Silicon in Agriculture

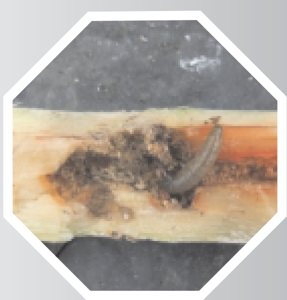
1st Annual Research Day

Tuesday, 4 August 2009

KwaShukela Auditorium,

South African Sugar Association,

Durban



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PROGRAMME

9h00 - 9h25 *Registration and tea/coffee*		
Session 1: Chair- Shaun Berry (SASRI)		
9h30 - 9h45 *Opening Address - Charlie Reinhardt, Research Manager, SASRI*		
9h45 - 10h10 *Effects of silicon concentrations on management of powdery mildew and growth of Zucchini and Zinnia*	Habtom Tesfagiorgis	Univ. KZN
10h10 - 10h35 *Control of sugar beet root diseases (* Rhizoctonia solani *and* Pythium *spp.) using silicon and biological control (* Bacillus *and* Pseudomonas *spp.)*	Sandile Hadebe	Univ. KZN
10h35 - 11h00 *Efficacy of Si soil applications for control of* Verticillium *wilt of potatoes*	Cornel Millard	Univ. Pretoria
11h00 - 11h30 *Tea/coffee and refreshments*		
Session 2: Chair- Malcolm Keeping (SASRI)		
11h30 - 11h55 *Solubilisation of silica from fly ash: interaction with root exudates*	Richard Kruger	Richonne Consulting
11h55 - 12h20 *Effect of silicon on a sugarcane nematode community in KwaZulu-Natal*	Shaun Berry	SASRI
12h20 - 12h45 *Investigating and manipulating silicon uptake in sugarcane*	Robyn Jacob/Clare Phyfer	SASRI
12h45 - 13h10 *Induced resistance in sugarcane to stalk borer and thrips: is there a role for soluble silicon?*	Malcolm Keeping	SASRI
13h15 - 14h15 *Lunch*		
Session 3: Chair- Mark Laing (Univ. KZN)		
14h15 - 14h40 *The use of silicon (potassium silicate) to control* Phakopsora pachyrhizi *(soybean rust) on soybean*	Dael Visser	Univ. KZN
14h40 - 15h05 *The potential of postharvest silicon dips to mitigate chilling injury in citrus fruit with special emphasis on lemon (c.v Eureka)*	Nhlanhla Mathaba	Univ. KZN
15h05 - 15h30 *The effect of Eco-T (* Trichoderma harzianum*) and silicon for the control of* Rhizoctonia solani *and* Sclerotinia sclerotiorum *on selected sunflower cultivars*	Elungi Konis	Univ. KZN
15h30 - 15h45 *Closing - Mark Laing (Univ. KZN)*		

Effects of silicon concentrations on management of powdery mildew and growth of Zucchini and Zinnia

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Concentration of Silicon (Si) in the nutrient solution plays an important role in disease control, growth and yield of plants growing in hydroponic systems. Zucchini and zinnia were grown in re-circulating nutrient solutions containing Si at different concentrations. Effects of Si concentration in the solution on powdery mildew (PM) control and plant growth, and accumulation of Si and selected elements in different parts of these two plant species were determined. Increased concentrations of Si in the solution improved efficacy of Si against PM, accumulations of potassium (K) in the shoots, and Si in leaves and roots of both plants without affecting its distribution to other plant parts. Adding Si into the nutrient solution at 50 - 100 mg ℓ^{-1} enhanced growth of plants by improving their uptake of P, Ca, and Mg. However, increased level of Si reduced accumulation of calcium (Ca) in plants and their growth and yield (for zucchini only).

Leaves of both plant species, infected with PM fungi, accumulated higher levels of Si and Ca, but less P, than leaves of uninfected plants exposed to the same levels of soluble Si. For optimal disease control and maximum growth and yields of these two plants, hydroponic applications of Si at 50-100 mg ℓ^{-1} are recommended.

Keywords: Accumulation, hydroponics, plant growth, powdery mildew, silicon, Zinnia, Zucchini.

Control of sugar beet root diseases (*Rhizoctonia solani* and *Pythium* spp.) using silicon and biological control (*Bacillus* and *Pseudomonas* spp.)

