SHORT COMMUNICATION

# DEPOSITION OF SILICON IN LEAVES OF SUGARCANE (*SACCHARUM* SPP. HYBRIDS) AND ITS EFFECT ON THE SEVERITY OF BROWN RUST CAUSED BY *PUCCINIA MELANOCEPHALA*

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Sugarcane is considered to be a silicon (Si) accumulator, and extensive research has been conducted on the role of Si nutrition in this crop. This study focused on the uptake and deposition of Si in the leaves of sugarcane plants and the associated effect on the severity of brown rust. Two trials were conducted, each consisting of varying treatments of potassium silicate ($K_2SiO_3$), applied weekly. For the disease severity trial, an additional treatment of Calmasil® was applied. Si uptake and deposition increased significantly with an increase in Si added. Using X-ray mapping, it was found that significantly more Si was deposited in the lower epidermis than in the upper epidermis and mesophyll. Disease severity was significantly reduced in plants treated with Si at 2000 mg/L. These results suggest that Si nutrition may play an important role in the management of brown rust.

*Keywords:* sugarcane, brown rust, silicon, Si, deposition, plant resistance

## Introduction

Brown rust of sugarcane, caused by *Puccinia melanocephala* H&P Sydow, was accidentally introduced into South Africa from India in 1941 and was first reported on variety Co301 (Bailey, 1995; Saumtally and Autrey, 1999). Even when it reappeared in the mid-1970s, brown rust was regarded as an economically unimportant disease. However, there was a resurgence of the disease in 2000, shortly after the release of variety N29.

Although brown rust in sugarcane is best managed through the use of varietal resistance, fungicides and nutrition management can be effective against the disease. An association between nutrients and rust severity has been identified (Anderson and Dean, 1986; Cadet *et al*., 2003, McFarlane *et al*., 2008). Silicon (Si) has been shown to induce resistance to fungal diseases in other crops (Datnoff *et al.*, 2007) as well as to promote the development of healthy sugarcane (Meyer and Keeping, 2001). Cadet *et al*. (2003) suggested that applications of Si could increase its content in the leaves and thus reduce the rate of rust infection. In addition, sugarcane is known to be a silicon accumulator, retaining up to 3% Si in the leaves (Savant *et al*. 1999; personal communication[1]). Silicon deposits are highest in the inner tangential walls of the root epidermis and in the silica cells of the leaf and stem epidermis (Kaufman *et al*., 1981).

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The aims of this study were to investigate the uptake of Si by N29 sugarcane plants, identify the leaf tissues in which Si accumulates and assess the effect of Si application on brown rust severity.

## Materials and Methods

Two trials were conducted, one to investigate uptake and deposition of Si and the other to investigate the effect of Si on brown rust severity. Each trial consisted of eight treatments, i.e. applications of $K_2SiO_4$ containing 100, 200, 400, 800, 1 200, 1 600 and 2 000 mg/L Si and a control with no added Si. The trial was replicated four times with six plants per replication. For the disease severity trial, an additional treatment of Calmasil® at a rate of 10.49 g/kg was incorporated into pine bark at planting. Trays were arranged in a randomised complete block design and all data was subjected to analysis of variance (ANOVA) using Genstat® Executable Release 9 statistical analysis software (Lawes Agricultural Trust, 2003). Least significant difference was determined at $P<0.05$.

For the uptake and deposition trial, the third leaf below the dewlap leaf was removed from the 0, 400, 800, 1 200, 1 600 and 2 000 mg/L Si treatments six weeks after planting. Transverse sections of the leaf were prepared and analysed for Si deposition in the different leaf tissues using energy dispersive X-ray microanalysis. To quantify Si deposition, the X-ray maps were analysed for percentage area covered by silicon deposits using image analysis. The total Si content in the remaining leaves, roots and stems was determined using inductively coupled plasma optical emission spectrometry (ICP-OES) (Haysom and Ostatek-Boczynski, 2006).

For the disease severity trial, plants were naturally infected with *P. melanocephala* from infected spreader plants growing within the tunnel. Plants were rated for brown rust weekly for eight weeks using a modified rating scale based on a soybean rust rating scale developed by Cedara Agricultural College and also the scale devised by Tai *et al.* (1981).

