Silicate fertilization in sugarcane: Effects on soluble silicon in soil, uptake and occurrence of stalk borer (*Diatraea saccharalis*)

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Abstract

The objectives were to evaluate yield, Si uptake and stalk borer damage in two cultivars of sugarcane (*Saccharum officinarum*, L.) growing with rates of Si in Brazil. The experiment was set up in Quartzapsament (March, 19 2009) in a completely randomized factorial scheme with four replications. Four Si rates (0, 55, 110 and 165 kg ha^{-1} Si) and two cultivars: IAC 87 3396 (A) and SP 89 1115 (B) were evaluated. The source of silicon was Ca-Mg silicate (262,1 g kg^{-1} Ca; 56,8 g kg^{-1} Mg; 108,4 g kg^{-1} de Si) applied in furrow at planting. All plots received the same Ca and Mg quantities with additions of lime (320g kg^{-1} Ca, 29.5 g kg^{-1} Mg) and/or $MgCl_2$ (11.9% Mg) when necessary. After harvest (July 01, 2009) the best yield was obtained by 103,2 kg ha^{-1} Si (952 kg ha^{-1} silicate) supplied to cultivar B and no differences were observed in cultivar A. There was an increase of soluble Si in 0.5 mol L^{-1}acetic acid and 0.01 mol L^{-1} $CaCl_2$.The Si concentration in leaves were just only different between cultivars (A =3 g kg^{-1}; B =2.18g kg^{-1}). In the stalks, best dry matter and Si uptake were obtained with 89 kg ha^{-1} Si, but no effect was observed on stalk borer damage.

Key Words
Yield, cultivar, nutrition, fertilization, monocots

Introduction

Silicon is the second most abundant element in the Earth´s crust but several soils in humid tropical areas show low silicon contents. Although silicon is not an essential plant element (Epstein, 1999), Si-accumulating plants such as sugarcane could exhibit reduced yields associated with the intensive management and monoculture in these soils (Korndörfer *et al*., 2002). Silicon fertilization has been shown to improve chlorophyll and structure of leaves, reduce lodging, and minimize biotic and abiotic stress (Savant *et al*., 1997), but there is little information in Brazil, the major world sugarcane producer.

Positive results have been obtained with silicon application in many countries, including Brazil (Berthelsen *et al*., 2002; Kingston *et al*., 2005; Elawad *et al*., 1982; Korndörfer *et al*., 2000; Brassioli *et al*., 2009). Most of these results were not exclusive from silicon because the high rates of silicate can improve pH, Ca, and Mg contents (Alcarde, 1992). The silicate fertilization applied in furrow planting could be useful to reduce the cost of this product used in rates similar to lime (>2 or 3 t ha^{-1}) and study the direct effects of Si on sugarcane.

Another beneficial advantage of silicon to sugarcane is the possibility of reducing damage of insects. Studies conducted in pots (Keeping & Meyer, 2006; Kvedaras *et al*., 2005) and field conditions (Meyer & Keeping, 2005) with Si has shown positive effects to control of African stalk borer *Eldana saccharina*. Stalk borer (*Diatraea saccharalis*) is a problem in Brazil controlled by biological methods and/or resistent cultivars. Good characteristics in sugarcane such as low fiber and high sugar are generally related to stalk borer tolerance. An increase of silicon uptake in sugarcane with silicate applications could reduce the damage of 'brazilian' stalk borer as showed by Elawad *et al*. (1982).

Considering the scarce information about silicate fertilization to sugarcane in Brazil, the objectives were to study the relationship between yield, Si uptake, and stalk borer damage in two cultivars of sugarcane (resistant, susceptible to borer), with and without silicon fertilization.

Methods

Site description

The study was conducted in the first crop of sugarcane (March, 19 2008 to July,1 2009) in a commercial area located at Piracicaba, in the south central region of São Paulo state. The chemical analysis of the soil at Quarzapsament (0-25cm) showed : organic matter (g dm^{-3})=17; 0.5 mol L^{-1} Si-acetic acid (AA) and 0.01 mol L^{-1} Si-$CaCl_2$(mg kg^{-1}Si) = 3.3 and 2.4; P anionic resin (mg dm^{-3})=4; K, Ca, Mg, CEC ($mmol_c$ dm^{-3})=0.4; 18; 1; 41.4; Sum of bases = 47 %. The content of clay, loam and sand were 6; 4 and 88 g kg^{-1}.
There were no problems with nematodes in the experimental area (75 x 100 m) and lime, termophosphate, and vinasse were not used in the 3 previous years. During this period the volume rain was 1079 mm and minimal and maximum temperature were: 28.5 and 14.6^o C, respectively.

