an international team of researchers in a research report in the journal *Science of the Total Environment*. They discovered the fixation of ammonium with both an old and a brand-new analytical method. Several older studies had shown that fixed ammonium from fertiliser in soils is re-released slowly over a couple of weeks. The researchers expect that the temporarily fixed ammonium has also been released in their experiments after a shorter or longer period of time.
The analytical measurements were part of a pot experiment with maize on phosphorus-poor subsoil from a brown soil derived from loess. The nitrogen source used in this experiment was powdered ammonium sulphate nitrate, with or without the nitrification inhibitor DMPP. The researchers investigated to what extent this nitrification inhibitor affected phosphate uptake from powdered forms of water-soluble (triple superphosphate) and water-insoluble (sewage sludge-based and hyperphosphate) fertilisers. They measured a slightly increased phosphorus uptake in maize supplied with ammonium sulphate nitrate plus nitrification inhibitor, irrespective of the applied phosphorus fertiliser type; but the difference with plants not supplied with nitrification inhibitor was not significant. Differences in dry matter yield were significant for maize plants receiving ammonium sulphate nitrate with or without nitrification inhibitor and supplied with hyper-phosphate or triple superphosphate. Dry matter yields of plants receiving sewage sludge-based fertiliser did not differ significantly with respect to the use of a nitrification inhibitor.

► Interesting aspects to investigate for granular struvite are the use of fertiliser additives, co-granulation with acidifying fertilisers or organic acids, co-granulation with water-soluble phosphate fertilisers (as recently tested, see page 9 of this issue), timing (fall and winter versus spring), placement (broadcast versus in-furrow), size of the granules, crop species. In this respect struvite researchers can learn from colleagues who try to improve the performance of low-reactive or low-grade rock phosphate and from fertiliser companies that explore how to use struvite as one of their raw materials. Preferably experiments with granular struvite would also include other sources of recycled phosphorus, such as phosphorus-rich ash or slag. Every plant nutrition specialist can add a series of research wishes, depending on the local soil type and growth conditions.
Are pot experiments with powdered struvite useless? Definitely not! It can help broaden and deepen knowledge about this magnesium ammonium phosphate mineral. Judging from the introductions of the dozens and dozens of research reports about struvite, the authors have practical application of their research results in mind. But then these studies should have a follow-up under real world conditions!
Incidentally, results of pot experiments with powdered struvite mixed through the potting soil could be of interest to the ornamental industry. Growers of bedding plants and pot plants use plant growth regulators, or restrict the phosphorus supply to retard the growth of ornamentals. But then rye grass and maize must be replaced by pelargonium, petunia, verbena or viola as test plants. And last but not least: powdery struvite can be used as 'additive' for soil amendments. However, that is not the application that researchers think of first when conducting pot experiments with arable crops.

Hazenite examined as fertiliser resource

Hazenite is a member of the struvite group of minerals. As such, this hydrous alkali magnesium phosphate mineral ($KNaMg_2(PO_4)_2 \cdot 14H_2O$) has slow-release properties. Researchers at Rhine-Waal University of Applied Sciences are likely the first to examine the fertiliser value of this relatively unknown and rare struvite relative. An SF-Soepenberg R&D manager was also involved in this work. Soepenberg produces and sells fertilisers made from secondary raw materials, including (industrial) waste material.
The German researchers compared the effectiveness of powdery fine hazenite with granular sources of potassium (potassium chloride), magnesium (kieserite) and phosphorus (triple superphosphate). The test crop (Italian ryegrass) was grown in pots filled with a 1:1 mixture of quartz sand and relatively acidic silt loam soil (pH 5.5). The final pH of this mixture has not been reported. The researchers note that the effectiveness of the used hazenite source may have been exaggeratedly high, compared to the granular fertilisers used in this experiment. Given its unusual ratio of phosphorus, potassium and magnesium, hazenite's ideal application would probably be in combination with other fertilisers, they conclude in their research report in the open access journal *Plant, Soil and Environment*.

Single superphosphate fertiliser out of rock phosphate and sewage sludge ash

Phosphorus-rich sewage sludge ash can partially replace phosphorus from rock phosphate in the production of single superphosphate. At least 8% of phosphorus from rock phosphate may be replaced, without increasing the required amount of mineral acid and while maintaining the solubility of phosphorus in the product. Researchers at the University of Hohenheim Department of Fertilization and Soil Matter Dynamics have found this in experiments with powdered mixtures of single superphosphate and sewage sludge ash. Increasing the amount of phosphorus from sewage sludge ash by more than 8% in the production of superphosphate fertilisers decreases the phosphorus solubility in the product, the researchers report in the *Journal of Plant Nutrition and Soil Science*. The reduced phosphorus solubility led to reduced plant growth in pot experiments with maize on an 80:20 mixture of phosphorus-poor loess subsoil (pH of 7.6) and quartz sand. Calculations of a financial break-even point are necessary to estimate a viable replacement factor, according to the German researchers.

Dual-release phosphate fertilisers

Co-compaction of monoammonium phosphate with less water-soluble phosphate sources yields phosphate fertilisers with both fast and slow-release properties. Researchers at the Fertiliser Technology Research Centre and the School of Chemical Engineering of the University of Adelaide (Australia) have found this while combining monoammonium phosphate with struvite or phosphorus-loaded graphene oxide. The dual-release properties of the co-compacted fertilisers are characterised in column perfusion experiments. The researchers conclude that the dual-release phosphate fertilisers have phosphate release patterns, phosphate leaching and phosphate runoff losses that are intermediate between highly soluble products and slowly soluble materials. They published a full report of the preparation and characterisation of the experimental fertilisers in the journal *Industrial & Engineering Chemistry Research*.

Polyhalite-calcium partly replaces potassium from clay

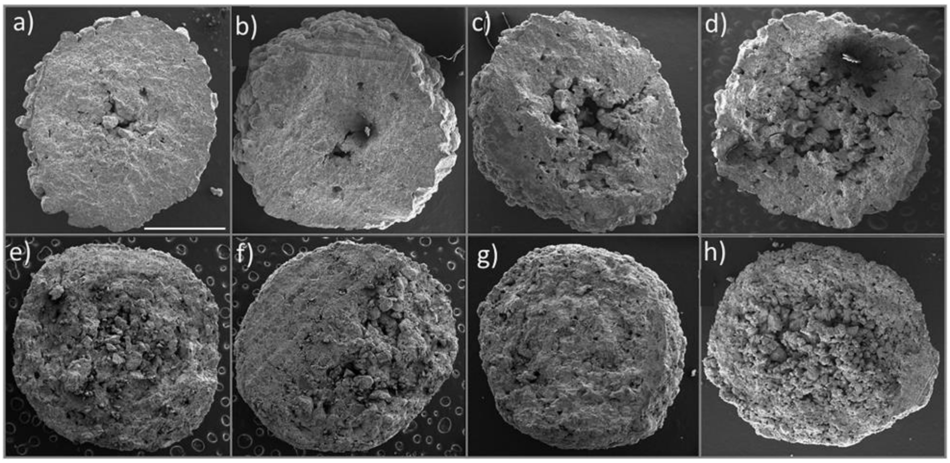
The divalent calcium cations from polyhalite can replace other cations from clay particles. That is one of the results of a laboratory experiment carried out by researchers at the University of Aberdeen School of Biological Sciences. They calculated that calcium from polyhalyte exchanged with soil potassium, thus increasing the amount of potassium in the soil solution. The polyhalite fertiliser used in this leaching study (POLY4) was mined by the British company Sirius Minerals, which is now wholly owned by mining company AgloAmerican. The researchers also examined the movement of magnesium, potassium and sulphate through the soil profile in leaching columns exposed to a flow of deionized water at an equivalent rainfall rate of 100 mm per hour. The cumulative rainfall of 4,500 mm is representative of 5–6 years for most of the United Kingdom, according to the researchers. They compared the leaching of three POLY4 variants (granular, crushed rock and powder) with leaching of potassium from granular potassium chloride. A report of this study is published as open access article in the journal *Soil Use and Management*.

Glauconite milled into source for potash fertilisers

Mechanical activation of the potassium-containing silicate mineral glauconite yields a powdery material that can be used to prepare potassium fertilisers. Glauconite is a typical mica and contains 4% to 8% K_2O. India has large glauconite deposits, but no exploitable soluble potassium reserves. Therefore, Indian researchers are increasingly paying attention to this iron-potassium phyllosilicate mineral as an alternative resource for potassium. The past decades several chemical processes to prepare potash fertiliser from glauconite have been explored and patented. Researchers at the CSIR-National Metallurgical Laboratory did their bit by investigating mechanical activation of glauconite using planetary ball milling to improve its cation exchange capacity. They found that the cation exchange capacity can be tailored by mechanical activation. Planetary ball milling is a clean and more environmental-friendly approach to prepare potassium fertiliser, according to the Indian engineers. Planetary ball milling is also a 'green alternative' to hitherto developed pyro- and/or hydro-metallurgical processes, the researchers note. They shared this proof-of-concept in *Powder Technology*, a journal on the science and technology of wet and dry particulate systems. They also presented strategies to implement this process.

Graphene enhances crushing strength of granular MAP and DAP

Graphene can be used as fertiliser additive to enhance the crushing strength of monoammonium phosphate (MAP) and diammonium phosphate (DAP). Researchers at the Fertiliser Technology Research Centre and the School of Chemical Engineering of the University of Adelaide (Australia) have found this in crushing tests with both NP-fertilisers cogranulated with various amounts of graphene. Crushing strength of the MAP granules was more improved by graphene addition compared to DAP granules, because the MAP granules had a softer structure than the DAP granules. The researchers also discovered that there is a critical graphene concentration for crushing strength improvement. Above this graphene concentration, crushing strength decreases due to the (water) barrier properties and aggregation of graphene sheets. Crushing strength improvement depends also on the method of graphene production and its specific surface area, the researchers report in the journal *Powder Technology*; graphene samples with a high degree of reduction and high specific surface area appeared to be more effective than others. This study is a follow-up to previous investigations into cogranulation of MAP with graphene sheets or graphene oxide. Cogranulation of low doses of graphene sheets enhanced the mechanical strength of MAP granules significantly, but inclusion of the same amounts of graphene oxide improved the mechanical strength to a lesser extent. Cogranulation of graphene or graphene oxide also improved the resistance of MAP granules to abrasion and enhanced the impact resistance. MAP granules containing some graphene or graphene oxide show less or no caking when exposed to pressure and humidity, the researchers said (see article).