## Results and Discussion

The deposition of Si and the response to Si application in the leaf was significantly different in the different tissue types, with the highest deposition observed in the abaxial epidermis and the lowest in the upper adaxial epidermis (Figure 1). The concentration of Si in the different plant parts increased with an increase in applied Si, and appeared to plateau between 1 600 and 2 000 mg/L (data not presented).

These results are consistent with previous studies, which showed that Si is deposited in high concentrations in the dumb-bell shaped silica cells of the leaf and stem epidermis (Artschwager, 1930; Wong You Cheong *et al*., 1971a, b). However, the relative number of silica cells in the upper and lower leaf epidermis may differ between sugarcane varieties (Kaufman *et al*., 1979). Wong You Cheong *et al*. (1971a) found that any Si available to the plant would first be deposited in the silica cells, then the trichomes and finally the stomatal walls. Studies on other crops have also indicated high levels of Si deposition in the epidermis (Samuels *et al*., 1991; Lux *et al*., 2003; Frantz *et al*., 2005; Ma and Yamaji, 2006; Motomura *et al*., 2006). Higher deposition in the lower epidermis could be attributed to a greater number of silica cells in this region (Kaufman *et al*., 1979; Ferreira *et al*., 2007).

That Si accumulation plateaued between 1 600 and 2 000 mg/L was evident in both the uptake and deposition results. This information is important when determining the rate of application, and could impact on the economics of Si fertiliser use.

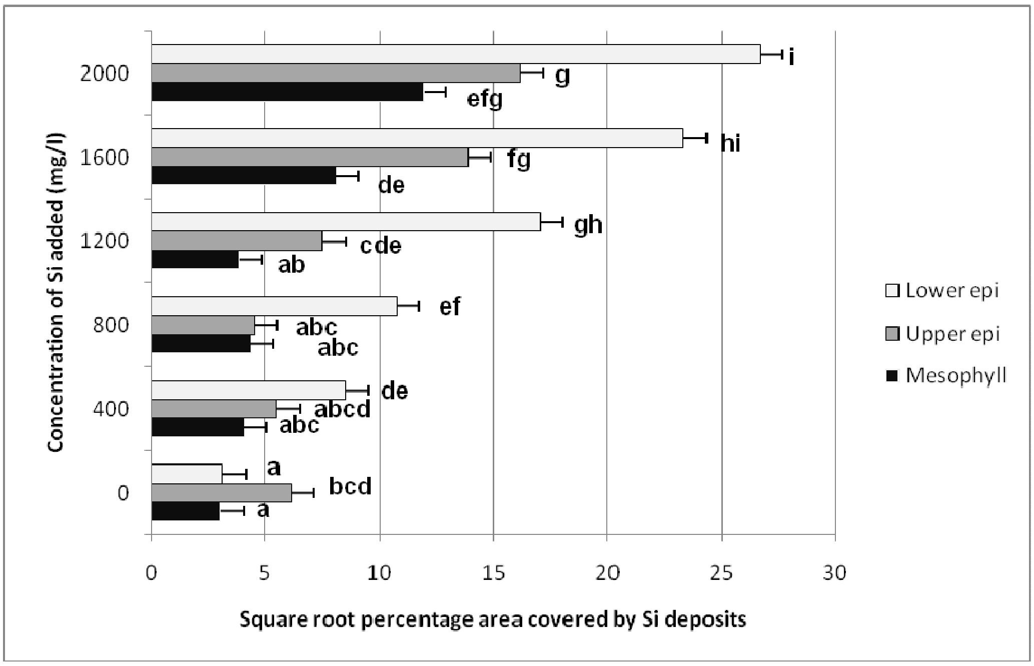


**Figure 1. Percentage area (square root transformed) covered by Si deposits in the upper epidermis, lower epidermis and mesophyll of leaves from variety N29 sugarcane plants in response to varying concentrations of Si applied as potassium silicate (ANOVA). Treatments with the same letter are not significantly different.**

An increase in Si concentration resulted in a significant decrease in brown rust severity (Figure 2).