Experimental design

The experiment was set up in a completely randomized factorial scheme with four silicon rates (0, 55, 110 and 165 kg ha^{-1} Si), two cultivars (IAC 87 3396 and SP 89 1115), and 4 replications. The source of silicon was Ca-Mg silicate containing 262.1 g kg^{-1} Ca; 56.8 g kg^{-1} Mg; 108.4 g kg^{-1} Si. All plots received the same Ca and Mg quantities with additions of dolomitic lime (320g kg^{-1} Ca, 29.5 g kg^{-1} Mg) and/or $MgCl_2$ (11.9% Mg) when necessary. The cultivars were chosen based upon yield potential, precocity, good number of sprouts under sugarcane mulch residue and differences on stalk borer tolerance (*Diatraea saccharalis*): low tolerance (SP 891115; Coopersucar) and intermediate tolerance (IAC 87 3396; Landell *et al*., 1997).

Sampling and data analysis

During sugarcane planting (March, 19 2008), the treatments were applied in furrow and soil was fertilized based upon soil analysis (Spironello *et al*., 1997). Rates of 40 kg ha^{-1} of N, 100 kg ha^{-1} of P_2O_5 and 100 kg ha^{-1} of K_2O (10-25-25) were used at planting . Each plot was 5 rows wide and10 m long. The surface nitrogen (40 kg ha^{-1} N was supplied as ammonium sulphate, 20%N) and potassium fertilization (postash, 60%K_2O) took place 30 days after planting.
Sugarcane was harvested (20 plants per plot) on July 01, 2009 and harvested materials was divided into leaves and stalks. The height and diameter of the stalks and the weight of the dry matter were evaluated. The Si content determination in plant was done as described by Elliot & Snyder (1991). After harvest, soil sampling (0-25; 25-50 cm) was done. The Si concentration in soil was performing with acetic acid (0.5 mol L^{-1}) and $CaCl_2$ (0.01 mol L^{-1}), according Korndörfer *et al*. (1999).The analyses of variance were made applying the F test. The soils were compared by the Tukey test and rates of Si by polynomial regression.

Results and Discussion

The rates of silicate increased soluble silicon in both extractants, in agreement with Korndörfer *et al*., 1999; Korndörfer *et al*., 2000. There was a significant effect on Si content extracted by acetic acid (AA) in samples collected at 0-25 and 25-50 cm (Figure 1). The values were 50% higher with cultivar SP 89 1115. This could be related to the larger volume of its root system. According to Ball-Coelho *et al*. (1992) there are large differences between cultivars in root system, and they provide increase of organic material during the growing period. The calcium chloride (CC) extractant showed no increase in Si concentration in the 0-25cm of soil (Figure 1), and the cultivars did not show any differences. The lower extraction power of CC is related to pH of the solution. The acetic acid has higher extraction due to the low pH (1.0-2.0) necessary to form a molybdosilic complex (Camargo *et al*., 2007).

Both cultivars showed higher sugarcane yield compare to the Sao Paulo state average (85 t ha^{-1}). The cultivar SP 89 1115 showed the highest yield, height, and stalk dry matter. The best yields were obtained by 103,2 kg ha^{-1} Si (952 kg ha^{-1} de silicato) to SP 89 1115 ($Y = -0.001X^2 + 0.2064X + 120.1; R^2 = 0.98^*$ where Y=yield; X=rates of Si; *=$p<0.05$ – data not shown) and no differences in yield due to Si supplementation were observed with cultivar SP 87 3396. Other studies have shown yields responses in sandy soils, but they used higher rates of silicate (2 t ha^{-1}) in broadcast and incorporated applications (Korndörfer *et al*., 2000a, 2002; Brassioli *et al*., 2009). On the other hand, Leite *et al*. (2008) did not observe significant increases in yield due to low rates of Si use (450 kg ha^{-1} of silicate).

The silicon content in leaves was higher than stalks, as expected. The Si concentration on leaves were different between cultivars (SP 891115 =3 g kg^{-1}; IAC 87 3396 =2.18g kg^{-1}). In the stalks, highest dry matter and Si uptake were obtained with 89 kg ha^{-1} Si without differences between cultivars. Unlike some studies (Kvedaras *et al*., 2005; Keeping & Meyer, 2006), there was no significant effect of silicate applied on stalk borer damage despite increases in Si uptake. It is possible that the low level of economic damage to control of stalk borer in field conditions (SP89 1115=4%; SP 87 3396 =2.8%) was responsible for absence of any significant effect due to silicon fertilization.