Scanning electron images of cross sections of:
a-d=DAP with 0.05, 0.2, 0.5 and 1% GN_{HT} *GN_{HT}=hydrothermally reduced graphene oxide*
e-f=MAP with 0.05, 0.2, 0.5 and 1% GN_{HT} *Scale bars represent 2 mm*

Photographs: Fertiliser Technology Research Centre, University of Adelaide

Urea coated with nano-sized zinc oxide improves wheat performance under drought

Zinc can mitigate drought stress effects in crops. Researchers at the US-based International Fertilizer Development Center make use of this property of zinc by applying this micronutrient in the form of zinc oxide coated onto granular urea fertiliser. The researchers examined both nanoparticle and 'bulk' sized zinc oxide in greenhouse experiments with pot-grown winter wheat. Under drought, zinc oxide nanoparticles reduced average time to panicle initiation by 5 days relative to control plants, but bulk zinc oxide did not affect time to panicle initiation. These and other results of this study are published in the open access journal *Frontiers in Plant Science*. The past few years, researchers at the International Fertilizer Development Center published a lot of studies into effects of nano-sized nutrients on crops such as sorghum, soybean and wheat. In 2018, they plead for more involvement of the fertiliser industry in nanotechnology in a perspective article in the *Journal of Agricultural and Food Chemistry*.

Seaweed useful as source of plant-available zinc

Seaweed generally contains higher zinc concentrations than crops. Seaweed is also relatively rich in other (micro) nutrients. Researchers at the British Teesside University have determined the kinetics of zinc release from the brown algae species *Fucus serratus* in a laboratory experiment. They observed that all zinc present becomes readily available. This seaweed species is a viable source of labile zinc and a low-cost option for mitigating zinc deficiency in soils, the researchers conclude. Experimental design and results are reported in the *Journal of Plant Nutrition and Soil Science*.

Water-only extraction reflects zinc availability of granular fertilisers best

Water-only extraction methods give the best indication of the zinc availability of granular fertilisers. That's because the reactions that control zinc solubility in the water extract are the same as the reactions that control the solubility at the granule:soil interface, according to researchers at the Fertiliser Technology Research Centre of the University of Adelaide (Australia). Water-only methods are therefore best suited for regulation or labeling of available zinc in granular fertiliser formulations, the researchers say. Extraction methods using pH buffers or chelating compounds should be avoided as an indicator of zinc availability, as they mask the differences in composition between the fertilisers. Using such methods results in a poor correlation with the agronomic effectiveness of zinc-containing granular fertilisers. The researchers base their conclusions on a comparison of various extraction methods in a laboratory set-up. The extraction methods are tested with different granular zinc-containing fertilisers. The protocols and results are described in an open access article in the *Journal of Plant Nutrition and Soil Science*.

Publications about new, experimental and potential fertiliser formulations

Nano-fertilisers

Facile coating of urea with low-dose ZnO nanoparticles promotes wheat performance and enhances Zn uptake under drought stress. Frontiers in Plant Science 11(2020):168

Response of maize (*Zea mays* L.) to potassium nano-silica application under drought stress. Journal of Plant Nutrition 43(2020)9:1205-1216

Specific release

Inorganic matter modified water-based copolymer prepared by chitosan-starch-CMC-Na-PVAL as an environment-friendly coating material. Carbohydrate Polymers 234(2020):115925

Facile coating of urea with low-dose ZnO nanoparticles promotes wheat performance and enhances Zn uptake under drought stress. Frontiers in Plant Science 11(2020):168

Engineered phosphate fertilizers with dual-release properties. Industrial & Engineering Chemistry Research 59(2020):5512-5524

Biodegradable urea formaldehyde/PBS and its ternary nanocomposite prepared by a novel and scalable reactive extrusion process for slow-release applications in agriculture. Journal of Agricultural and Food Chemistry 68(2020)16:4595-4606

Polymer-coated rock mineral fertilizer has potential to substitute soluble fertilizer for increasing growth, nutrient uptake, and yield of wheat. Biology and Fertility of Soils 56(2020)3:381–394

Nitrogen

Biodegradable urea formaldehyde/PBS and its ternary nanocomposite prepared by a novel and scalable reactive extrusion process for slow-release applications in agriculture. Journal of Agricultural and Food Chemistry 68(2020)16:4595-4606

Phosphorus

Co-pyrolysis of maize stover and igneous phosphate rock to produce potential biochar-based phosphate fertilizer with improved carbon retention and liming value. ACS Sustainable Chemistry & Engineering 8(2020)10:4178-4184

Hazenite: a new secondary phosphorus, potassium and magnesium fertiliser. Plant, Soil and Environment 66(2020)1:1-6

Engineered phosphate fertilizers with dual-release properties. Industrial & Engineering Chemistry Research 59(2020):5512-5524

Polymer-coated rock mineral fertilizer has potential to substitute soluble fertilizer for increasing growth, nutrient uptake, and yield of wheat. Biology and Fertility of Soils 56(2020)3:381–394

Partial replacement of rock phosphate by sewage sludge ash for the production of superphosphate fertilizers. Journal of Plant Nutrition and Soil Science 183(2020)2:233-237

Potassium

Response of maize (*Zea mays* L.) to potassium nano-silica application under drought stress. Journal of Plant Nutrition 43(2020)9:1205-1216

Hazenite: a new secondary phosphorus, potassium and magnesium fertiliser. Plant, Soil and Environment 66(2020)1:1-6

On mechanical activation of glauconite: Physicochemical changes, alterations in cation exchange capacity and mechanisms. Powder Technology 360(2020):337-351

Lime / pH

Co-pyrolysis of maize stover and igneous phosphate rock to produce potential biochar-based phosphate fertilizer with improved carbon retention and liming value. ACS Sustainable Chemistry & Engineering 8(2020)10:4178-4184

Magnesium

Hazenite: a new secondary phosphorus, potassium and magnesium fertiliser. Plant, Soil and Environment 66(2020)1:1-6

Zinc

Facile coating of urea with low-dose ZnO nanoparticles promotes wheat performance and enhances Zn uptake under drought stress. Frontiers in Plant Science 11(2020):168

Kinetics of water-extractable zinc release from seaweed (*Fucus serratus*) as soil amendment. Journal of Plant Nutrition and Soil Science 183(2020)2:136-143

Silicon

Silicon (Si) use efficiency in sandy soil amended by Si-loaded hydrogel. Communications in Soil Science and Plant Analysis 51(2020)6:746-756

Crop and soil together determine nutrient availability

Soil nutrient availability affects crop yield and is also significantly affected by the crop. This sophisticated interplay of supply and demand deserves much more attention in crop nutrition, according to French scientists. They therefore draw attention to the role of plant physiology, the interactions among different nutrients in soils and plants and interactions with soil life in the rhizosphere. They argue for physiologically-based crop nutrition diagnosis to quantify the degree of satisfaction for nutrients.

Soil nutrient availability affects crop yield. It is an external factor to which crops respond. Conversely, soil nutrient availability is also significantly affected by crops themselves. It is this complicated interaction of supply and demand that French scientists are drawing attention to in a just published review paper in the *European Journal of Agronomy*. They emphasize that plant-availability of nutrients is the result of the functioning of the whole soil-crop ecosystem, including the macro- and microorganisms in and around the roots.

Plants are a key driver of the soil nutrient availability, say the researchers. Plants shape soil life in the rhizosphere via root exudates and interactions and associations with fungi, bacteria and other soil living organisms around their roots. In this way they play an active role in the availability of nutrients in soils. Furthermore, plants can modify physico-chemical properties of soil either directly by root exudates or indirectly through soil-inhabiting micro- and macroorganisms. This can also lead to changes in the soil nutrient availability. Thus plant-availability of nutrients in soil as an external factor to which plants respond does not correspond to the reality. The traditional approach of crop fertilisation based only on crop yield responses to fertiliser application and the chemical assessment of nutrient availability is no longer adequate, the researchers conclude. They also argue that the availability of one plant nutrient depends highly on the availability of other nutrients. They therefore propose a more complex and integrated understanding of soil nutrient availability. They further argue for physiologically-based crop nutrition diagnosis to quantify the degree of satisfaction for nutrients.

Crop adjusts nutrient uptake to demand

Plants also determine to a large extent how much of the available nutrients they absorb. Uptake of nitrogen – for instance – is regulated by both soil nitrogen availability and crop growth. As scientists at the National Institute of Agricultural Research (INRA, now INRAE), they found that plants can regulate the nutrient uptake capacity to their own growth capacity. In this way, plants can adjust the acquisition of nutrients to their own demand. Gilles Lemaire - honorary director of research at INRAE-Lusignan – draws particularly attention to this phenomenon. As co-author in this review paper, but actually from his first publications about the relationship between growth and nitrogen uptake in forage grasses. A related aspect he had studied was the variation in the nitrogen content of a crop during its growth period. As early as 1981, Lemaire and his chef Jean Salette formulated a 'law of nitrogen dilution in the dry matter' based on the analysis of the variation of nitrogen contents of the fodder grasses during their growth.

