Potassium in Agriculture: Status and Perspectives

By Christian Zorb, Mehmet Senbayram and Edgar Peiter

A German research group recently published a review paper taking a fresh look at the behavior of K in soil and in plants. A few of their new findings are summarized here.

Potassium in Soils… What is New?

Root Exudates: The ability of plants to utilize non-exchangeable K sources in soil can be important. Various species have been reported to differ in their capacity to use non-exchangeable K. For example, ryegrass and sugar beet are 3 to 6 times more efficient in mobilizing K than wheat and barley. Crop differences in K uptake are in part due to mobilization of non-exchangeable K by root exudates. One group of compounds released by roots is organic acids, including: citric, oxalic, tartaric, and malic acids. Similarly, amino acids detected in root exudates of wheat and sugar beet were found to enhance the release of K from clay minerals.

Soil Bacteria: Some soil microorganisms are able to release K from geologic minerals by excreting organic acids. These organic acids either directly dissolve rock K or chelate the associated silicon (Si), bringing the K into solution. The practicality of adding K-solubilizing microorganisms is now being studied. Little information currently exists on the field application of such methods.

Potassium in Plants

In the agronomic literature, high K concentrations in crops are often classified as "luxury consumption." However, the authors report that high accumulation of K by crops during optimal growing conditions may be considered as an "insurance strategy" to enable plants to better survive sudden environmental stresses.

Photosynthesis and Photosynthates: In contrast to N and P deficiency, K deficiency results in an accumulation of sugars, a consequence of impaired sucrose export from leaves. One reason for this is that sucrose export to the root is reduced in K-deficient plants, caused by a K requirement for the loading of the phloem with sucrose.

Phloem Transport: The translocation of photosynthates from leaves to the roots and fruit generally occurs in the phloem. As the most abundant inorganic cation in the phloem, K has an additional function in counterbalancing mobile anions in the phloem. It is often the dominant counter-ion for nitrate (NO_3^-) in long-distance transport in the xylem

Drought Stress

Potassium is quantitatively the most important component in regulating the internal osmotic pressure and is a main determinant of cell turgor. Adequate turgor pressure is required for cell expansion, so this is especially important for growing plants. For a crop growing in an increasingly dry soil, adjusting osmotic pressure may be accomplished by the synthesis of organic compounds, but this process is very costly to the plant. In contrast, the uptake and storage of increased amounts of K is an energetically 'cheaper' alternative. In the field, an ample K supply will support osmotic adjustment and sustain

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Reduced crop stress often results in higher quality produce as seen above showing tomato grown with adequate soil K supply (left) versus low soil K (right).

cell expansion in dry soil conditions.

As N is often a limiting nutrient for crops, increased N fertilization requires a further increase in K availability to maintain the plant's water status, particularly in dry conditions. As an osmoticum (i.e., a substance that acts to supplement osmotic pressure in the plant), K also plays a central role in regulating stomatal aperture and limiting water loss. Potassium is required for proper stomatal opening by providing the osmotic driving force for water influx into the guard cell vacuole of the leaf.

There is evidence that a major share of the alleviation of drought stress by K is not only from regulating the stomatal aperture, but due to non-stomatal effects on photosynthesis, CO_2 fixation, primary metabolism, phloem loading, as well as on the osmotic pressure in the sieve tubes and thus the flow rate of photosynthates into the sink organs.

To maintain CO_2 assimilation, the requirement of a sufficient K supply by a crop is higher under drought as compared to well-watered conditions. High soil K supplies may mitigate drought effects, particularly in crops with small root systems, such as many legumes.