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Sugar beet is a temperate biennial root crop whose roots are rich in sucrose. Its yield potential is more than 200tons/ha in 7 months at 24% sucrose compared to 14% sucrose in 18 months for sugarcane. Root diseases are a major obstacle in cultivating sugar beet in South Africa. Silicon application has been shown to increase Silicon content in the roots and leaves of plants, and to enhance the plant immune systems. Biological control has been recognised worldwide as a safe and cheap method of controlling soilborne pathogens. Therefore the aim of this project is to investigate the potential of Silicon, *Bacillus* and *Pseudumonas* in controlling sugar beet root diseases caused by *Rhizoctonia solani* and *Pythium*. 121 *Bacillus* and 42 *Pseudomonas* isolates have been isolated so far. The bacterial isolates will be tested in the laboratory to see they produce clearing zone or hinder growth of the pathogen hyphae. Replicates from successful bacteria will be screened to quantify clearing zones. Electron microscopy will be conducted visualise the interaction. Successful isolates will be tested in the greenhouse alone and in conjunction with Silicon against the pathogens. Silicon will also be tested alone against the pathogens. The parameters tested for in the greenhouse will be percentage germination and fresh and dry shoot weight of sugar beet seedlings.

Keywords: Biological control, germination, root diseases, silicon.

Efficacy of Si soil applications for control of *Verticillium* wilt of potatoes

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Verticillium wilt is a vascular disease resulting in premature senescence of the foliage with subsequent yield loss. The disease is difficult to control due to the inability of fungicides to affect the pathogen once it enters the vascular tissue. A number of studies indicate a benefit of silicon nutrition in plants by increasing resistance to pathogenic fungi. Three greenhouse trials and 1 field trial were completed to determine the efficacy of Silicon soil applications for the control of Verticillium wilt of potatoes. Potato tubers were planted in pots filled with sandy soil infected with *V. dahliae* and uninfected soil respectively. The soil was treated as follows: Untreated control, 0.11 g/kg soil Si fume (100% Si), 0.45 g/kg soil Lime, Slag (30% Si) and Fly-ash (50% Si) respectively. Air-dried stems and roots were plated on a selective medium to quantify the inoculum level. Silicon treatment with 100% silicon, resulted in 50 to 71% reduction in number of microsclerotia / g dry stem material, while Fly-ash and Slag treatments resulted in more than 80% reduction in number of microsclerotia / g dry stem material respectively. Based on results in the greenhouse further research has focused on evaluation of Si soil application at different soil inoculum levels in natural infested fields in the Western Cape, South Africa.

Keywords: Disease control, potatoes, silicon, Verticillium wilt.

Solubilisation of silica from fly ash: interaction with root exudates

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Fly ash from coal-fired power stations has successfully been used to ameliorate acid mine spoil. The beneficial effect has been ascribed to the increase in pH, the dissolution of the amorphous silicate phase and the concomitant supply of elements required for plant growth over a protracted period.

It is known that low molecular weight organic acids (LMWOA) are exuded by the roots in rhizosphere as a means of assimilating nutrients.

The interaction between a series of LMWOA and fly ash has been investigated.

Results presented show the dissolution of the fly ash matrix and the solubilisation of macro and trace minerals depends upon the specific LMWOA and the composition of the glass phase of the particular fly ash.

The data suggests that the application of fly ash to soil would raise the pH while providing a source of silica and trace elements beneficial to agricultural crops.

It is suggested that the efficacy of fly ash as an alternative source of Si for sugarcane be studied especially in view of the simultaneous supply of essential trace nutrients.

Keywords: Agriculture, amorphous phase, fly ash, silicon, soil pollution, trace elements.

Effect of silicon on a sugarcane nematode community in KwaZulu-Natal

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Silicon (Si) is known to alleviate biotic and abiotic stresses in many crops. Most of the research on the biotic influence of Si has dealt with insects and fungi, there being no proper studies on the effect of Si on plant-parasitic nematodes. To investigate this effect, a replicated field trial was planted with sugarcane in KwaZulu-Natal, comparing two Si carriers, fly ash and filtercake (both by-products of the sugar milling process), with other treatments and an untreated control. Applying the Si carriers to the soil was not always sufficient to increase levels of Si in the sugarcane leaves. Uptake of Si by sugarcane required a particular chemical balance in the soil. As a consequence, Si treatment, *per se,* had no effect on the nematode community. However, a comparison between Si-rich and Si-poor plots, selected independently of the treatments, showed that total numbers of plant parasitic nematodes and numbers of *Pratylenchus zeae* and *Helicotylenchus dihystera* in the soil were significantly lower in plots where foliar Si levels were higher. The same trend was true for the number of *P. zeae* in the roots, but the difference was not significant. In a pot experiment, root Si was found to be correlated with foliar Si. Multivariate analysis showed that while numbers of some of the nematodes in the soil were depressed in the higher Si plots, this was not so for the most pathogenic species able to feed on the deeper cells within the roots. Potential consequences of this trend are discussed.

