Silicon Products:

At the border between and Plant Protection

Silicon, the second most abundant element in the earth's crust, is a beneficial element for plant growth and development. Silicon helps plants to overcome various abiotic and biotic stresses. Unfortunately, the role of silicon in plant growth and development was long overlooked until the beginning of 20th century. Because of the element's abundance in nature and since visible symptoms of either Si deficiency or toxicity is not very apparent; plant physiologists' have largely disregarded this element from any meaningful plant experiments. However, in the field where plants are constantly exposed to different stresses, especially in soils that are deemed to be low or limiting in plant available silicon, the awareness of silicon deficiency in soil has become recognized as being a limiting factor for crop production. Although silicon still is not recognized as an essential element for plant growth, its beneficial effects on growth, development, yield and disease resistance have been observed in a wide variety of plant species and countries. Countries where the addition of Silicon has improved the performance of crops in fields and greenhouses include Australia, Brazil, Canada, China, Colombia, India, Iran, Japan, Korea, the Netherlands, Russia, South Africa, Thailand, the UK, the US, Venezuela and Vietnam. A number of manufacturers & suppliers of inputs to the farmers and growers are showing a growing but still not highly enthusiastic interest to include silicon-based specialities in their product range. The IV Silicon in Agriculture Conference recently held in South Africa was a good opportunity for New Ag International to ask Prof Datnoff, a world expert in Silicon in Agriculture, to help us summarize the main developments in Silicon science and technology around the world.


Courtesy of NAI

Prof. Datnoff

To bring together scientists from a broad range of disciplines related to silicon in agriculture, and to provide a forum for researchers to exchange new knowledge, ideas, and techniques, Silicon in Agriculture Conferences have been held every three years. Since the first conference in the USA in 1999, the second in Japan in 2002, the third in Brazil in 2005, the IV Silicon in Agriculture Conference was held recently from 26 to 31 October 2008 in South Africa. The event was organized by the University of Kwazulu-Natal and South African Sugarcane Research Institute with financial support from Agripower, CalMasil, Distell, Floratine Bio-Sciences, Inc., Oil & Protein Seeds Development Trust, Omnia Nutriology, PQ Corporation, Protein Research Foundation, South African National Research Foundation, and United States Department of Agriculture-Agricultural Research Service.

Over 125 researchers, teachers, producers and students attended from 29 countries. Leading scientists updated the participants on the status of silicon research in their area of expertise. These included: Richard Bélanger (Canada); Lawrence Datnoff (United States); Graham Kingston (Australia); Stephen Kinrade (Canada); Olivia Kvedaras (Australia); Gaspar Korndörfer (Brazil); Mark Laing (South Africa); Yongchao Liang (China); Jan Meyer (South Africa); and Fabrício Rodrigues (Brazil).

Fifty-nine oral presentations and 13 posters were presented along with published abstracts of each presentation. The presentations underscored the numerous roles silicon plays in plant biology especially under conditions of stress. Many new

Plant Nutrition

Courtesy of L. Datnoff

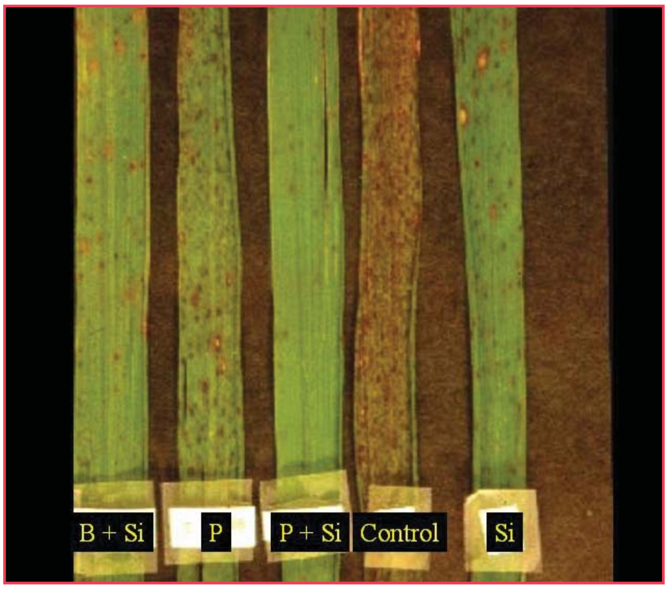
findings about silicon were highlighted by plant scientists from the fields of agronomy, plant biochemistry, plant pathology, plant physiology, and soil science. These included transporter genes are involved in moving this element across root membranes in dicots such as pumpkins; transcriptome analysis that revealed that a number of defensive and metabolic genes are actively and uniquely up and down regulated by silicon in rice and wheat; findings that primary cell wall thickness will decrease up to 80% in silicon amended plants supporting a cross link hypothesis; demonstrations that silicon reduces Cd in wheat and maize by hardening cell walls of the stele and increasing root extensibility; and that silicon increases ladybug choice in feeding, this suggests that plants amended with this element release specific volatiles to attract the most appropriate enemy. In addition, a number of ornamental plants were found to be silicon-accumulating such as verbena and zinnia. Other topics of interest were presented in broad sessions which included a) chemistry of silicon in soils; b) silicon in plants; c) silicon and plant stress; d) silicon and disease management; and e) silicon and pest management. As a final note, information about silicon in humans was presented for the first time. It has been found that the distribution of silicon is more than all the other trace elements combined (1gm silicon/10 kg body weight); high levels are found in the bone, nails, tendons, wall of the aorta, arteries and kidneys; medium levels in red blood cells, serum, liver, spleen and lungs, and it is found in breast milk.