Critical nitrogen dilution curve

The following decades this hypothesis of 'critical nitrogen dilution curve' has extensively elaborated. At first mainly by colleagues at the INRA research centers with which they were affiliated, but later on also other by investigators all over the world. In the just published review, Lemaire and his colleagues discuss recent studies that substantiate the underlying original allometric relationships – the phenomenon that plants have a more or less fixed nitrogen:dry matter ratio that slightly decreases during the growth period.

Growing degrees days indicate optimal time for nitrogen sensing in wheat

Summing up growing degrees days is helpful to find the ideal point in the growing season for reliably sensing the nitrogen status of winter wheat using normalized difference vegetation index (NDVI) readings. The number of growing degrees days above zero is a much more reliable indicator for the nitrogen sensing time than subjective morphological scales, according to researchers at the Oklahoma State University Department of Plant and Soil Sciences. They base their conclusion on an analysis of two field experiments. This work is published in an open access article in *Agronomy Journal*.

Portable devices for whole leaf imaging

Engineers at the Purdue University Plant Phenotyping Lab have developed three low-cost portable phenotyping devices for whole leaf imaging. By imaging an entire leaf, these novel devices enable to analyse the distribution of nitrogen and stress across the leaf. These devices are intended to be alternative to existing portable instruments for non-destructively plant measurements that measure only one small leaf area at one measurement. The Leaf Scanner is a low-cost multispectral maize leaf scanner to measure nitrogen contents and leaf area, the LeafSpec is a hyperspectral imaging device for maize plants to measure the nitrogen content and relative water content and the patent pending LeafScope is a multispectral imager for leaves of dicotyledon plants species. The researchers have plans to adapt the LeafScope device for use in field-grown crops. This may require a mechanism for auto cleaning the imaging chamber and models that detect different stresses such as nitrogen, water, diseases and pests. They will also develop a field robot to manipulate LeafScope to image leaves automatically. LeafScope and LeafScanner are 'side projects' carried out by students and postdoc researchers at the Plant Phenotyping Lab. The LeafSpec will be sold by LeafScpec LLC. This startup company is led by Jian Jin, director of the Purdue University lab.

Leaf manganese concentration reflects rhizosphere levels of organic anions

Plants that release large amounts of organic anions tend to have relatively high manganese concentrations in mature leaves. Organic anions such as carboxylates not only mobilize phosphorus, but also some of the transition metal cations, especially manganese, copper, iron and zinc. Up to now this relationship between organic anion release and leaf manganese concentration is only studied in few plant species. Whereas manganese accumulates to significant levels (even in soils with low manganese availability), concentrations of most other micronutrients only increase to a small extent. Therefore, scientists related to the University of Western Australia School of Biological Sciences suggest to consider the use of mature leaf manganese concentration as an easily measurable proxy for the amounts of organic anions in the rhizosphere. This proxy offers a new, simple and reliable tool to evaluate rhizosphere organic anions under low phosphorus availability, they say in an article that is published in the journal *Plant and Soil*. If organic anions are consumed by rhizosphere microbes, the amount of 'effective' rhizosphere organic anions is low. Consequently, the leaf manganese concentration is not high, the researchers say. They further observed that the mature leaf manganese concentration is also affected by other factors than carboxylate exudation. They propose to use the mature leaf manganese concentration to select for genotypes that are more efficient at acquiring phosphorus when soil phosphate availability is low.

Assay for simultaneously measurements of net nitrogen mineralisation and denitrification rates

Rates of net nitrogen mineralisation and denitrification can be measured simultaneously with a nitrification inhibitor assay system. Researchers at the Agriculture and Agri-Food Canada Fredericton Research and Development Centre and Dalhousie University recently developed and tested this assay system in a series of laboratory experiments. They used two contrasting soils (clay loam and sandy loam) with various soil water contents (35%, 55% and 85% water-filled pore space). The assay is relatively simple to perform and avoids some of the technical challenges for implementation of techniques as isotope pool dilution. Another advantage mentioned by the Canadian researchers are the limited material costs; the primary costs are for soil mineral nitrogen analyses. The new assay can also be readily scaled up to routinely test multiple soils in an efficient manner, the researchers say in an open access article in the *Canadian Journal of Soil Science*. A limitation of this method is that it does not provide explicit tracking of the fate of nitrate disappearance. Thus the new test cannot discriminate between pathways of denitrification or dissimilatory nitrate reduction to ammonium.

Spraying specific chitin compounds enhances mycorrhization

Spraying plants with a solution of short-chain chitin oligomers enhances the root colonization by arbuscular mycorrhizal fungi. Researchers at universities in Toulouse (France) and Turin (Italy) observed this effect in a pot experiment with the clover species *Medicago truncatula*. They supplied the test plants with a mixture of short chain chitin oligomers purified from crustacean manufacturing side-products. The researchers were inspired by the knowledge that arbuscular mycorrhizal fungi release short-chain chitin oligomers (chito-oligosaccharides) to trigger symbiotic signaling in host plants.

Most of the spray solution was actually reaching the quartz sand substrate, either directly or by dripping along plant stems. Irrigation of the plants with short-chain chitin oligomers also increased arbuscular mycorrhizal colonization, the researchers report in the journal *Carbohydrate Polymers*. The comparable effects of both irrigation and spray treatments suggest that the supply method does not significantly influence the plant response, the researchers conclude from their experiment. A possible systemic effect resulting from short-chain chitin oligomer absorption from the aerial parts is not excluded, but remains to be demonstrated. A number of previously published reports suggests that the related lipo-chitooligosaccharide molecules can directly impact plant growth and development, separate from any role in plant symbioses. For instance, it has been shown that maize and the grass *Setaria viridis* respond with an enhanced root growth to treatment with lipo-chitooligosaccharides.

Rhizobia make legumes more disease-resistant

Rhizobia provide their leguminous host plants with nitrogen, but they can also induce systemic resistance to the pathogens of their hosts. Argentinian researchers highlight this underexposed phenomenon in a review article in the journal *Plant and Soil*. The Universidad Nacional de Río Cuarto researchers lard their article with examples of induced systemic resistance-like responses in several legume species. They leave out of account that yield increases attributed to nitrogen fixation may in part be due to induced systemic resistance-like responses. The researchers wonder whether induction of systemic resistance is a side effect of the host innate immunity manipulation, or a requisite for successful symbiosis. In the latter case, it could be related to a more general phenomenon involving self-regulation of all types of mutualism.

Some domesticated plants ignore beneficial microbes

Domestication of plants yields bigger crops on the cost of the responsiveness to beneficial soilborne microbes. Through millennia of human tending, many cultivated plants lost some ability to interact with soil microbes that provide necessary nutrients, according to biologists Joel Sachs (University of California, Riverside) and Stephanie Porter at (Washington State University). Both researchers reviewed 120 studies of microbial symbiosis in plants and concluded that many types of domesticated plants show a degraded capacity to form symbiotic communities with soil microbes. They published their review in the journal *Trends in Ecology and Evolution*. Sachs and Porter recommend reintroduction of genes from the wild relatives of commercial crops that restore domesticated plants' ability to interact with beneficial soil microbes.

Publications about plant nutrition research

General

General

Reappraisal of the central role of soil nutrient availability in nutrient management in light of recent advances in plant nutrition at crop and molecular levels. European Journal of Agronomy 116(2020):126069

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General

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Arable crops - cereals and grasses

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Greenhouse gas emission

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Comparison of two alkali trap methods for measuring the flush of CO_2. Agronomy Journal 112(2020)2:1279-1286

Soil incubation study showed biogas digestate to cause higher and more variable short-term N_2O and N_2 fluxes than mineral-N. Journal of Plant Nutrition and Soil Science 183(2020)2:208-219

Fertilizer timing affects nitrous oxide, carbon dioxide, and ammonia emissions from soil. Soil Science Society of America Journal 84(2020)1:115-130

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Mapping, sensing, sampling and analytics

General

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Nitrogen mineralized in anaerobiosis as indicator of soil aggregate stability. Agronomy Journal 112(2020)1:592-607

Comparison of two alkali trap methods for measuring the flush of CO_2. Agronomy Journal 112(2020)2:1279-1286

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General
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Rice
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Arable crops - potato and sugar beet
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Maize
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Row-injected cattle slurry can replace mineral P starter fertiliser and reduce P surpluses without compromising final yields of silage maize. European Journal of Agronomy 116(2020):126057
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Foliar fertilisation

Fruit and vegetable crops
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Organic fertilisers and industrial wastes (selection)

General
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Effect of Ca:Mg ratio and high ammoniacal nitrogen on characteristics of struvite precipitated from waste activated sludge digester effluent. Journal of Environmental Sciences 86(2019):65-77
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Can an amino sugar test estimate potentially available nitrogen from biosolids? Soil Science Society of America Journal 84(2020)1:274-286

Publications about plant nutrition research

Arable crops - cereals and grasses

Maize

Damage to the primary root in response to cattle slurry placed near seed may compromise early growth of corn. Agronomy Journal 112(2020)2:1346-1359

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Arable crops - potato and sugar beet

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Arable crops - other crops

Indirect nitrous oxide emissions from oilseed rape cropping systems by NH_3 volatilization and nitrate leaching as affected by nitrogen source, N rate and site conditions. European Journal of Agronomy 116(2020):126039

Grassland and forage

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Hazenite: a new secondary phosphorus, potassium and magnesium fertiliser. Plant, Soil and Environment 66(2020)1:1-6

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Arable crops - cereals and grasses

Do cover crops improve the productivity and industrial quality of upland rice? Agronomy Journal 112(2020)1:327-343

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Arable crops - legumes

Establishing winter annual cover crops by interseeding into maize and soybean. Agronomy Journal 112(2020)2:719-732

Nitrogen fertilization offsets the N_2O mitigating effects of cover-crops and double-crop soybean in a wheat-sorghum system. Agronomy Journal 112(2020)2:772-785

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Publications about plant nutrition research

Biochar

General

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A comparison of liquid binders for drum granulation of biochar powder. Powder Technology 367(2020):487-496