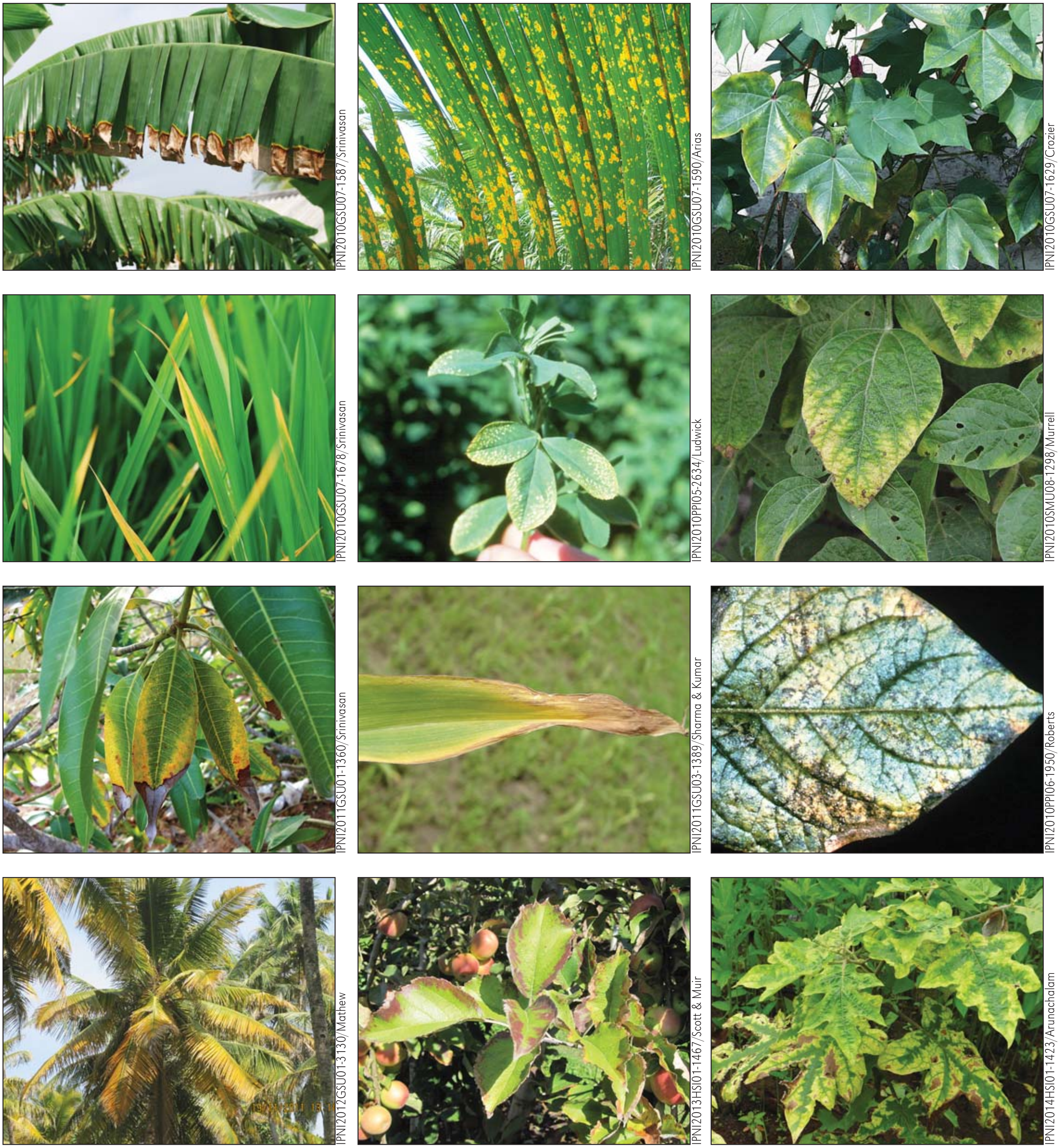
In dry soil, root growth is impeded. The smaller root system leads to a further reduction in K uptake. The poorer K supply in dry soils renders a crop less drought resistant, which impairs growth further, again reducing K uptake. This vicious circle may be overcome by optimizing soil or plant factors. To prepare plants for periods of drought stress, K fertilization above the level required for optimum yield under non-stressed conditions may be needed. Since K uptake by roots is hampered under drought, foliar application of K has been suggested, but more research is required. Continued uptake of K from a drying soil can be increased by a deep placement of the K fertilizer, but there is still much to learn about the efficacy of this practice.

Potassium deficiencies are appearing in regions where minimum or no-till cultivation practices dictate that fertilizer be applied to the soil surface. In these situations, applied K accumulates at the uppermost soil layers, which becomes inaccessible to roots during dry periods. Furthermore, soil K concentrations are decreasing in many parts of the world due to a lack of adequate K fertilization.

High Light Stress

In K-deficient plants, CO_2 assimilation is impaired due to

Abbreviations and Notes: N = nitrogen; P = phosphorus; K = potassium; CO_2 = carbon dioxide.



