SHORT COMMUNICATION

AN ASSESSMENT OF SOIL EXTRACTION METHODS FOR PREDICTING THE SILICON REQUIREMENT OF SUGARCANE

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Abstract

Crop and sucrose loss from *Eldana saccharina* Walker (Lepidoptera: Pyralidae) damage still ranks as being the most important factor limiting productivity in the South African sugar industry. Recent studies at the South African Sugarcane Research Institute (SASRI) have emphasised the important role of applied silicon (Si) in improving the resistance of sugarcane to eldana infestation, especially in the more susceptible varieties such as N26 and N30. Available results from trials have indicated that the silicon requirement of sugarcane is predominantly a function of soil type, and properties such as soil pH, texture, organic matter and plant available silicon. This paper documents the results of recent glasshouse and laboratory studies of six published soil test procedures to determine the soil extractant that showed the best correlation with silicon uptake and prediction of a yield response to applied Si in sugarcane.

Keywords: soils, soil tests, soil extractant, silicon, *Eldana. saccharina*, calcium silicate, soil pH

Introduction

Silicon(Si) is recognised as a major constituent of soils. It is present in the solid phase of soils as alumino-silicate clay minerals and crystalline minerals, and also in a number of amorphous forms such as plant phytoliths. In the soil solution, or liquid phase, Si is present as mono- and poly-silicic acids, and is also present as complexes with inorganic and organic compounds. While it is the mono-silicic acid component that is taken up by plants and has a direct influence on crop growth, the poly-silicic acids, and probably the inorganic and organic Si complexes, are important as sources/sinks of Si that can replenish the soil solution following crop use (Savant *et al*, 1999).

Like many grasses, sugarcane is thought to actively accumulate Si, suggesting both a physiological and morphological role in growth. A 12-month crop can accumulate 380 kg/ha Si in the above-ground tissues, compared with 180 kg/ha K, 140 kg/ha N and 20 kg/ha P (Samuels, 1969).

A reliable soil test procedure for diagnosing the Si status of soils is crucial in determining the need for applying a silicate carrier such as calcium silicate to soils, as well as the optimum amount of the carrier to apply, to ensure that the risk of damage from eldana due to a potential lack of silicon is minimised (Meyer and Keeping, 2000). Several soil Si test methods have been reported by different authors, including Fox *et al*. (1967), Khalid *et al*. (1978), Barbosa-Filho *et al*. (2001), Korndorfer *et al*. (1998), Berthelsen *et al*. (1999), and Snyder *et al*. (2001). In this study, six different soil extractants used to estimate plant available Si were evaluated in a glasshouse trial with the objective of identifying the soil extractant that showed the best correlation with silicon uptake in sugarcane.

Methodology

A trial with five different acid soils, treated with three candidate Si sources applied at rates equivalent to 3 and 6 t/ha, and using a split-split-plot design with four replications, was established in the Jake Wilson glasshouse at the South African Sugarcane Research Institute (SASRI). Bulk soil samples were collected from sugarcane fields that have been under continual cane production for many years. These included an Arcadia (Ar) form soil (44% clay) from Mount Edgecombe; a Cartref (Cf) form soil (19% clay) from Eshowe; a Glenrosa (Gs) form soil (13% clay) from Kearsney; a Longlands (Lo) form soil (4% clay) from Mount Edgecombe; and a Nomanci (No) form soil (6% clay) from Paddock. *Sorghum sudanense* Stapf. was initially planted as an indicator crop, followed by sugarcane variety N35. In all, three crops of sorghum and one crop of sugarcane were harvested. Measurements included leaf surface area, chemical analysis of the plant material, fresh and dry matter yield production, and soil analyses before planting and harvesting each crop. The Si sources used were Calmasil, a blast furnace calcium silicate slag produced as a by-product from the stainless steel industry (9.85% Si), Slagment, a low grade cement (15.2% Si) and Wollastonite, which was supplied by a local grower. The following Si extraction methods were tested:

(i) modified Truog-extractable Si (Fox *et al*, 1967)
(ii) distilled water (H_2O)-extractable Si (Fox *et al,* 1967)
(iii) 0.05 N sulfuric acid (H_2SO_4)-extractable Si (Rayment and Higginson, 1992)
(iv) 0.5 M acetic acid (CH_3COOH)-extractable Si (Korndörfer *et al,* 1998)
(v) 0.5 M ammonium acetate (CH_3COONH_4) pH 4.8-extractable Si (Fox *et al,* 1967)
(vi) 0.01 M calcium chloride dihydrate ($CaCl_2.2H_2O$)-extractable Si (Haysom and Chapman, 1975).