Arable crops - potato and sugar beet

Nutrient uptake and growth of potato: Arbuscular mycorrhiza symbiosis interacts with quality and quantity of amended biochars. Journal of Plant Nutrition and Soil Science 183(2020)2:220-232

Arable crops - other crops

N_2O emissions during *Brassica oleracea* cultivation: Interaction of biochar with mineral and organic fertilization. European Journal of Agronomy 115(2020):126021

Nano-fertilisers

Arable crops - cereals and grasses

Facile coating of urea with low-dose ZnO nanoparticles promotes wheat performance and enhances Zn uptake under drought stress. Frontiers in Plant Science 11(2020):168

Response of maize (*Zea mays* L.) to potassium nano-silica application under drought stress. Journal of Plant Nutrition 43(2020)9:1205-1216

Nitrification and urease inhibitors

General

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Arable crops - cereals and grasses

Barley and wheat

The effects of split application of enhanced efficiency fertilizers on non-winter nitrous oxide emissions from winter wheat. Canadian Journal of Soil Science 100(2020)1:26-43

Application of urease inhibitor improves protein composition and bread-baking quality of urea fertilized winter wheat. Journal of Plant Nutrition and Soil Science 183(2020)2:260-270

Maize

Row-injected cattle slurry can replace mineral P starter fertiliser and reduce P surpluses without compromising final yields of silage maize. European Journal of Agronomy 116(2020):126057

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Publications about plant nutrition research

Arable crops - cereals and grasses

Barley, oat, rye and wheat

Effect of slow-release nitrogen on the nitrogen availability in an andisol and the critical nitrogen concentration in wheat. Agronomy Journal 112(2020)2:1250-1262

Polymer-coated rock mineral fertilizer has potential to substitute soluble fertilizer for increasing growth, nutrient uptake, and yield of wheat. Biology and Fertility of Soils 56(2020)3:381–394

The effects of split application of enhanced efficiency fertilizers on non-winter nitrous oxide emissions from winter wheat. Canadian Journal of Soil Science 100(2020)1:26-43

Facile coating of urea with low-dose ZnO nanoparticles promotes wheat performance and enhances Zn uptake under drought stress. Frontiers in Plant Science 11(2020):168

Maize

Polymer-coated urea effects on maize yield and nitrogen losses for hilly land of southern China. Nutrient Cycling in Agroecosystems 116(2020)3:299-312

Arable crops - potato and sugar beet

Nitrogen source and rate effects on residual soil nitrate and overwinter NO_3-N losses for irrigated potatoes on sandy soils. Canadian Journal of Soil Science 100(2020)1:44-57

Nitrogen

General

Nitrogen mineralized in anaerobiosis as indicator of soil aggregate stability. Agronomy Journal 112(2020)1:592-607

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Coordinated transport of nitrate, potassium, and sodium. Frontiers in Plant Science 11(2020):247

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Arable crops - cereals and grasses

General

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Barley, oat, rye and wheat

Applied use of growing degree days to refine optimum times for nitrogen stress sensing in winter wheat. Agronomy Journal 112(2020)1:537-549

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The plasticity of root distribution and nitrogen uptake contributes to recovery of maize growth at late growth stages in wheat/maize intercropping. Plant and Soil 447(2020)1-2:39-53
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Using an active sensor to develop new critical nitrogen dilution curve for winter wheat. Sensors 20(2020)6:1577

Maize
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Perennial cover crop influences on soil C and N and maize productivity. Nutrient Cycling in Agroecosystems 116(2020)2:135-150
Agronomic effectiveness of urea deep placement technology for upland maize production. Nutrient Cycling in Agroecosystems 116(2020)2:179-193
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Effects of fertilizer timing and variable rate N on nitrate–N losses from a tile drained corn-soybean rotation simulated using DRAINMOD-NII. Precision Agriculture 21(2020)2:311-323
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Rice
High-density planting with lower nitrogen application increased early rice production in a double-season rice system. Agronomy Journal 112(2020)1:205-214
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Sorghum
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Arable crops - legumes
General
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Lucerne
Enhancement of rhizosphere citric acid and decrease of NO_3^-/NH_4^+ ratio by root interactions facilitate N fixation and transfer. Plant and Soil 447(2020)1-2:169-182

Pea
Biological nitrogen fixation in field pea and vetch: Response to inoculation and residual effect on maize in the Pampean region. European Journal of Agronomy 115(2020):126016

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Other

Biological nitrogen fixation in field pea and vetch: Response to inoculation and residual effect on maize in the Pampean region. European Journal of Agronomy 115(2020):126016

Peanut nitrogen credits to winter wheat are negligible under conservation tillage management in the southeastern USA. Field Crops Research 249(2020):107739

Arable crops - potato and sugar beet

Response of potato to nitrogen and phosphorus fertilizers at Assosa, western Ethiopia. Agronomy Journal 112(2020)2:1227-1237

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Identification of QTLs associated with nitrogen use efficiency and related traits in a diploid potato population. American Journal of Potato Research 97(2020)2:185-201

Nitrogen source and rate effects on residual soil nitrate and overwinter NO_3-N losses for irrigated potatoes on sandy soils. Canadian Journal of Soil Science 100(2020)1:44-57

Nutrient uptake and growth of potato: Arbuscular mycorrhiza symbiosis interacts with quality and quantity of amended biochars. Journal of Plant Nutrition and Soil Science 183(2020)2:220-232

Optimizing soil nitrogen balance in a potato cropping system through legume intercropping. Nutrient Cycling in Agroecosystems 117(2020)1:43-59

Arable crops - other crops

Brassica

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Winter canola response to soil and fertilizer nitrogen in semiarid Mediterranean conditions. Agronomy Journal 112(2020)2:801-814

N_2O emissions during *Brassica oleracea* cultivation: Interaction of biochar with mineral and organic fertilization. European Journal of Agronomy 115(2020):126021

Indirect nitrous oxide emissions from oilseed rape cropping systems by NH_3 volatilization and nitrate leaching as affected by nitrogen source, N rate and site conditions. European Journal of Agronomy 116(2020):126039

Coffee

Water deficit changes nitrate uptake and expression of some nitrogen related genes in coffee-plants (*Coffea arabica* L.). Scientia Horticulturae 267(2020):109254

Cotton

Nitrogen preference and genetic variation of cotton genotypes for nitrogen use efficiency. Journal of the Science of Food and Agriculture 100(2020)6:2761-2773

Variable-rate application of high spatial resolution can improve cotton N-use efficiency and profitability. Precision Agriculture 21(2020)3:695-712

Grassland and forage

Corn intercropped with tropical perennial grasses as affected by sidedress nitrogen application rates. Nutrient Cycling in Agroecosystems 116(2020)2:223-244

Positive legacy effect of previous legume proportion in a ley on the performance of a following crop of *Lolium multiflorum*. Plant and Soil 447(2020)1-2:497-506

Fruit, vegetable and herb crops

Cucumber, eggplant, melon, pepper and tomato

Nondestructive determination of nitrogen, phosphorus and potassium contents in greenhouse tomato plants based on multispectral three-dimensional imaging. Sensors 19(2019)23:5295

Effect of cultivar on chlorophyll meter and canopy reflectance measurements in cucumber. Sensors 20(2020)2:509

Fruit trees and grape

Estimation and mapping of nitrogen content in apple trees at leaf and canopy levels using hyperspectral imaging. Precision Agriculture 21(2020)2:198-225

Herbs

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Phosphorus

General
Phytase-based phosphorus recovery process for 20 distinct press cakes. ACS Sustainable Chemistry & Engineering 8(2020)9:3913-3921
Co-pyrolysis of maize stover and igneous phosphate rock to produce potential biochar-based phosphate fertilizer with improved carbon retention and liming value. ACS Sustainable Chemistry & Engineering 8(2020)10:4178-4184
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3D-printed graphene electrodes applied in an impedimetric electronic tongue for soil analysis. Chemosensors 7(2019)4:50
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Effect of Ca:Mg ratio and high ammoniacal nitrogen on characteristics of struvite precipitated from waste activated sludge digester effluent. Journal of Environmental Sciences 86(2019):65-77

Arable crops – cereals and grasses
Barley, oat, rye and wheat
Polymer-coated rock mineral fertilizer has potential to substitute soluble fertilizer for increasing growth, nutrient uptake, and yield of wheat. Biology and Fertility of Soils 56(2020)3:381-394
Facile coating of urea with low-dose ZnO nanoparticles promotes wheat performance and enhances Zn uptake under drought stress. Frontiers in Plant Science 11(2020):168
Phosphorus uptake and partitioning in two durum wheat cultivars with contrasting biomass allocation as affected by different P supply during grain filling. Plant and Soil 449(2020)1-2:179-192
Effects of intercropping on field-scale phosphorus acquisition processes in a calcareous soil. Plant and Soil 449(2020)1-2:331-341

Maize
Corn response to long-term manure and fertilizer applications on a preceding perennial forage crop. European Journal of Agronomy 115(2020):125990
Row-injected cattle slurry can replace mineral P starter fertiliser and reduce P surpluses without compromising final yields of silage maize. European Journal of Agronomy 116(2020):126057
The relative contributions of pH, organic anions, and phosphatase to rhizosphere soil phosphorus mobilization and crop phosphorus uptake in maize/alfalfa polyculture. Plant and Soil 447(2020)1-2:117-133
Mycorrhizal impacts on root trait plasticity of six maize varieties along a phosphorus supply gradient. Plant and Soil 448(2020)1-2:71-86
Changes in soil phosphorus fractions following sole cropped and intercropped maize and faba bean grown on calcareous soil. Plant and Soil 448(2020)1-2:587-601
Soil plant-available phosphorus levels and maize genotypes determine the phosphorus acquisition efficiency and contribution of mycorrhizal pathway. Plant and Soil 449(2020)1-2:357-371
Effects of a nitrification inhibitor on nitrogen species in the soil and the yield and phosphorus uptake of maize. Science of the Total Environment 715(2020):136895