USING SILICON FERTILIZERS FOR REDUCING IRRIGATION WATER APPLICATION RATE?

This is what is suggested by Drs. Bocharnikova and Matichenkov, two Russian Scientists from the Russian Academy of Sciences who tested a new technology for reducing irrigation water application rate in laboratory and field experiments. The technology is based on the use of Si fertilizer with a high content of active Si. Plants adsorb Si in an amount exceeding that of other nutrients. Optimization of Si nutrition results in increased weight and volume of roots by 20 to 200% and enhanced drought and salt resistance in cultivated plants. Active Si compounds are shown to be extremely important for formation of soil fertility. These compounds have a direct effect on soil texture and increase soil water holding capacity by 20 to 30% and exchange capacity by 10 to 25%. Barley, wheat and grass were used in the greenhouse experiments and sorghum was used in the field trial, which were conducted on sandy soils. The active Si benefits were demonstrated to include improved soil adsorption capacity (increased by 20 to 40%) and soil water holding capacity (increased by 10 to 30%) as well as enhanced plant resistance to water deficiency and salt toxicity. The greenhouse tests with different water regimes and salt concentrations in irrigation water allowed determination of the most effective sources of solid and liquid Si fertilizers which could be used on commercial fields. The technology allows reducing irrigation water application rate by 10 to 40% without negative influence on crop productivity and quality. The field demonstration showed that the application of commercial Si fertilizer ensured the survival of the sorghum crop in the treated plot, while in the control plot all plants withered. The elaborated technology can be adapted for any soil climatic conditions and quality of irrigation water. This preliminary analysis of the use of active Si in agriculture relative to crop production, water discharge and environmental benefits was conducted in the dry and semi-dry regions of different countries..

SILICON AND PLANT DISEASES: A NEW TECHNOLOGY FOR POWDERY MILDEW PROTECTION IN IPM STRATEGIES

A number of papers were presented in South Africa on the use of silicon in combating plant diseases. From a product development viewpoint, however, one of the most innovative approaches was presented by the Spanish Company Bioiberica. Powdery mildew type fungi are among the most persistent plant pathogens that cause numerous common diseases limiting production of a wide range of crops worldwide. In addition to direct damage caused by the pathogen, this fungal disease also weakens the plant's resistance to any biotic or abiotic stress factor. With this in mind, the R&D Department of Bioiberica SA, focused on plant stress management to develop a new foliar spray product containing amino acids plus soluble active Si. This approach combines the well-known beneficial properties of both components: the biostimulant effect of amino acids, which helps plants to rapidly overcome physiological stress, and the effect of Si on the plant's resistance to fungal infections. Two modes of action have been reported to elucidate the Si effect: a structural reinforcement function due to its deposition underneath the plant cell wall and, more recently, the role of soluble Si as an inducer of plant defense responses. Findings from Bioiberica confirm a synergic effect of amino acids plus Si on a reduction in the incidence and severity of powdery mildew in different plant species of agricultural interest, such as fruit trees and horticultural crops. The use of this new double-action product permits a reduction in the number of fungicide applications while improving plant health and yield parameters in sustainable crop management.

