SILICON ALLEVIATES ALUMINUM TOXICITY IN YOUNG SUGARCANE PLANTS: CHLOROPHYLLS CONTENTS AND FOLIAR GROWTH

SILÍCIO ATENUA TOXICIDADE DO ALUMÍNIO EM PLANTAS JOVENS DE CANA-DE-AÇÚCAR: TEORES DE CLOROFILAS E CRESCIMENTO FOLIAR

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ABSTRACT

Aiming to evaluate if silicon (Si) attenuates aluminum (Al) toxicity in young sugarcane plants, in this work chlorophyll contents and leaf area of two cultivars were verified. The experiment was carried out in hydroponics system under a 2x4x2 factorial layout, with two sugarcane cultivars (CTC9002 and CTC9003), four aluminum sulfate concentrations (0.0; 10.0; 15.0 and 20.0 mg L^{-1}) and two potassium silicate concentrations (0.0; 20.0 mmol L^{-1}). Three evaluations of growth were performed with three replicates, and for chlorophyll determinations were composed by three sub-replicates. Si application improved leaf area, what can be related to the higher chlorophyll a and b contents in plants under Al toxicity. CTC9003 was less sensitive and presented higher responses to Si when compared to cv. CTC9002.

Keywords: *Saccharum* spp.. potassium silicate. aluminum sulfate. leaf area. chlorophyllian pigments.

RESUMO

Com o intuito de verificar se o silício (Si) atenua a toxidez do alumínio (Al) em plantas jovens de duas cultivares de cana-de-açúcar neste trabalho foram estudados a área foliar e o conteúdo dos pigmentos clorofilianos. O experimento foi conduzido em hidroponia e o delineamento experimental foi em esquema fatorial 2x4x2, com duas cultivares (CTC9002 e CTC9003), quatro concentrações de sulfato de alumínio (0,0; 10,0; 15,0 e 20,0 mg L^{-1}) e duas concentrações de silicato de potássio (0,0; 2,0 mmol L^{-1}). Foram realizadas três repetições na avaliação da área foliar e para os teores de clorofilas, as repetições foram em triplicatas. A aplicação de Si melhorou a área foliar, o que pode estar relacionado com os maiores teores de clorofila a e b em plantas sob toxicidade de Al. A cv. CTC9003 foi menos sensível e apresentou respostas mais elevadas ao Si quando comparado a cv. CTC9002

Palavras-chave: *Saccharum* spp., silicato de potássio. sulfato de alumínio. área foliar. pigmentos clorofilianos.

Al stress is one of the main abiotic constraints for crop production [1]. Sugarcane is grown in several tropical and subtropical regions of the world, and is estimated that 50% of the soils used for this crop are affected by Al toxicity [2,3]. In Brazil, where 32% of the soils have toxic levels of Al[4,5] and sugarcane has a high socio-economic importance, the cultivation of this crop has been expanding into Cerrado, a biome known for acid soils with exchangeable Al as the predominant cation [6,7,8]. Soil acidification can be corrected through liming, neutralizing H^+ and Al^{3+} ions; however, as these applied materials usually are low soluble and with limited mobility in soils, neutralizing effects of liming are restricted to superficial layers[9]. The most studied deleterious effect caused by Al in plants is root growth inhibition[10]; yet, there are also reports of lower chlorophyll contents in leaves triggered by Al, negatively affecting photosynthesis and plant growth[11].

Silicon (Si) has been studied for its benefits in improving plant tolerance to abiotic stresses [12,13]. Considering Al stress, Si acts both *ex plant* and *in plant*, complexing with Al and turning it unavailable for absorption or inducting biochemical and physiological changes in plants[9]. Several researches conclude that interaction between Si and Al occur mainly within the plant[14]. *In plant* attenuator effect of Si in plants under Al toxicity has been verified in maize[9,15], rice[14], potato[16], eucalyptus[17] and other species.

There is still a lack of information on the use of Si to attenuate Al toxic effects in sugarcane. Based on the hypothesis that Si improves sugarcane development under Al stress, young plants in hydroponics were grown in different Al concentrations in the presence or absence of Si, to assess if the attenuation effect is related to foliar growth and chlorophylls contents.