Rice
Agronomic practices affect rice yield and nitrogen, phosphorus, and potassium accumulation, allocation and translocation. Agronomy Journal 112(2020)2:1238-1249
Arbuscular mycorrhiza contributes to the control of phosphorus loss in paddy fields. Plant and Soil 447(2020)1-2:623-636

Arable crops – legumes
The relative contributions of pH, organic anions, and phosphatase to rhizosphere soil phosphorus mobilization and crop phosphorus uptake in maize/alfalfa polyculture. Plant and Soil 447(2020)1-2:117-133

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Release of tartrate as a major carboxylate by alfalfa (*Medicago sativa* L.) under phosphorus deficiency and the effect of soil nitrogen supply. Plant and Soil 449(2020)1-2:169-178
Changes in soil phosphorus fractions following sole cropped and intercropped maize and faba bean grown on calcareous soil. Plant and Soil 448(2020)1-2:587-601
Effects of intercropping on field-scale phosphorus acquisition processes in a calcareous soil. Plant and Soil 449(2020)1-2:331-341

Arable crops - potato and sugar beet
Response of potato to nitrogen and phosphorus fertilizers at Assosa, western Ethiopia. Agronomy Journal 112(2020)2:1227-1237
Potato response to struvite compared with conventional phosphorus fertilizer in Eastern Canada. Agronomy Journal 112(2020)2:1360-1376
Testing critical phosphorus dilution curves for potato cropped in tropical Oxisols of southeastern Brazil. European Journal of Agronomy 115(2020):126020
Nutrient uptake and growth of potato: Arbuscular mycorrhiza symbiosis interacts with quality and quantity of amended biochars. Journal of Plant Nutrition and Soil Science 183(2020)2:220-232

Grassland and forage
Phosphorus speciation and fertiliser performance characteristics: A comparison of waste recovered struvites from global sources. Geoderma 362(2020):114096
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Hazenite: a new secondary phosphorus, potassium and magnesium fertiliser. Plant, Soil and Environment 66(2020)1:1-6

Fruit and vegetable crops
Nondestructive determination of nitrogen, phosphorus and potassium contents in greenhouse tomato plants based on multispectral three-dimensional imaging. Sensors 19(2019)23:5295

Ornamentals and turf
Phosphorus restriction influences P efficiency and ornamental quality of poinsettia and chrysanthemum. Scientia Horticulturae 267(2020):109316

Potassium

General
3D-printed graphene electrodes applied in an impedimetric electronic tongue for soil analysis. Chemosensors 7(2019)4:50
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Coordinated transport of nitrate, potassium, and sodium. Frontiers in Plant Science 11(2020):247
On mechanical activation of glauconite: Physicochemical changes, alterations in cation exchange capacity and mechanisms. Powder Technology 360(2020):337-351
Retention and release of nutrients from polyhalite to soil. Soil Use and Management 36(2020)1:117-122

Arable crops - cereals and grasses
Barley, oat, rye and wheat
High potassium application rate increased grain yield of shading-stressed winter wheat by improving photosynthesis and photosynthate translocation. Frontiers in Plant Science 11(2020):134

Maize
Polyhalite as a potassium and multinutrient source for plant nutrition. Archives of Agronomy and Soil Science 66(2020)5:667-678
Response of maize (*Zea mays* L.) to potassium nano-silica application under drought stress. Journal of Plant Nutrition 43(2020)9:1205-1216

Rice
Agronomic practices affect rice yield and nitrogen, phosphorus, and potassium accumulation, allocation and translocation. Agronomy Journal 112(2020)2:1238-1249
Diagnosis of nitrogen nutrition in rice leaves influenced by potassium levels. Frontiers in Plant Science 11(2020):165
Monitoring leaf potassium content using hyperspectral vegetation indices in rice leaves. Precision Agriculture 21(2020)2:324-348

Arable crops - potato and sugar beet
Nutrient uptake and growth of potato: Arbuscular mycorrhiza symbiosis interacts with quality and quantity of amended biochars. Journal of Plant Nutrition and Soil Science 183(2020)2:220-232

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Grassland and forage
Hazenite: a new secondary phosphorus, potassium and magnesium fertiliser. Plant, Soil and Environment 66(2020)1:1-6

Fruit and vegetable crops
Production of low-potassium onions based on mineral absorption patterns during growth and development. Scientia Horticulturae 267(2020):109252
Nondestructive determination of nitrogen, phosphorus and potassium contents in greenhouse tomato plants based on multispectral three-dimensional imaging. Sensors 19(2019)23:5295

Calcium

General
Retention and release of nutrients from polyhalite to soil. Soil Use and Management 36(2020)1:117-122

Arable crops - cereals and grasses
Polyhalite as a potassium and multinutrient source for plant nutrition. Archives of Agronomy and Soil Science 66(2020)5:667-678
Effects of intercropping on field-scale phosphorus acquisition processes in a calcareous soil. Plant and Soil 449(2020)1-2:331-341

Arable crops - legumes
Effects of pH and bicarbonate on the nutrient status and growth of three *Lupinus* species. Plant and Soil 447(2020)1-2:9-28
Effects of intercropping on field-scale phosphorus acquisition processes in a calcareous soil. Plant and Soil 449(2020)1-2:331-341

Arable crops - potato and sugar beet
The in-season variability in the calcium concentration in potato organs and its relationship with the tuber yield. Journal of Elementology 25(2020)1:107-124

Lime / pH

General
Co-pyrolysis of maize stover and igneous phosphate rock to produce potential biochar-based phosphate fertilizer with improved carbon retention and liming value. ACS Sustainable Chemistry & Engineering 8(2020)10:4178-4184

Arable crops - cereals and grasses
Does gypsum increase crop grain yield on no-tilled acid soils? A meta-analysis. Agronomy Journal 112(2020)2:675-692
The relative contributions of pH, organic anions, and phosphatase to rhizosphere soil phosphorus mobilization and crop phosphorus uptake in maize/alfalfa polyculture. Plant and Soil 447(2020)1-2:117-133
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Arable crops - legumes
Does gypsum increase crop grain yield on no-tilled acid soils? A meta-analysis. Agronomy Journal 112(2020)2:675-692
Effects of pH and bicarbonate on the nutrient status and growth of three *Lupinus* species. Plant and Soil 447(2020)1-2:9-28
The relative contributions of pH, organic anions, and phosphatase to rhizosphere soil phosphorus mobilization and crop phosphorus uptake in maize/alfalfa polyculture. Plant and Soil 447(2020)1-2:117-133

Fruit and vegetable crops
Physiological and nutritional responses of ‘HB’ Pummelo [*Citrus grandis* (L.) Osbeck ‘Hirado Buntan’] to the combined effects of low pH levels and boron deficiency. HortScience 55(2020)4:449-456

Magnesium

General
Magnesium fertilization improves crop yield in most production systems: A meta-analysis. Frontiers in Plant Science 10(2020):1727
Retention and release of nutrients from polyhalite to soil. Soil Use and Management 36(2020)1:117-122

Arable crops - cereals and grasses
Polyhalite as a potassium and multinutrient source for plant nutrition. Archives of Agronomy and Soil Science 66(2020)5:667-678
Diagnosis of nitrogen nutrition in rice leaves influenced by potassium levels. Frontiers in Plant Science 11(2020):165

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Magnesium accumulation, partitioning and remobilization in spring maize (*Zea mays* L.) under magnesium supply with straw return in northeast China. Journal of the Science of Food and Agriculture 100(2020)6:2568-2578

Grassland and forage
Hazenite: a new secondary phosphorus, potassium and magnesium fertiliser. Plant, Soil and Environment 66(2020)1:1-6

Fruit and vegetable crops
Changes of plant biomass partitioning, tissue nutrients and carbohydrates status in magnesium-deficient banana seedlings and remedy potential by foliar application of magnesium. Scientia Horticulturae 268(2020):109377

Sulphur

General
Retention and release of nutrients from polyhalite to soil. Soil Use and Management 36(2020)1:117-122

Arable crops - cereals and grasses
Polyhalite as a potassium and multinutrient source for plant nutrition. Archives of Agronomy and Soil Science 66(2020)5:667-678
Nitrogen and sulfur interaction on nutrient use efficiencies and diagnostic tools in maize. European Journal of Agronomy 116(2020):126045

Boron

Arable crops - other crops
Boron, zinc and manganese suppress rust on coffee plants grown in a nutrient solution. European Journal of Plant Pathology 156(2020)3:727-738

Fruit and vegetable crops
Foliar supplied boron can be transported to roots as a boron-sucrose complex via phloem in citrus trees. Frontiers in Plant Science 11(2020):250
Physiological and nutritional responses of 'HB' Pummelo [*Citrus grandis* (L.) Osbeck 'Hirado Buntan'] to the combined effects of low pH levels and boron deficiency. HortScience 55(2020)4:449-456

Chloride

Fruit and vegetable crops
Response of kiwifruit yield and fruit quality to chloride-containing fertilizers. Agronomy Journal 112(2020)2:1012-1020

Copper

Grassland and forage
Fodder quality improvement and enrichment of oats with Cu through biofortification: a technique to reduce animal malnutrition. Journal of Plant Nutrition 43(2020)10:1378-1389

Iron

General
Potential of microbes in the biofortification of Zn and Fe in dietary food grains. A review. Agronomy for Sustainable Development 40(2020)2:15
Editorial: Iron nutrition and interactions in plants. Frontiers in Plant Science 10(2020):1670

Arable crops - cereals and grasses
Rice
The effects of elevated atmospheric carbon dioxide [CO_2] on micronutrient concentration, specifically iron (Fe) and zinc (Zn) in rice; a systematic review. Journal of Plant Nutrition 43(2020)10:1571-1578