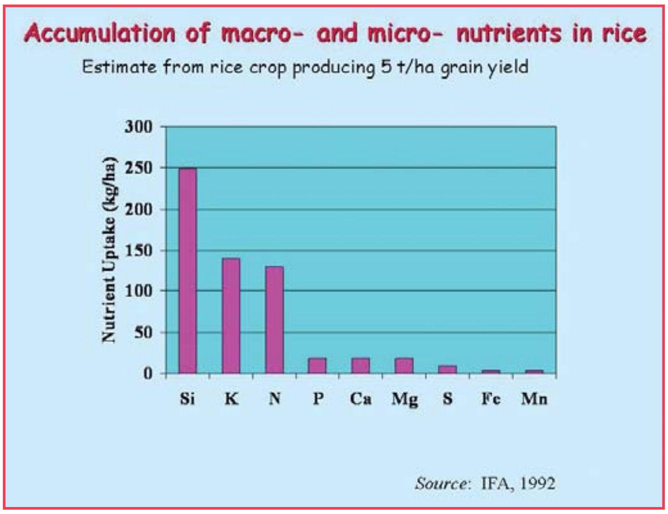


Courtesy of L. Datnoff

SILICON FERTILISERS: A NEED TO DEVELOP NEW PRODUCTS?

Responses to Si fertilisers in Si accumulator field crops such as rice and sugarcane are associated with depleted capacity of the root zone to supply sufficient plant available Si. "There is a clear sustainability issue for the rice industry and other production systems on weathered tropical soils. Soil and plant based criteria are available to determine the likelihood of economic responses in rice and sugarcane crops to application of silicate fertilisers", says G. Kingston, from BSES Limited in Queensland, Australia.

However, no similar criteria were identified for dicotyledons and non-Si accumulator crops, other than recommendations for use of potassium silicate in nutrient solutions for soilless culture of curcurbits. Reduced incidence of foliar disease and stimulation of photosynthesis have been attributed to foliar applications of potassium silicate. It is not clear that such responses are due to in planta, or merely topical effects, as similar responses occur with non-Si products. In planta Si responses are not usually reported and incorporation of foliar applied Si in leaf tissue is contrary to current understanding of Si uptake, transport and deposition. The first commercial Si fertilisers were derived from steel industry slags registered in 1955 in Japan. Subsequent fertiliser registrations followed in Korea and Brazil. By-product silicate fertilisers now include a range of slags derived from the steel and elemental phosphorus industries. These are applied at 1.5-2.0 t/ha/year in the rice industry and 4.0-7.5 t/ha every four to five years for sugarcane and rice/sugarcane cropping systems. Significant manufactured products include fused potassium and magnesium silicates and calcium meta-silicate. Significant liquid products include potassium silicate and the soluble Si in irrigation waters. Geological materials such as wollastonite, crushed rocks and diatomaceous earths are used as silicate fertilisers,



but use is constrained by market availability of wollastonite and the high rates of application required for low solubility crushed rock and diatomaceous earth. Yield responses to silicate fertilisers of 1-30% were achieved in rice crops (depending on the disease pressure) and 7-45% in sugarcane, where response mechanisms are not clear, but may include greener leaves, resistance to stem borers and lower impact of aluminium and manganese on phosphorus nutrition. Silicate fertilisers also have a clear role in improving food quality by suppressing uptake of heavy metals such as cadmium. "Knowledge of benefits of Si fertilisation must now be translated into practical and economic strategies based on suitable products to underpin improvements in crop yield and quality while arresting degradation of the soil environment", says G. Kingston, from BSES Limited in Queensland, Australia.

The number of suppliers of silicon-based fertiliser products is not very big and most of them have a national, sometimes regional marketing approach. The main market potential seems to be in the Southern hemisphere but the need for alternative plant disease protection treatments has also recently aroused more interest in the northern hemisphere due to limitations on the use of pesticides and environmental concerns. This is a more specialized and certainly more lucrative niche where a number of companies who position their products at the border between plant nutrition, plant protection and plant biostimulation, should find interest to invest!