Keywords: Nematodes, silicon, sugarcane.

Investigating and manipulating silicon uptake in sugarcane

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The benefits of silicon (Si) amendments have been well documented in plants. These include enhanced productivity and tolerance to various biotic and abiotic stresses, such as freezing, drought, pests and diseases. In sugarcane (*Saccharum* spp. hybrids), Si application is especially beneficial in reducing infestations of the stalk borer *Eldana saccharina*. Studies have shown that South African sugarcane varieties vary in their ability to accumulate Si. The exact mechanisms of Si uptake and transport in sugarcane are unknown. However, there has been much progress made in understanding these mechanisms in rice, a typical Si-accumulating plant, efficient in the uptake and transport of silicon. Reported here are progresses made towards the development of a methodological approach to determine the mode of Si uptake, either active or passive, in sugarcane. Also reported are the initial molecular steps taken towards the manipulation of Si uptake by expressing an active Si transporter gene from rice. This work could allow the tailoring of South African varieties for increased Si uptake, which will be particularly useful for those varieties that are not able to accumulate Si at high enough levels to be beneficial.

Induced resistance in sugarcane to stalk borer and thrips: is there a role for soluble silicon?

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Induced plant resistance to insect herbivores may provide an opportunity to elevate the normally low endogenous pest resistance of susceptible crop cultivars to levels characteristic of resistant cultivars. Numerous studies have addressed the role of jasmonate (JA) and salicylate (SA) in inducing plant resistance to insects, while a small but growing research effort has explored the contribution of silicon (Si) in this regard. Silicon-amended sugarcane enjoys significantly greater resistance to stalk borer attack, but the relative contributions of amorphous versus soluble Si to plant defence have yet to be established. Adverse mechanical effects of silica on borer feeding efficiency and survival are likely. Trials incorporating Si, JA and SA treatments have indicated that while Si alone does not reduce infestations of sugarcane thrips, JA and SA may interact with Si to increase resistance to the insect, along with crop yield. This suggests that soluble, rather than amorphous Si may play a role in thrips resistance and that its effects are dependent on the concurrent activity of both JA and SA. As for Si-mediated defence against plant pathogens, there appears to be growing support for an active role of Si in anti-herbivore defence, in addition to its passive one.

The use of silicon (potassium silicate) to control *Phakopsora pachyrhizi* (soybean rust) on soybean

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Phakopsora pachyrhizi, the causal organism of soybean rust (SBR), is a fungal pathogen causing significant soybean yield losses throughout the world. With the recent emergence of silicon (Si) for the effective control of many other plant diseases, field trials in the 2007/08 and 2008/09 growing seasons, were undertaken to determine the effect of various concentrations of Si, in the form of potassium silicate, at Baynesfield Estate and in the form of potassium silicate and a slow release fertilizer, at Cedara. Si (potassium silicate) was applied at 100, 250, 500, 1000 and 2000 mg ℓ^{-1} (2 times during the growing season) at Baynesfield and at 500, 1000 and 2000 mg ℓ^{-1} (2 and 3 times during the growing season) and at 25g/m^2 and 50g/m^2 (K2.6 slow release fertilizer) at Cedara, at 30 day intervals. An untreated control and a treatment with the fungicide Punch C (800 mℓ ha^{-1}) were also included. Plants in the middle two rows were rated on a scale of 0-9, area under disease progress curve (AUDPC) was calculated and yield was determined. At Baynesfield, plants treated with 2000 mg ℓ^{-1} Si showed a significantly lower AUDPC (64.8) than all other Si treatments and the untreated control. AUDPCs from the remaining Si treatments were not significantly different from one another, but were significantly lower the untreated control (95.8). Yield of plants treated with 500, 1000 and 2000 mg ℓ^{-1} were significantly higher (667, 667 and 697g, respectively) from the other Si treatments. Regression analysis showed a good correlation between AUDPC/Yield and Si applied (R^2 = 0.91 and 0.71, respectively). At Cedara, plants treated with 1000 mg ℓ^{-1} (x3) Si and the slow release fertilizer (broadcast) showed significantly lower AUDPCs (45.10 and 46.32, respectively) than the uninoculated control. Yield of plants treated with 1000 (x3) and 2000 (x3) mg ℓ^{-1} were significantly higher (267.5 and 283.2g, respectively) than the control (221.5g). Regression analysis showed a good correlation between AUDPC/Yield and Si applied. Application of potassium silicate to soybeans at concentrations of 1000 - 2000 mg ℓ^{-1}, consistently reduced levels of SBR, and increased yields.