Miscellaneous crops
The geomagnetic field is a contributing factor for an efficient iron uptake in *Arabidopsis thaliana*. Frontiers in Plant Science 11(2020):325

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Manganese

General
Manganese in plants: From acquisition to subcellular allocation. Frontiers in Plant Science 11(2020):300
Root-released organic anions in response to low phosphorus availability: recent progress, challenges and future perspectives. Plant and Soil 447(2020)1-2:135-156

Arable crops - other crops
Boron, zinc and manganese suppress rust on coffee plants grown in a nutrient solution. European Journal of Plant Pathology 156(2020)3:727-738

Sodium

General
Coordinated transport of nitrate, potassium, and sodium. Frontiers in Plant Science 11(2020):247

Fruit and vegetable crops
Tracing root-felt sodium concentrations under different transpiration rates and salinity levels. Plant and Soil 447(2020)1-2:55-71

Zinc

General
Potential of microbes in the biofortification of Zn and Fe in dietary food grains. A review. Agronomy for Sustainable Development 40(2020)2:15
Kinetics of water-extractable zinc release from seaweed (*Fucus serratus*) as soil amendment. Journal of Plant Nutrition and Soil Science 183(2020)2:136-143
Comparison and modelling of extraction methods to assess agronomic effectiveness of fertilizer zinc. Journal of Plant Nutrition and Soil Science 183(2020)2:248-259

Arable crops - cereals and grasses
Barley, oat, rye and wheat
Facile coating of urea with low-dose ZnO nanoparticles promotes wheat performance and enhances Zn uptake under drought stress. Frontiers in Plant Science 11(2020):168
Zinc-nitrogen interaction effect on wheat biofortification and nutrient use efficiency. Journal of Plant Nutrition and Soil Science 183(2020)2:169-179

Rice
The effects of elevated atmospheric carbon dioxide [CO_2] on micronutrient concentration, specifically iron (Fe) and zinc (Zn) in rice; a systematic review. Journal of Plant Nutrition 43(2020)10:1571-1578

Arable crops - other crops
Boron, zinc and manganese suppress rust on coffee plants grown in a nutrient solution. European Journal of Plant Pathology 156(2020)3:727-738

Aluminium

Arable crops - cereals and grasses
Does gypsum increase crop grain yield on no-tilled acid soils? A meta-analysis. Agronomy Journal 112(2020)2:675-692

Arable crops - legumes
Does gypsum increase crop grain yield on no-tilled acid soils? A meta-analysis. Agronomy Journal 112(2020)2:675-692

Selenium

General
Current knowledge on selenium biofortification to improve the nutraceutical profile of food: A comprehensive review. Journal of Agricultural and Food Chemistry 68(2020)14:4075-4097

Publications about plant nutrition research

Arable crops - cereals and grasses

Agronomic biofortification with selenium impacts storage proteins in grains of upland rice. Journal of the Science of Food and Agriculture 100(2020)5:1990-1997

Fruit and vegetable crops

Selenium application in two methods promotes drought tolerance in *Solanum lycopersicum* plant by inducing the antioxidant defense system. Scientia Horticulturae 266(2020):109290

Rare earth elements

Miscellaneous crops

Effects of rare earth elements on growth and determination of secondary metabolites under in vitro conditions in *Salvia miltiorrhiza*. HortScience 55(2020)3:310-316

Rhizobia, mycorrhiza etc.

General

Potential of microbes in the biofortification of Zn and Fe in dietary food grains. A review. Agronomy for Sustainable Development 40(2020)2:15
Dead *Rhizophagus irregularis* biomass mysteriously stimulates plant growth. Mycorrhiza 30(2020)1:63–77
Agriculture and the disruption of plant-microbial symbiosis. Trends in Ecology and Evolution 35(2020)5:426-439

Arable crops - cereals and grasses

Barley, oat, rye and wheat

Polymer-coated rock mineral fertilizer has potential to substitute soluble fertilizer for increasing growth, nutrient uptake, and yield of wheat. Biology and Fertility of Soils 56(2020)3:381–394

Maize

Mycorrhizal impacts on root trait plasticity of six maize varieties along a phosphorus supply gradient. Plant and Soil 448(2020)1-2:71–86
Soil plant-available phosphorus levels and maize genotypes determine the phosphorus acquisition efficiency and contribution of mycorrhizal pathway. Plant and Soil 449(2020)1-2:357–371

Rice

Arbuscular mycorrhiza contributes to the control of phosphorus loss in paddy fields. Plant and Soil 447(2020)1-2:623-636

Arable crops - legumes

Induced systemic resistance *-like* responses elicited by rhizobia. Plant and Soil 448(2020)1-2:1–14
Short chain chito-oligosaccharides promote arbuscular mycorrhizal colonization in *Medicago truncatula*. Carbohydrate Polymers 229(2020):115505

Arable crops - potato and sugar beet

Nutrient uptake and growth of potato: Arbuscular mycorrhiza symbiosis interacts with quality and quantity of amended biochars. Journal of Plant Nutrition and Soil Science 183(2020)2:220-232

Silicon promotes compensatory growth of earworm-attacked wheat

Silicon helps wheat to compensate growth when attacked by larvae feeding on leaves or roots. Scientists at Western Sydney University have found this in a pot experiment with wheat infested with larvae of the corn earworm (also known as cotton bollworm) and larvae of the pruinose scarab. Wheat leaves damaged by corn earworm larvae had 50% higher silicon concentrations than leaves from plants that were not exposed to these leaf-feeding larvae. This led the researchers to conclude that the increased silicon concentration is an inducible defensive response. The silicon source used is calcium silicate from Australian Steel Mill Services. This company provided a part of the funding for this research. Inspection of foliar calcium concentrations indicated similar levels for calcium silicate-treated and untreated wheat.
The researchers also investigated the above- and belowground growth of wheat plants infested or not with these herbivores and with or without additional silicon in the growing medium. Silicon supplementation facilitated compensatory growth such that shoot losses were more than compensated for and root losses were minimized, the researchers reported in an open access article in the journal *Biology Letters*. Wheat plants did not complete their life cycle, so that possible calcium silicate effects on grain yield remain unknown.
Silicon supplementation did not increase the biomechanical resistance to the larvae, measured as the force required to cut leaves (force of fracture), leaf consumption by the larvae and relative growth rates of the larvae. Therefore, the researchers propose that the silicon-based defence of both larvae operates in wheat via tolerance either in addition or as an alternative to resistance-based defence.

Complex role of silicon in protection against aphids

The role of silicon in the protection of wheat against aphids is far more complicated than often thought. This can be deduced from just published studies into possible effects of silicon application on the performance of three aphid species in wheat. Researchers at the Federal University of Uberlândia (Brazil) found that silicon supplementation changed the blend of wheat volatiles, thus reducing the attractiveness of this host to the bird cherry-oat aphid (*Rhopalosiphum padi*) and attracting its parasitoid *Lysiphlebus testaceipes*. Conversely to previously published studies, silicon supplementation by itself seems to work as an elicitor of induced defences in wheat and not as a priming agent, the researchers report in the open access journal *PLoS ONE*. In a related study, researchers of this Brazilian university found that silicon application didn't reduce the population growth of the wheat aphid *Schizaphis graminum* in sorghum. However, parasitoids (*Lysiphlebus testaceipes*) had higher weight when reared from aphids fed on silicon-treated plants. This study is published in the online version of the journal *Neotropical Entomology*.
Corn aphid (*Rhopalosiphum maidis*) and Russian wheat aphid (*Diuraphis noxia*) didn't alter feeding behaviour when wheat plants are supplemented with silicon, researchers of Western Sydney University recently reported in the *Journal of Pest Science*. They conclude that silicon enrichment of wheat is unlikely to be an effective control strategy for both aphid species.

Existence of silicon transporters questioned

Plants absorb silicon in the form of silicic acid. This small, neutral molecule passes with water through water channels (aquaporins) in membranes. Japanese scientists identified an aquaporin in rice that appeared to mediate the passage of silicic acid. They reported their findings in a widely cited paper in *Nature*. Others reported similar silicon transporter-named channels in all kind of plant species. Fourteen years after the first publication of a silicon transporter in rice, the existence of this transporter is questioned. Three scientists have critically reviewed the published data on the characterisation of this channel in question. They say to have identified possible caveats in results and limitations in the research methods used. "Our analysis does not support the suggestion that the identified channels are specific for silicic acid", they say in an open access paper in the journal *Silicon*. They further say the term "transporter" is confusing, because the biochemical definition of a transporter is a protein that binds to the transported solute and as of today there is no evidence for binding of silicic acid by any water channel. Computational analyses of the size of the transporter-named pore suggest that it may not play a significant role in mediating the movement of silicic acid *in planta*, the researchers add.

Sweet chestnut benefits from potassium silicate

Soil application of a potassium silicate solution increases the tolerance of sweet chestnut seedlings to chestnut blight. Potassium silicate enhances the production of phenolic compounds showing *in vitro* antifungal activity against the fungus that causes chestnut blight (*Cryphonectria parasitica*) as well as the fungus that cause ink disease (*Phytophthora cinnamomi*). Researchers at the University of Trás-os-Montes and Alto Douro report about this effect of potassium silicate in the *Journal of Plant Diseases and Protection* (see article and article). In a previously published report they had already mentioned that potassium silicate application contributed to the increased resistance against chestnut ink disease. The Portuguese researchers also found that soil application of potassium silicate enhanced the high temperature tolerance of sweet chestnut (see article). Foliar application of this silicon source increased both growth and photosynthesis in pot-grown sweet chestnut. Young trees sprayed with potassium silicate had large and thinner leaves than untreated control plants, which led to an increased transpiration rate (see article). Another study by the Portuguese university found positive effects of soil-applied potassium silicate on the chemical and sensory profile of chestnut fruits (see article).