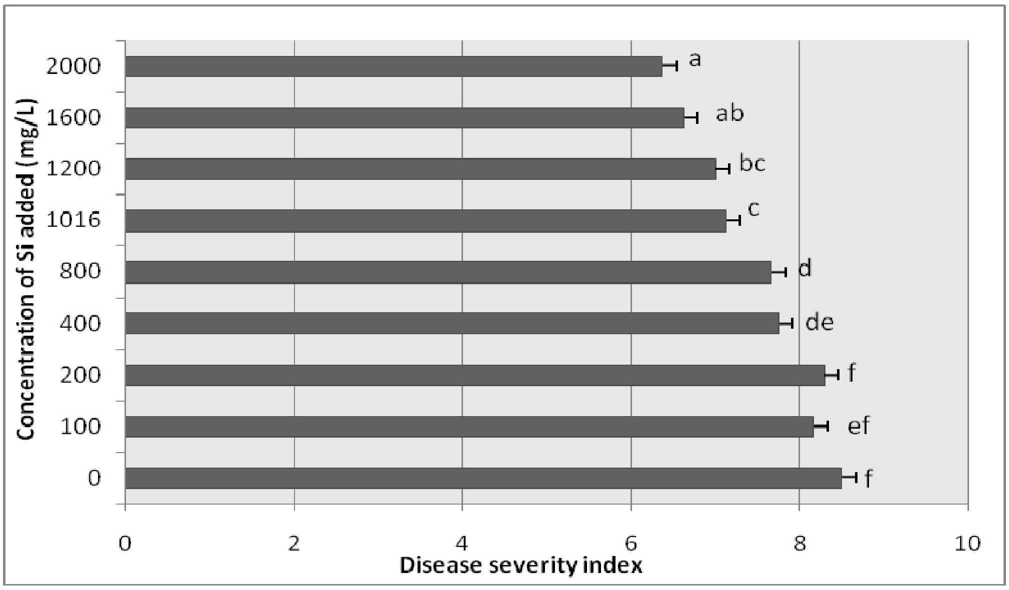


**Figure 2. Disease severity index of variety N29 sugarcane plants treated with different concentrations of Si, applied as potassium silicate and calcium silicate (ANOVA). Treatments**

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Older leaves on control plants were densely covered with pustules and lesions, and in some cases were necrotic. The pustules and lesions extended to less mature leaves, and an average disease rating of 8.5 was assigned to the control. Rust severity in plants treated with 2 000 mg Si/L was rated as 6.4, with lesions present on older leaves but few or no lesions on younger leaves, indicating that Si not only reduced disease incidence but also slowed down disease progress. A once-off application of Calmasil® (1 016 mg/L) was as effective as a weekly application of $K_2SiO_4$ at a concentration of 1 200 mg/L.

Anderson and Dean (1986) showed a relationship between rust severity and nutrient status of the soil. Cadet *et al*. (2003) suggested that Si could have an effect on brown rust incidence in sugarcane, given its ability to induce disease resistance in other crops. In this study, the application of high levels of Si led to a reduction in disease severity and disease progress. Brown rust tends to be more severe in two to six month old cane (Péros and Lombard, 1986). Therefore, the application of $K_2SiO_3$ during the early stages of plant growth or even as a once -off treatment of calcium silicate may reduce brown rust levels. The once-off application would be more practical and cost-effective as the Si could be incorporated into the soil at planting. Better rust control might be achieved by increasing the rate of Calmasil® applied. There was no significant difference in control between 1 600 Si mg $\ell^{-1}$ and 2 000 mg Si/L. These results are consistent with the results from the uptake and deposition trial. If used as part of an integrated management programme, our results indicate that Si could be effective in the control of brown rust of sugarcane, particularly since the pathogen infects the plant through the lower epidermis where the greatest Si deposition occurred.

## REFERENCES


Anderson DL and Dean JL (1986). Relationship of rust severity and plant nutrients in sugarcane. *Phytopathology* 76: 581-585.

Artschwager E (1930). A comparative study of the stem epidermis of certain sugarcane varieties. *J Agric Res* 41: 853-865.

Bailey R.A. (1995). Coping with disease problems: Changing approaches to the challenges presented to the South African sugarcane crops by diseases. *Proceedings of the South African Sugarcane Technologists' Association* 69:215-216.