Results and Discussion

Overall, the two strong acid extractants, 0.05 N sulfuric acid (H_2SO_4) and 0.5 M Acetic Acid (HOAc) were found to remove the greatest quantities of Si from the five soils investigated. The high clay content Arcadia soil form showed the highest range of Si removed by all extractants, whereas the remaining light textured soils showed the least removed. In general, clay content was highly correlated with Si concentration in all the extractants, with 0.02 N sulfuric acid, producing the best correlation (R^2=0.98). All the Si sources gave positive cumulative sorghum dry matter yield responses. The relative cumulative yields of sorghum obtained for each Si treatment, expressed as a percent of the maximum yielding treatments (100%) showed that the highest response to Si treatment occurred on the Glenrosa form soil, followed in descending order by Longlands > Arcadia > Nomanci > Cartref. Overall, the Calmasil treatments were superior to the other two carriers, with significant responses recorded to the high rate of Calmasil in all soils. As with sorghum, there was a significant cane dry biomass yield increase with increasing rates of Si application on all soil forms except Arcadia, which showed a significant cane dry biomass yield decrease ($P \leq 0.05$). Overall, the response to Si treatment declined in the order: Nomanci > Longlands > Glenrosa > Cartref >>> Arcadia. When Si sources were compared, Calmasil again performed the best, especially in its ability to influence cane canopy development. The means for the Slagment and Wollastonite did not differ significantly; however, they differed significantly ($P<0.001$) from the Calmasil mean (Table 1).

Table 1. Dry matter relative yield (%) per soil form and Si source application levels of sugarcane grown in pots.

Silicon source	Silicon level	Cane dry biomass relative yield (%) by soil form				
		Arcadia	Cartref	Glenrosa	Longlands	Nomanci
Control	0 t/ha	100.0	85.8	52.8	52.3	47.7
Calmasil	3 t/ha	83.6	92.9	85.1	100.0	100.0
	6 t/ha	85.8	85.7	92.7	96.1	84.8
Slagment	3 t/ha	94.3	100.0	77.6	90.4	60.1
	6 t/ha	89.9	90.6	97.6	97.4	99.5
Thompson	3 t/ha	92.0	92.2	100.0	81.8	91.6
	6 t/ha	85.4	72.0	83.5	92.0	93.9
LSD	(P=0.05)	10.6	7.8	21.2	15.4	13.4
Overall Si carrier means	3 t/ha	89.9	95.0	87.5	90.7	87.2
	6 t/ha	87.0	82.8	91.2	95.2	95.5

In this evaluation of Si extractants, soil Si values as extracted by different extractants, after amendment of the soil by different Si sources, were plotted as a function of the Si accumulated in the above-ground part of both the sorghum and the cane crop (Figure 1). The correlations between the total Si taken up by sorghum and cane, and Si extracted from soils by all extraction methods, were all statistically significant ($P\leq 0.05$ to $P\leq 0.001$) with the 0.05 N sulfuric acid (H_2SO_4) extractant showing the best correlation with total Si uptake by sorghum and sugarcane (R^2=0.7188***). However, a comparison of the slopes of the curves representing the different extractants showed that the sulfuric acid and acetic acid procedures were above the 1:1 line, indicating over-estimation of plant available Si, while the slopes of three weak extraction curves were well below the 1:1 line, indicating under-estimation of plant available Si. It is very likely that if the Si uptake of the root systems of the harvested sorghum and cane crops had been incorporated with the Si uptake of the rest of the crop, that the slope of the sulphuric acid methods would have conformed more closely with the 1:1 line, and the slopes of the weak extractant curves would have deviated even further from the 1:1 line.

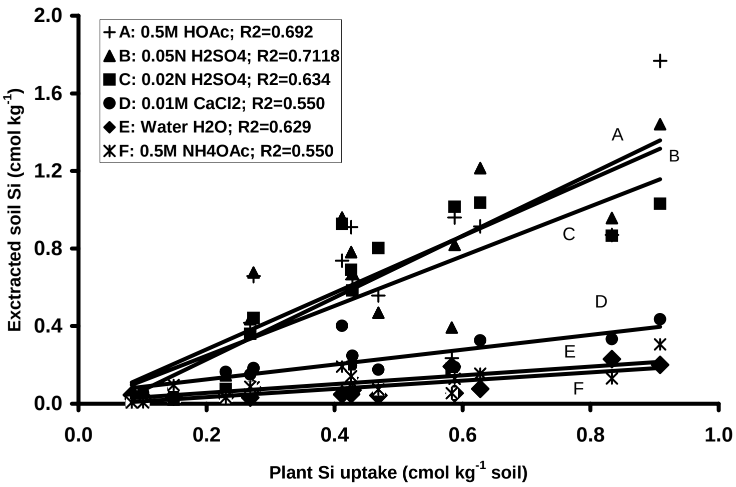

Figure 1. Soil silicon extracted by six different extractants as a function of plant Si uptake.

Conclusions

Of the six Si extractants studied, the 0.05 N sulfuric acid (H_2SO_4) appeared to be the most suitable for predicting the Si uptake of sugar cane and evaluating Si availability in acid soils of the sugar industry. The graphical method of Cate and Nelson (1965, 1971) was used to separate the soil test results into "deficient" and "no deficient" groups and to estimate the critical soil Si level for each soil for the best performing 0.05 N sulfuric acid (H_2SO_4) Si extractant. A response to the application of Si is likely when the soil test level using 0.05 N sulfuric acid is below 0.16 cmol/kg (<45 ppm) for sandy soils (<15% clay), below 0.23 cmol/kg (<65 ppm) for loamy sands to sandy clay loams (15 to 30% clay) and 0.36 cmol/kg (<100 ppm) for clay soils (>30% clay). However, further calibration studies will be needed to validate these interim recommendations.

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