Recent silicon publications

General

Silicon mitigates ammonium toxicity in plants. Agronomy Journal 112(2020)2:635-647
Visualising silicon in plants: Histochemistry, silica sculptures and elemental imaging. Cells 9(2020)4:1066
Silicification of root tissues. Plants 9(2020)1:111
Transpiration and transporters: teasing apart passive and active transport of plant silicon. Abstract EGU General Assembly 2020

Crop protection

Insecticidal efficiency and safety of zinc oxide and hydrophilic silica nanoparticles against some stored seed insects. Journal of Plant Protection Research 60(2020)1:77-85

Soil and fertilisers

Do climate and land use affect the pool of total silicon concentration? A digital soil mapping approach of French topsoils. Geoderma 364(2020):114175

Arable crops

Wheat When resistance is futile, tolerate instead: silicon promotes plant compensatory growth when attacked by above- and belowground herbivores. Biology Letters 15(2019)1:20190361
Silicon (Si) use efficiency in sandy soil amended by Si-loaded hydrogel. Communications in Soil Science and Plant Analysis 51(2020)6:746-756
Cereal aphid performance and feeding behaviour largely unaffected by silicon enrichment of host plants. Journal of Pest Science 93(2020)1:41-48
Silicon-induced changes in plant volatiles reduce attractiveness of wheat to the bird cherry-oat aphid *Rhopalosiphum padi* and attract the parasitoid *Lysiphlebus testaceipes*. PLoS ONE 15(2020)4:e0231005

Maize Response of maize (*Zea mays* L.) to potassium nano-silica application under drought stress. Journal of Plant Nutrition 43(2020)9:1205-1216

Rice Silicon mediated improvement in agronomic traits, physiological parameters and fiber content in *Oryza sativa*. Acta Physiologiae Plantarum 42(2020):38
Silicon enhances yield and nitrogen use efficiency of tropical low land rice. Agronomy Journal 112(2020)2:758-771
Nitrogen supply reduces the earthworm-silicon control on rice blast disease in a Ferralsol. Applied Soil Ecology 145(2020):103341
Silicon improves rice salinity resistance by alleviating ionic toxicity and osmotic constraint in an organ-specific pattern. Frontiers in Plant Science 11(2020):260
Silicon induces phytochelatin and ROS scavengers facilitating cadmium detoxification in rice. Plant Biology 22(2020)3:472-479
Role of silicon and salicylic acid in the mitigation of nitrogen deficiency stress in rice plants. Silicon 12(2020)5:997-1005

Grass Elevated atmospheric CO_2 suppresses jasmonate and silicon-based defences without affecting herbivores. Functional Ecology 34(2020)5:993-1002
Silicon alters leaf surface morphology and suppresses insect herbivory in a model grass species. Plants 9(2020)5:643

Fruit and vegetable crops

Apple Silicon nutrition counteracts salt-induced damage associated with changes in biochemical responses in apple. Bragantia 79(2020)1:1-7

Collard (B. oleracea) Combined effects of soil silicon and drought stress on host plant chemical and ultrastructural quality for leaf-chewing and sap-sucking insects. Journal of Agronomy and Crop Science 206(2020)2:187-201

Castanea Effect of silicon fertilization on the tolerance of *Castanea sativa* Mill. seedlings against *Cryphonectria parasitica* Barr. Journal of Plant Diseases and Protection 127(2020)2:197-210
The role of silicon fertilization in the synthesis of phenolic compounds on chestnut plants infected with *P. cinnamomi* and *C. parasitica*. Journal of Plant Diseases and Protection 127(2020)2:211-227

Melon Alleviating effect of silicon on melon seed germination under autotoxicity stress. Ecotoxicology and Environmental Safety 188(2020):109901
Influence of silicon fertilization on nutrient accumulation, yield and fruit quality of melon grown in northeastern Brazil. Silicon 12(2020)4:937-943

Ornamentals

Orchid Silicon toxicity induced by different concentrations and sources added to *in vitro* culture of epiphytic orchids. Scientia Horticulturae 265(2020):109272

Rosa Pre-harvest silicon treatment improves quality of cut rose stems and maintains postharvest vase life. Journal of Plant Nutrition 43(2020)10:1418-1426

Miscellaneous crops

Arabidopsis Silicon modulates multi-layered defense against powdery mildew in Arabidopsis. Phytopathology Research 2(2020):7

Many events are postponed or cancelled due to the spread of the novel coronavirus. The below list has been completely updated on 16-06-2020.

General interest

► 12th International Biometals Symposium	05-07 / 09-07 - 2020	Live websymposium
► 104th Annual Meeting of the Potato Association of America	2020	Virtual offerings considered
7th Annual National Strip-Tillage Conference	06-08 / 07-08 - 2020	Omaha, Nebraska, USA
► Plant Health 2020	10-08 / 14-08 - 2020	Virtual event
► 260th ACS Virtual Meeting & Exposition	17-08 / 20-08 - 2020	Virtual event
► New Ag International China	22-09 / 23-09 - 2020	Xi'an, China
► 2020 Ag Formulation & Application Technology Congress (FAT 2020)	10-09 / 11-09 - 2020	Hangzhou, China
► 18th New Ag International conference	28-09 / 02-10 - 2020	Virtual event
► AgroChemEx & IFAE & AGROTECH 2020	12-10 / 14-10 - 2020	Shanghai, China
► 21st Triennial Conference of the European Association for the Potato Research	02-11 / 06-11 - 2020	Warsaw, Poland
ASA-CSSA-SSSA International Annual Meeting	08-11 / 11-11 - 2020	Phoenix, Arizona, USA
► Acres U.S.A. 2020 Eco-Ag Conference & Trade Show	01-12 / 04-12 - 2020	Columbus, Ohio, USA
ICSC 2020: International Conference on Solution Chemistry	03-12 / 04-12 - 2020	Tokyo, Japan
Pacifichem 2020	15-12 / 20-12 - 2020	Honolulu, Hawaii, USA
► 29th annual National No-Tillage Conference	12-01 / 15-01 - 2021	Indianapolis, Indiana, USA
► 4th International Symposium on Horticulture in Europe	08-03 / 12-03 - 2021	Stuttgart, Germany
► III International Symposium on Soilless Culture and Hydroponics	21-03 / 24-03 - 2021	Lemesos, Cyprus
► European Geosciences Union General Assembly 2020	25-04 / 30-04 - 2021	Vienna, Austria
► ISAA 2021 - ISAA Agrochemical Network	17-05 / 21-05 - 2021	Bordeaux, France
► 11th Symposium of the International Society of Root Research	24-05 / 28-05 - 2021	Missouri, Columbia, USA
► Global Conference on Sandy Soils - Properties and Management	30-05 / 03-06 - 2021	Madison, Wisconsin, USA
► 11th World Potato Congress	31-05 / 03-06 - 2021	Dublin, Ireland
► 19th Int Symp Solubility Phenomena and Related Equilibrium Processes (ISSP)	July 2021	Albuquerque, New Mexico, USA
► Phyllosphere 2020 - 11th International Symposium on Leaf Surface Microbiology	25-07 / 29-07 - 2021	Davis, California, USA
► Eurosoil 2020	23-08 / 27-08 - 2021	Geneva, Switzerland

Precision Agriculture / intelligent agriculture

► InfoAg 2020	15-12 / 17-12 - 2020	St. Louis, Missouri, USA
► Segundo Congreso Latinoamericano de Agricultura de Precisión (CLAP 2020)	2021	Córdoba, Argentina
► 13th European Conference on Precision Agriculture	19-07 / 22-07 - 2021	Budapest, Hungary
► 15th International Conference on Precision Agriculture	26-06 / 29-06 - 2022	Minneapolis, Minnesota, USA

Biostimulants

► US Biostimulants Summit 2020	01-10 / 02-10 - 2020	Raleigh, North Carolina, USA
► Partnerships in Biocontrol & Biostimulants Congress: USA	19-10 / 20-10 - 2020	Raleigh-Durh, N Carolina, USA
► BioAg World Congress	26-10 / 28-10 - 2020	Sacramento, California, USA
► Biocontrol & Biostimulants in Brazil	17-11 / 18-11 - 2020	São Paulo, Brazil
► Biostimulants Europe 2020	18-11 / 19-11 - 2020	Granada, Spain

Plant nutrition and fertilisers general

► Fertilizer Canada Annual Conference	17-08 / 19-08 - 2020	Halifax, Nova Scotia, Canada
► IFA Crossroads Asia Pacific	20-10 / 22-10 - 2020	Singapore
► European Mineral Fertilizer Summit	November 2020	Europe
► 28th International Symposium of the Scientific Centre for Fertilizers (CIEC)	02-11 / 06-11 - 2020	Athens, Greece
► T3 Fertilizer Conference - Trends, Technology, and Transportation	04-11 / 06-11 - 2020	West Palm Beach, Florida, USA
► IFA Strategic Forum	16-11 / 18-11 - 2020	Kigali, Rwanda
► High Level Forum on Plant Nutrition	19-11 / 20-11 / 2020	Kigali, Rwanda
► Specialty Fertilizer Global Summit 2020	10-12-2020	Raleigh, North Carolina, USA
► 88th IFA Annual Conference	07-04 / 09-04 - 2021	New Delhi, India
International Conference on Soil Science and Plant Nutrition (ICSSPN 2021)	25-01 / 26-01 - 2021	Paris, France
► 11th China International Fertilizer Show	03-02 / 05-02 - 2021	Shanghai, China
► 2020 IFS Technical Conference	May 2021	Amsterdam, The Netherlands
► IX International Symposium on Mineral Nutrition of Fruit Crops	27-06 / 01-07 - 2021	Ma'ale HaHamish, Israel
► 95th Annual Southwestern Fertilizer Conference	17-07 / 21-07 - 2021	Denver, Colorado, USA
19th International Plant Nutrition Colloquium	30-08 / 03-09 - 2021	Foz do Iguaçu, Brazil