The experimental design was a 2x4x2 factorial layout, with two sugarcane cultivars (CTC9002 and CTC9003), four concentrations of aluminum sulfate ($[Al_2(SO_4)_3.18H_2O]$) (0.0; 10.0; 15.0 and 20.0 mg L^{-1}) and two concentrations of potassium silicate (K_2SiO_3Si) (0.0 and 2.0 mmol L^{-1}). For chlorophylls evaluation, three replicates with three sub-replicates. Mini-stems, provided by AZOCANA (Guariba-SP) were sown in 2L pots filled with washed and sterilized sand. Thirty days after sowing, seedlings were exposed for ten days to Clark solution[18]for acclimatization. Then, seedlings were transferred to hydroponics, with plants fixed in polystyrene trays while roots were immersed in nutrient solution with constant aeration. Seedlings were exposed for fifteen days to the following aluminum sulfate concentrations: 0.0; 10.0; 15.0; and 20.0 mg L^{-1}. After this period, Si treatments were applied, adding the two potassium silicate concentrations in the different aluminum solutions. After twenty days under the treatments, leaf area was evaluated with the image analysis system Delta-T Devices LTD with the software Delta-T Image Analysis System. Chlorophyll a and b contents from the +1 leaf were obtained according to Lichtenhaler[19] and Arnon[20], using 0.025 g of leaf tissue. Data were submitted to variance analysis through F test and means were compared by Tukey's test at probability level $\alpha < 0.05$.

The results showed that Si improved leaf area of both sugarcane cultivars (Figures 1A; 1B).

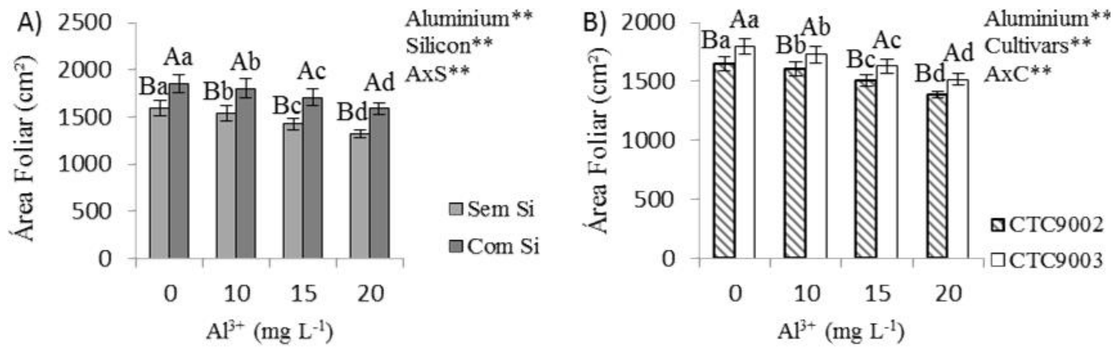

Figure 1. Leaf area of young sugarcane plants from two cultivars under Al^{3+} toxicity, in the presence or absence of Si. (A) Effect of Si on leaf area of both cultivars under Al^{3+}; (B) leaf area within cultivars under Al^{3+} exposure. Values under the same capital letter (at the same Al concentration) and same small letters (within Al concentrations) did not differ from each other by Tukey's test ($p<0.05$).

The significant increase of leaf area in the presence of Si was observed for all Al treatments, with an increase of 17%, 19% and 20%, respectively, for the Al concentrations of 10, 15 and 20 mg L^{-1} (Figure 1A). These results corroborate with other studies[21], where Si applied to salt-stressed maize improved leaf area. It was also verified in not-stressed plants (0.0 mmoL^{-1} Al), leaf area was 15% higher in Si presence. The increase of Al concentrations in the presence of Si nonetheless resulted in lower leaf area, although this decrease was smaller than the observed in plants not treated with Si. Similar results were observed for rice plants under Al and Si treatments [22]. Comparing the cultivars, it was observed that Al deleterious effects were more intense in cv. CTC9002 than CTC9003 (Figure 1B). CTC9003 seems to be more vigorous than CTC9002, as it had higher leaf area in the absence of stress (0.0 mg L^{-1} of Al).

The importance of evaluating chlorophyll a and b contents in young sugarcane plants is based on their significant relationship with crop yield. These pigments are strongly affected by environmental factors as light, water and nutrients, therefore they can be useful indicatives of plant stress(24). In the present study, Al toxicity resulted in lower chlorophyll contents and chlorophyll a/b ratio (Figure 2).