THE DEFINITE NEED TO BETTER PROMOTE AND SHARE THE KNOWLEDGE ON THE ROLE OF SILICON IN AGRICULTURE

The knowledge on Si's role in plants, however, is not shared by the general community of plant biologists, who largely ignore the element. The baffling contrast is based on two sets of experiences. First, higher plants can grow to maturity in nutrient solutions formulated without Si. This has led to the conventional

The New Ag International Selection of Papers & Posters at the IV Silicon in Agriculture conference

Chemistry of Silicon in Soils

Effects of soil type, source of silicon, and rate of silicon source on development of gray leaf spot of perennial ryegrass turf, by Uddin, Nanayakkara, Datnoff

Silicon and Plant Stress

Effect of Si on growth and tolerance to stressful environments and plant diseases in higher plants including protein and oil-bearing crops, by Liang

Silicon application alleviated salinity stress in wheat (Triticum aestivum L.) grown in hydroponics and field conditions, by Tahir, Aziz, Rahmatullah

Alleviation of abiotic stress with silicon addition:
a meta-analysis, by Cooke

Using Si fertilizers for reducing irrigation water application rate, by Bocharnikova, Matichenkov

Active silicon for increasing salt tolerance in plants, by Kosobryukhov, Shabnova,Kreslavsky, Matichenkov.

Understanding the benefits of silicon feeding in plants through transcriptomic analyses, by Belanger

Silicon and Disease Management

Influence of insoluble and soluble silicon on leaf blast development in rice, by Datnoff, Ma, Mitani

Cold stress ameliorating effect of silicon and its impact on Fusarium wilt of banana, by Kidane, Laing

Movement of silicon through Saccharum officinarum (sugarcane) and its effect on Puccinia melanocephala (brown rust), by Naidoo, Caldwell, McFarlane

Preharvest or postharvest silicon treatment for the control of postharvest Penicillium digitatum of citrus fruit, by Abraham, Laing, Bower, Clark

Assessing the effectiveness of silicon content materials against blast disease of rice, by Quazi, Mohammed

A new Silicon technology for powdery mildew protection in IPM strategies, by Botta, Sierras,Marin, Carrion, Pinol

Silicon in Plants/ Silicon Fertilisers

Evaluating silicon uptake in floriculture crops grown in the U.S., by Frantz, Locke

Silicon in dicotyledonous plants, by Laing, Kidane

Effect of oligomeric silicon and low dose boron as foliar application on wet land rice, by Prakash, Chandrashekhar, Mahendra,Thippeshappa, Patil , Laane

Calcium silicate as silicon source and its interaction with nitrogen in aerobic rice, by Shashidhar, Chandrashekhar, Narayanaswamy, Mahendra, Prakash

Steel slag as a silicon source for sugarcane: evaluation of Si availability and plant accumulation, by Ferreira, Nascimento, Silva, Costa

Response of rice and sugarcane to Mg silicate in different soils of Colombia, South America, by Bernal

Silicon fertilisers - requirements and field experiences, by Kingston

Silicates in contemporary Australian Farming: A 20 year review, by Lynch

Silicon for humans: beneficial or essential? by Laane

Note: the full list of conference papers & posters and the corresponding abstracts can be downloaded from http://www.siliconconference.org.za wisdom that Si is not an essential element, or nutrient, and thus can be disregarded. Second, the world's plants, however, do not grow in the benign environment of solution culture in plant biological research establishments. They grow in the field, under many conditions that are often anything but benign. It is there, in the real world, with its diverse stressful features, that the Si status of plants can make a huge difference in their performance. The stresses that are alleviated by Si range all the way from biotic, such as diseases and pests, to abiotic, such as extremes in temperature and metal toxicities. Silicon performs its functions in two ways: (i) by the polymerization of silicic acid leading to the formation of amorphous, hydrated silica, and (ii) by being instrumental in the formation of organic defense compounds through alterations of gene expression often affected by Si. The Si nutrition of plants is not only scientifically intriguing, but important in a world where more food will have to be wrung from a finite area of land, for that will put crops under stress.

Silicon is an integral and quantitatively major component of the soil-plant system that exists in nature and agriculture. It plays a major role in the life, performance and health of plants in the real world especially in regard to alleviating a number of chemical and physical stresses and enhancing host plant resistance to diseases and pest. With so many important roles in plant life, how can it be disregarded in plant biological thinking and experimentation? As a consequence, the time has come where this element should be considered along with all the other macro- and micro- nutrients critical to plant function and development. Thanks also to the Silicon conferences, Si as a plant nutrient, has made it into the consciousness of a broader agricultural public, especially in the Southern Hemisphere, where the problem is so widespread. It is estimated that well over 40% of Africa's soils are deficient to severely deficient in plant available Si. The next meeting will be held in Beijing, China in 2011. ■