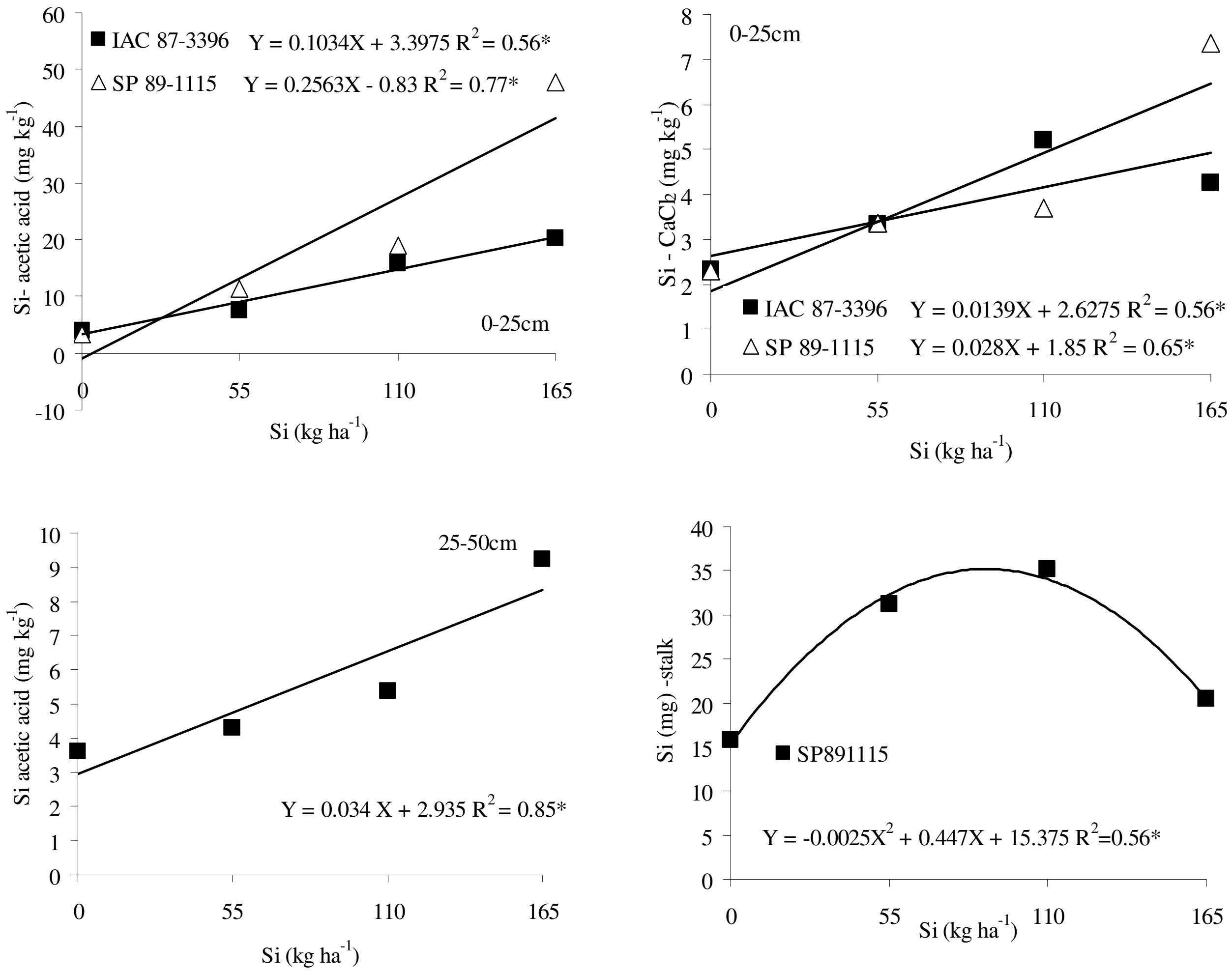

Figure 1. Soluble silicon concentration in 0.5 mol L^{-1} acetic acid and 0.01 mol L^{-1} $CaCl_2$ in soil samples (0-25cm and 25-50 cm) and Si uptake on stalks of two cultivars of sugarcane with rates of Ca-Mg silicate.

Conclusions

Added Si as calcium magnesium silicate increased the amounts of extractable Si in a Quartzapsament soil, as well as increasing the yield and Si uptake in stalks of cultivar SP 89 1115. Rates of 103 kg ha^{-1} Si and 89 kg ha^{-1} Si provided the best yield and absorption of silicon of SP 89 1115, respectively, but it did not promote less stalk borer damage.

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