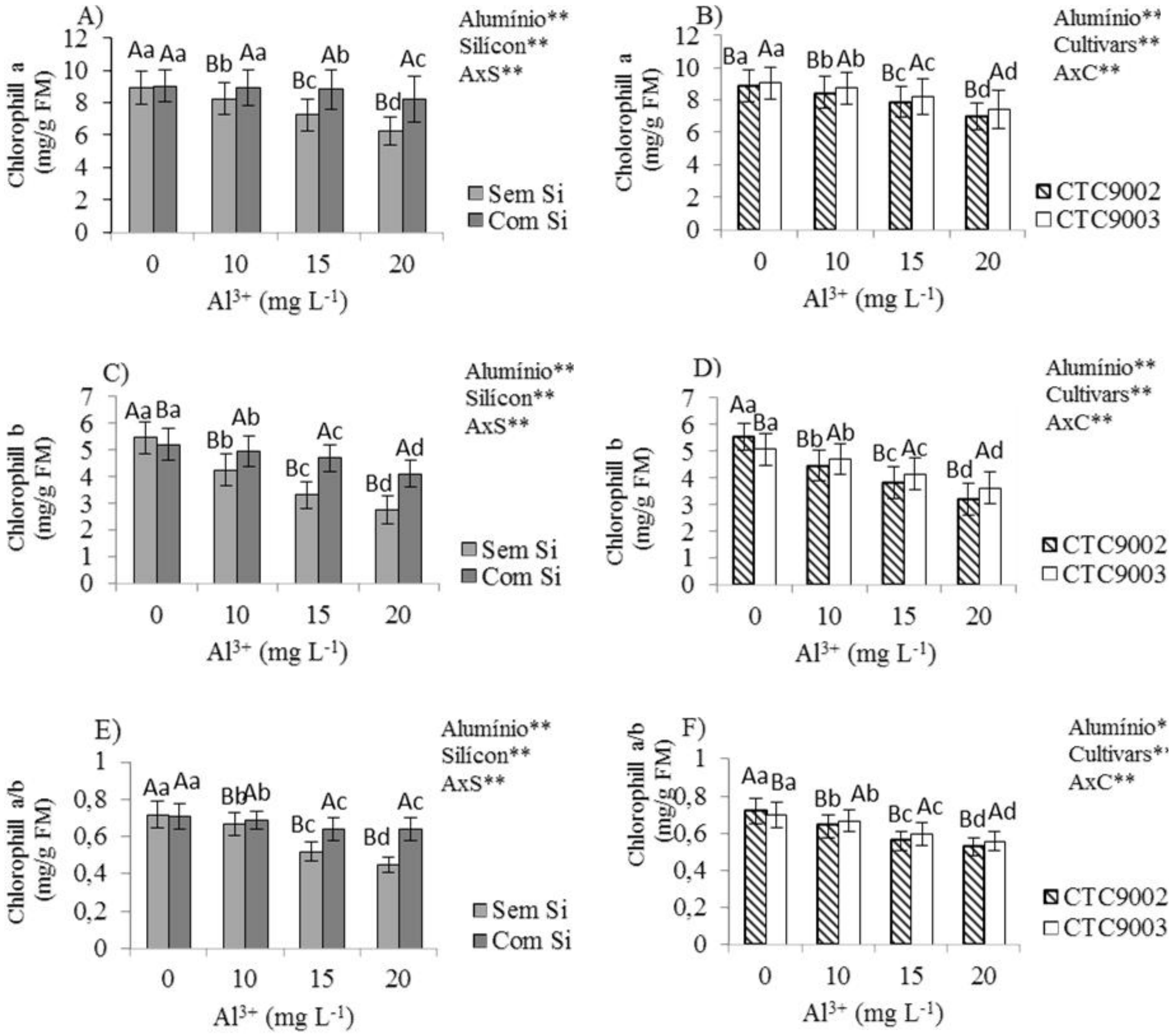

Figure 2. Chlorophyll pigments contents of young sugarcane plants from two cultivars under Al toxicity and Si treatments. Chlorophyll a content (A and B); Chlorophyll b content (C and D); chlorophyll a/b ratio (E and F). Values followed by the same capital letters (within each Al concentration) and small letters (between Al concentrations) did not differ significantly through Tukey's test ($p<0.05$).

This response was also found in young sugarcane plants from cv. IAC91-5155 grown in soil with toxic levels of Al (23). Lower chlorophyll contents due to Al toxicity were reported for several other crops, as soybean, maize and rice (24,25). High levels of this metal inhibit δ-aminolevulinic dehydratase (ALA-D) activity, an enzyme related to porphobilinogen synthesis, a precursor compound of chlorophylls[27]. However, Si presence resulted in lower decreases of these pigments (Figures 2A, 2B and 2C). Thus, at Al concentrations of 10, 15 and 20 mg L^{-1}, Si enhanced chlorophyll a contents in 8%, 21% and 31% (Figure 2A), chlorophyll b levels in 16%, 41% and 49% (Figure 2B) and chlorophyll a/b ratio in 2%, 23% and 42% (Figure 2C). These results suggest that Si might be related to Mg and N contents, the main components of chlorophyll structure, through amelioration of Al toxic effects on these elements absorption and transport. Comparing cultivars, it was observed that toxic Al raised chlorophyll a, chlorophyll b, and a/b ratio of cv. CTC9003, when compared to cv. CTC9002 (Figures 2D, 2E and 2F). However, along with the higher Al concentrations, all pigments parameters were reduced, but this decrease was smaller in cv. CTC9003. The presence of Si inhibited the deleterious effects of Al on chlorophyll contents in cv.CTC9003 in comparison to cv. CTC9002. We conclude that CTC9003 is less sensitive to Al toxicity than cv. CTC9002. Also, these results show that Si alleviates Al toxic effects on sugarcane, as it increases leaf area and chlorophyll contents under stress condition. The cv. CTC9003 has better responses to Si application in comparison to cv. CTC9002, which revealed to be more sensitive to this stress.

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