Keywords: Glycine max, Phakopsora pachyrhizi, potassium silicate, silicon, soybean rust.

The potential of postharvest silicon dips to mitigate chilling injury in citrus fruit with special emphasis on lemon (c.v Eureka)

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Citrus fruits are sensitive to chilling injury in particularly lemons. Long distance shipping may require low temperature storage, and cold injury is of concern if cold sterilization is necessary for phytosanitory purposes. Global agricultural industry has just realized the potential of silicon (Si) to improve crop quality and induce stress resistance. Therefore, the aim of this work was to investigate the potential of silicon postharvest dips to mitigate chilling injury in citrus fruit. Lemon fruit from 2 different growing regions were dipped postharvest into Si solution at 0.5, 1.3 and 2.5 x 10^4 ppm for 30 min. fruits were then stored at -0.5°C and sampled at 0, 7, 14, 21, and 28 days for evaluating chilling injury, weight loss, electrolyte leakage immediately after storage and 5 days after withdrawal from cold storage. After evaluation fruits were peeled and the peeled freeze-dried, milled under liquid nitrogen and stored at -21°C for further use. Fruit from Ukulinga farm showed no chilling symptoms but higher electrolyte leakage. Si-2.5 x 10^4 showed symptoms of chilling injury for fruit sourced from Thornville packhouse which seem to be linked to high weight loss, and membrane damage as confirmed by electron microscopic images. Lower Si concentration seems to have greater potential in mitigating chilling injury.

Keywords: Chilling injury, citrus fruit, lemon fruit, silicon.

The effect of Eco-T (*Trichoderma harzianum*) and silicon for the control of *Rhizoctonia solani* and *Sclerotinia sclerotiorum* on selected sunflower cultivars

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Seed treatment with biocontrol agents such as *Trichoderma harzianum*, provides a potential and environmental friendly method for the control of numerous plant diseases and also enhances plant growth. The current study was undertaken to evaluate the effect of silicon (Si) and a biocontrol agent, *T. harzianum* (Eco-T), alone and in combination for the control of sunflower diseases caused by *Sclerotinia sclerotiorum* and *Rhizoctonia solani*. In addition, the sporulation behaviour of both pathogens and their interactions with the host were studied in rhizotrons. Results indicate that Si, Eco-T, and Si+Eco-T caused a significant increase on percentage germination of cultivar KKS318 by 35, 41 and 46% respectively when compared to the uninoculated pathogen control plants. Compared with *R*. *solani* infested control plants, Eco-T and Si+Eco-T caused an increase in percentage germination by 25.4% and 29.0% respectively on Cultivar KKS318 and 21% and 36.9% on cultivar DKF68-22. Cultivar NK FERTI showed a 21.3% and 27% increase in percentage germination when separately applied with Si and Eco-T. In addition, the number of leaves and plant height of cultivar KKS318 were also increased by 168.7% and 98% with Eco-T application and by 131% and 83.5% when treated with Si+Eco-T. Number of leaves and plant height of Cultivar NK FERTI were also increased by 107.5% and 105.6% respectively with Eco-T treatments and by 107.5% and 98% respectively with Si+Eco-T treatment. On *Sclerotinia* infected plants, applications of Eco-T and Si+Eco-T caused an increase in dry weight of cultivar KKS318 seedlings (45.5% and 35.7% respectively) compared to the *Sclerotinia* control. Application of Si increased the number of leaves and head dry weight of cultivar NK FERTI by 47% and 146% respectively, while Si+Eco-T caused an increase on head dry weight of KKS318 by 86% compared to the *Sclerotinia* infested control. Rhizotron studies showed that *S. sclerotiorum* infected the host through the roots and the stem whereas *R. solani* infect the host through the roots. The implications of these results will be discussed.