Potassium deficiency symptoms in selected crops (left to right: top row) banana, oil palm, cotton; (second row) rice, alfalfa, soybean; (third row) mango, corn, potato; (bottom row) coconut, apple, eggplant. Source: IPNI Image Collection of Crop Nutrient Deficiency Symptoms, http://ipni.info/nutrientimagecollection.

suboptimal activation of enzymes, inefficient phloem loading and transport, and a decreased stomatal aperture. High light intensity puts an extra strain on these processes because of the excessive energy input in the form of excited electrons. Accordingly, K-deficient plants are more prone to high light damage.

Cold Stress and Frost

With decreasing temperature, enzymatic processes and transporters in the plant are slowed down. Inhibition of these processes causes an enhanced generation of damaging reactive oxygen species (ROS) because the incoming light energy cannot be properly funneled into assimilatory processes, but is instead transferred onto oxygen (O_2). A high K supply is believed to reduce the ROS load of cold-stressed plants.

There is evidence that K has further beneficial roles in freezing stress. Freezing the internal water within a plant causes severe damage. An increased accumulation of K increased the symplastic (inside the cell plasma membrane) osmotic pressure, thereby limiting freeze-induced dehydration. For example, frost damage is often ameliorated by high K fertilization, such as in potato.

Optimized K fertilization is crucial to maximize plant response. There are many advances yet to be made in K fertilization, understanding K behavior in soils, and in improving plant utilization of K. BC

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Further information and detailed scientific references are available in the original in J. Plant Physiol. paper available online, October 17, 2013 http://dx.doi.org/10.1016/j.jplph.2013.08.008

Fertilizer Industry Round Table Recognition Award Deadline is June 30

Fertilizer Industry Round Table

Criteria

1) The award recognizes outstanding achievements in research, extension and/or education that centers on fertilizer technology and associated benefits to agricultural productivity and sustainability.
2) Applicant will be judged based on research originality, quality and practical application as demonstrated by concrete results, letters of recommendation, dissemination of findings, contribution to sustainability, and po tential for international application.
3) Applicant must be a resident of Canada or the United States.

Application Procedures

1) Electronic copy of three letters of support. If a student, one should be from the major professor.
2) A description of the focus of the research presented to be evaluated on originality, scope, innovation and potential application.
3) Award recipients are not eligible for more than one award.
4) Priority will be given to those who support the mission of the Fertilizer Industry Round Table (FIRT).
5) Questions and application materials should be directed in electronic form to: DMessick@sulphurinstitute.org.

Selection Process - A panel of three individuals will select the award winner. The panel will consist of representatives from academia, industry and an environmental-focused entity.

Award - US$2,500 and travel to FIRT's annual conference.

Conversion Factors for U.S. System and Metric

Because of the diverse readership of *Better Crops with Plant Food*, units of measure are given in U.S. system standards in some articles and in metric units in others…depending on the method commonly used in the region where the information originates. For example, an article reporting on corn yields in Illinois would use units of pounds per acre (lb/A) for fertilizer rates and bushels (bu) for yields; an article on rice production in Southeast Asia would use kilograms (kg), hectares (ha), and other metric units.

Several factors are available to quickly convert units from either system to units more familiar to individual readers. Following are some examples which will be useful in relation to various articles in this issue of *Better Crops with Plant Food*.

To convert Col. 1 into Col. 2, multiply by:	Column 1	Column 2	To convert Col. 2 into Col. 1, multiply by:
	Length		
0.621	kilometer, km	mile, mi	1.609
1.094	meter, m	yard, yd	0.914
0.394	centimeter, cm	inch, in.	2.54
	Area		
2.471	hectare, ha	acre, A	0.405
	Volume		
1.057	liter, L	quart (liquid), qt	0.946
	Mass		
1.102	tonne[1] (metric, 1,000 kg)	short ton (U.S. 2,000 lb)	0.9072
0.035	gram, g	ounce	28.35
	Yield or Rate		
0.446	tonne/ha	ton/A	2.242
0.891	kg/ha	lb/A	1.12
0.0159	kg/ha	bu/A, corn (grain)	62.7
0.0149	kg/ha	bu/A, wheat or soybeans	67.2

[1]The spelling as "tonne" indicates metric ton (1,000 kg). Spelling as "ton" indicates the U.S. short ton (2,000 lb). When used as a unit of measure, tonne or ton may be abbreviated, as in 9 t/ha. A metric expression assumes t=tonne; a U.S. expression assumes t=ton.