Cadet P, McFarlane SA and Meyer JH (2003). Association between nutrients and rust in sugarcane in KwaZulu-Natal. *Proc S Afr Sug Technol Ass* 77: 223-229.

Datnoff LE, Rodrigues FA and Seebold KW (2007). Silicon and plant disease. pp 233-246 In: LE Datnoff, WH Elmer and DM Huber (Eds), *Mineral Nutrition and Plant Disease.* The American Phytopathological Society, St. Paul, MN, USA.

Ferreira EA, Ventrella MC, Santos JB, Barbosa MHP, Silva AA, Procópio SS and Silva EAM (2007). Leaf blade quantitative anatomy of sugarcane cultivars and clones. *Planta Daninha, Vicosa-MG* 25: 25-34.

Frantz J, Dharmalingam D, Locke J, Horst L and Krause C (2005). Foliar silica deposition in New Guinea Impatients: Plant health progress.
Available: http://www.plantmanagementnetwork.org/php.

Haysom MB and Ostatek-Boczynski ZA (2006). Rapid, wet oxidation procedure for the estimation of silicon in plant tissue. *Communications in Soil Science and Plant Analysis* 37: 2299-2306.

Kaufman PB, Ghosheh NS, Lee M, Carlson TJ, Jones JD, Rigot W, Bigelow WC and Kraus S (1981). Effect of gibberellic acid on silica content and distribution in sugarcane. *Plant Physiology* 68: 314-317.

Kaufman PB, Takeoka Y, Carlson TJ, Bigelow WC, Jones JD, Moore PH and Ghosheh NS (1979). Studies on silica deposition in sugarcane (*Saccharum* spp.) using scanning electron microscopy, energy-dispersive X-ray analysis, neutron activation analysis, and light microscopy. *Phytomorphology* 29: 185-193.

Lux A, Luxova M, Abe J, Morita S and Inanaga S (2003). Silicification of bamboo (*Phyllostachys heterocycla* Mitf.) root and leaf. *Plant and Soil* 255: 85-91.

Ma JF and Yamaji N (2006). Silicon uptake and accumulation in higher plants. *Trends in Plant Science* 11: 392-397.

McFarlane SA, Meyer JH, Cadet P and Rutherford RS (2008). Investigation into the effect of nutrition on brown rust development in sugarcane. *Proc S Afr Sug Technol Ass* 82: 388-392.

Meyer JH and Keeping MG (2001). Past, present and future research of the role of silicon for sugarcane in southern Africa. pp 257-275 In: LE Datnoff, GH Snyder and GH Korndörfer (Eds), *Silicon in Agriculture, Studies in Plant Science 8.* Elsevier, Amsterdam.

Motomura H, Fujii T and Suzuki M (2006). Silica deposition in abaxial epidermis before the opening of leaf blades of *Pleioblastus chaino* (Poaceae, Bambusoideae). *Annals of Botany* 97: 513-519.

Péros JP and Lombard H (1986). Epidemiology of sugarcane rust in Réunion. *Sugar Cane* 3: 15-17.

Samuels AL, Glass ADM, Ehret DL and Menzies JG (1991). Mobility and deposition of silicon in cucumber plants. *Plant, Cell and Environment* 14: 485-492.

Saumtally S and Autrey LJC (1999). Common rust of sugarcane: Progress and prospects. In: GP Rao, A Bergamin Fihlo, RC Magarey and LJC Autrey (Eds), *Sugarcane Pathology Volume 1: Fungal Diseases*. Science Publishers Inc, USA.

Savant NK, Korndörfer GH, Datnoff LE and Snyder GH (1999). Silicon nutrition and sugarcane production: A review. *Journal of Plant Nutrition* 22:1853-1903.

Tai PYP, Miller JD and Dean JL (1981). Inheritance of resistance to rust in sugarcane. *Field Crops Res* 4: 261-268.

Wong You Cheong Y, Heitz A and Deville J (1971a). Foliar symptoms of silicon deficiency in the sugarcane plant. *Proc Int Soc Sug Cane Technol* 14: 766-776.

Wong You Cheong Y, Heitz A and Deville J (1971b). The effect of silicon on enzyme activity *in vitro* and sucrose production in sugarcane leaves. *Proc Int Soc Sug Cane Technol* 14: 777-785.