► Argus Added Value Fertilizers Africa	September 2021	Africa
► Argus Europe Fertilizer	October 2021	Europe

Environment (climate change / greenhouse gas emission etc)

► International Symposium on Climate-Resilient Agri-Environmental Systems	03-11 / 06-11 - 2020	Dublin, Ireland

Mapping, sensing, sampling and analytics

► Analytica 2020	19-10 / 22-10 - 2020	Munich, Germany
AOAC 134th Annual Meeting & Exposition	11-09 / 17-09 - 2020	Orlando, Florida, USA
► PittCon 2021: 72th Pittsburgh Conf Analytical Chemistry and Appl Spectroscopy	06-03 / 10-03 - 2021	New Orleans, Louisiana, USA
► 69th ASMS Conference on Mass Spectrometry and Allied Topics	06-06 / 10-06 / 2021	Philadelphia, Pennsylvania, USA
EuroAnalysis 2021	22-08 / 27-08 - 2021	Nijmegen, The Netherlands

Chelates / ligands / metal complexes

► 44th International Conference on Coordination Chemistry (ICCC 2020)	27-06 / 02-07 - 2021	Rimini, Italy

Organic matter/fertilisers, green manure, industrial wastes, biochar, humic acids etc)

► 5th Asia Pacific Biochar Conference	22-10 / 25-10 - 2020	Hong Kong, China
► ESNI - European Sustainable Nutrient Event	26-10 / 27-10 - 2020	Brussels, Belgium
► European Biosolids & Organic Resources Conference	24-11 / 25-11 - 2020	Newcastle-upon-Tyne, UK
► Intercropping for Sustainability	19-01 / 20-01 - 2021	Reading, UK
► Biofumigation 7 - Int Symp Biocidal Non-Biocidal Plants to improve Soil Health	Spring 2021	Crans-Montana, Switzerland
► 7th International Slag Valorisation Symposium	Spring 2021	Belgium
► 20th Conference of International Humic Substances Society	15-08 / 20-08 - 2021	Estes Park, Colorado, USA
► North American Manure Expo 2021	25-08 / 26-08 - 2021	Listowel, Ontario, Canada

Specific release / nitrification and urease inhibitors

► 47th Annual Meeting & Exposition of the Controlled Release Society	29-06 / 02-07 – 2020	Virtual meeting

Nitrogen

► Nitrogen North America 2020	To be decided	Houston, Texas, USA
14. International Conference on Nitrogen Fixation (ICNF 2020)	29-06 / 30-06 - 2020	London, UK
► 65th Annual Safety in Ammonia Plants and Related Facilities Symposium	30-08 / 03-09 - 2020	Munich, Germany
► 8th Global Nitrogen Conference	2021	Berlin, Germany
► Nitrogen + Syngas USA 2021	16-02 / 18-02 - 2021	Tulsa, Oklahoma, USA
► Nitrogen + Syngas 2021	01-03 / 03-03 - 2021	Rome, Italy
► 4th European Power to Ammonia Conference (NH_3 Event)	May 2021	Rotterdam, The Netherlands
► 14th European Nitrogen Fixation Conference	26-08 / 29-08 - 2021	Naples, Italy
► 25th North American Symbiotic Nitrogen Fixation Conference	May/June 2022	Madison, Wisconsin, USA

Phosphorus

► Phosphorus Forum 2020	Postponed	Washington, DC, USA
► 23rd International Conference on Phosphorus Chemistry	Postponed	Ningbo, Zhejiang, China
► Iron phosphate chemistry applied to phosphorus stewardship and P-recovery	13-07 / 14-07 - 2020	Online event
International workshop Organic Phosphorus 2020: From Land to Sea	07-09 / 11-09 - 2020	Abisko, Sweden
► DPP-Forum 2020	24-09-2020	Frankfurt am Main, Germany
► Phosphate Days 2020 Split in Young Researchers Days and International Conference on Phosphates	13-10 / 17-10 - 2020	Virtual conference
► Expert forum sewage sludge treatment and phosphorus recovery (German)	04-11-2020	Nuremberg
► 4th European Sustainable Phosphorus Conference	31-05 / 02-06 - 2021	Vienna, Austria
► Benefication of Phosphates IX	13-06 / 18-06 - 2021	Helsinki, Finland

Sulphur

► Sulphur Products Summit	08-10-2020	Atlanta, Georgia, USA
► Sulphur + Sulphuric Acid 2020	02-11 / 04-11 - 2020	The Hague, The Netherlands

Boron

► Boram 2020 - 17th Boron Chemistry Meeting in the Americas	01-06 / 05-06 - 2021	Blacksburg, Virginia, USA
► 17th International Meeting on Boron Chemistry (IMEBORON XVII)	July 2021	Rennes, France

Copper

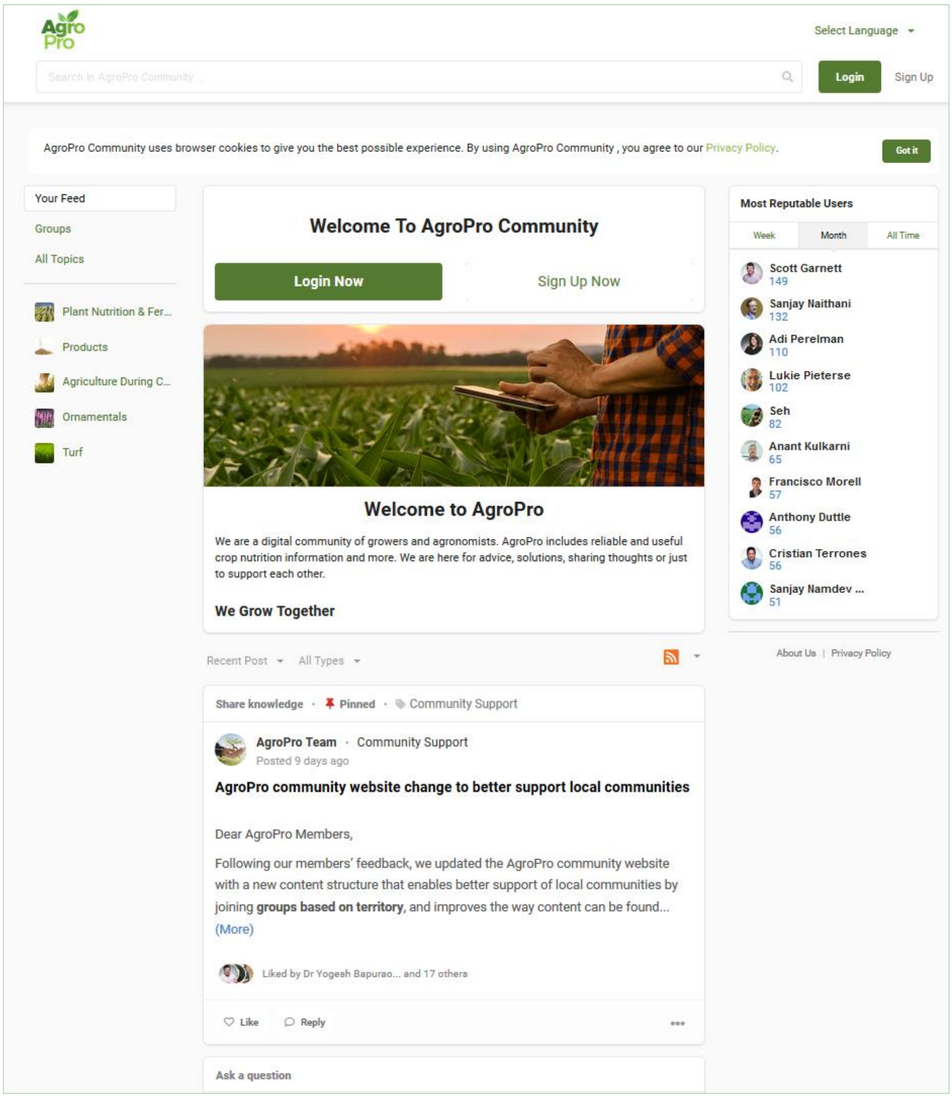
► World Copper Conference 2021	12-04 / 14-04 - 2021	Santiago, Chile

AgroPro

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

Website AgroPro
URL https://www.agropro.com
Languages 13 languages
Offered by ICL

Description
A free of charge information site about crop nutrition for farmers and professional agronomists. AgroPro aims to provide professional answers to crop nutrition questions from all over the world that are asked publicly or anonymously.
The Israeli fertilisers and specialty chemicals company ICL launched this platform in response to the agronomic communication challenges caused by the COVID-19 pandemic. Agronomy experts from ICL participate actively in this forum, but experts from outside ICL are also on this forum. The forum has, for instance, also information about control of potato late blight and crown gall disease and even on Syngenta's plans on the commercialisation of its fungicidal and nematicidal active ingredient cyclobutrifluram.



Iron

► Iron phosphate chemistry applied to phosphorus stewardship and P-recovery	13-07 / 14-07 - 2020	Online event
► Int. Symposium on Iron Nutrition and Interaction in Plants (ISINIP 2020)	June/July 2021	Reims, France

Zinc

► 4th International Zinc Conference (Europe)	07-09 / 09-09 - 2020	Istanbul, Turkey

Silicon

8th International Silicon Conference	26-10 / 29-10 - 2020	New Orleans, Louisiana, USA

Mycorrhiza and other microorganisms improving a crop's nutritional status

14. International Conference on Nitrogen Fixation (ICNF 2020)	29-06 / 30-06 - 2020	London, UK
10th International Symbiosis Society Congress	18-07 / 23-07 - 2021	Lyon, France
► 14th European Nitrogen Fixation Conference	26-08 / 29-08 - 2021	Naples, Italy
► 25th North American Symbiotic Nitrogen Fixation Conference	May/June 2022	Madison, Wisconsin, USA

► New or additional information added

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