EFFECTS OF NITROGEN AND SILICON ON WATER USE EFFICIENCY OF SUGARCANE (*Saccharum*spp.)

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ABSTRACT: Silicon (Si) is not considered an essential element for plant growth and development. However, in many agricultural soils, are deficient in plant-available Si, making Si supplementation necessary. We assessed the effect of silicon and nitrogen fertilization on the water use efficiency (WUE) of sugarcane, planted on a soil classified as Typic Hapludox (Eutrophic Red Latosol in Brazil), the plants were grown within 11 L pots in greenhouse at the Department of Biosystems Engineering, ESALQ/USP, Brazil. The experimental design was completely randomized with 4 blocks with 8 treatments in a factorial scheme (2 x 3)+ 2, made up by two levels of nitrogen (N) (0,6 and 0,9 g pot^{-1}) and three levels of Si (5, 10 and 15 g pot^{-1}). The results were submitted to analysis of variance by the Test F and the differences between the treatments were compared by at 5% of significance. Our results indicate that high levels of N combined with Si do not improve the efficiency of water use in sugarcane.

KEYWORDS: ammonium, cement, sugarcane.

EFEITO DO NITROGÊNIO E DO SILÍCIO SOBRE A EFICIÊNCIA DO USO DA ÁGUA EM MUDAS DE CANA-DE-AÇÚCAR (*Saccharum*spp.)

RESUMO: O silício (Si) geralmente não é considerado entre o grupo de elementos essenciais ou funcionais para o crescimento das plantas. No entanto, em muitos solos agrícolas são deficientes em Si disponível para as plantas, tornando necessária a suplementação com Si. Este trabalho teve como objetivo estudar o efeito da adubação com silício e nitrogênio na eficiência de uso da água da cana-de-açúcar, em um solo Latossolo Vermelho Amarelo, fase arenosa, denominado "Série Sertãozinho". As mudas de cana-de-açúcar foram plantadas em vasos de 11 L, em casa de vegetação no Departamento de Engenharia de Biossistemas da Escola Superior de Agricultura "Luiz de Queiroz", em Piracicaba, São Paulo. O delineamento experimental adoptado foi inteiramente casualizado contendo 4 blocos com 8 tratamentos em esquema

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fatorial (2x3)+2, sendo duas doses de nitrogênio (0,6 e 0,9 g vaso^{-1}), três doses de silício (5, 10 e 15, g vaso^{-1}). Os resultados foram submetidos à análise de variância pelo Teste F e as diferenças entre as demandas de água foram comparadas a significância de 5%. Níveis elevados de N combinado com Si não melhora a eficiência do uso da água na cana-de-açúcar.

PALAVRAS-CHAVE: Amônia, cimento, cana-de-açúcar.

INTRODUCTION

Silicon (Si) is generally not considered among the group of essential or functional elements for the growth of plants. However, Si is important in mitigating abiotic and biotic plant stresses; But many agricultural soils are deficient in Si available to plants, necessitating supplementation with Si. However, the uptake of Si by sugarcane (Saccharum spp.) is limited, even when silicate applications improve the status of Si in the soil (BOKHTIAR et al., 2012a; LIANG et al., 2015).

The beneficial effects of Si on different plant species are well documented. Despite the advantages found of this element as a beneficial nutrient in the sugarcane crop, although silicon there is still some discrepancy in relation to its interaction with other leaf nutrients and soil properties as well (SAHEBI et al., 2015& BOKHTIAR et al., 2012).In contrast, lack of documented evidence leads researchers to find the proper role of this element in plants (SAHEBI et al., 2015).

Silicon is absorbed by the plant in the form of monosilicic acid (H4SiO4), together with water (mass flow), and accumulates mainly in the areas of maximum transpiration (trichomes, thorns, etc.) as polymerized silicic acid, which is the ($SiO_2.nH_2O$), which causes a mechanical protection effect against biotic and abiotic stresses (KORNDÖRFER, 2007 &KORNDÖRFER; NOLLA; RAMOS, 2005).

RAMOUTHAR; CALDWELL; MCFARLANE, (2016) found that with an increase in Si content in leaves, under controlled greenhouse conditions, a reduction in the severity of brown rust occurs.

To achieve plant tolerance, Si promotes plant photosynthesis through the favorable exposure of leaves to light. On the other hand, the role of this element has proven to be different in response to abiotic and biotic stress (SAHEBI et al., 2015). The higher the Si content in the plant, the greater the plants ability to tolerate the lack of water in the soil (KORNDÖRFER; PEREIRA; CAMARGO, 2002).

The cane variety influences the silicon application response, therefore it is possible that drought intolerant cultivars, when subjected to water stress, will experience a greater response to silicon (soluble and / or amorphous) to increase resistance to stress compared to cultivars (KVEDARAS et al., 2007).

The objective of this study was to determine the effect of fertilization with silicon and nitrogen on the efficiency of the use of water in sugarcane.

MATERIALS AND METHODS

The data in this study were collected from June 2015 to September 2015in greenhouse at the experimental area of the Department of Biosystems Engineering "Luiz de Queiroz" College of Agriculture/University of São Paulo, Piracicaba, São Paulo State, Brazil (22º42';47º38'W, 540 m elev.). A greenhouse with 6.4m wide by 22.54 m in length and a direct foot of 3.0 m, the ceiling coated with transparent polyethylene with 150 microns thickness, treated against action of ultraviolet rays and anti-aphid screens.

The sugarcane was planted in 11 L pots with soil classified as TypicHapludox (Eutrophic Red Latosol in Brazil), With approximately the following physical and chemical characteristics: 13.5% clay, 8.3% silt and 78.2% sand, bulk density 1.53 kg m^{-3}; pH ($CaCl_2$) = 5.67; P (Resin) = 22.67 mg dm^{-3}; K^+ = 0.87 mmolc dm^{-3}; Ca^{+2} = 23 mmolc dm^{-3}; Mg^{+2} = 12.33 mmolc dm^{-3}; H + Al = 16.67 mmolc dm^{-3}; CTC = 53 mmolc dm^{-3}; V = 68.67%; M.O. = 17.6 g dm^{-3}; Cu = 0.9 mg dm^{-3}; Fe = 18 mg dm^{-3}; Mn = 5.7 mg dm^{-3}; Zn = 1.9 mg dm^{-3}.

Current and historical weather data: temperature (ºC), solar radiation (MJ m^{-2} d^{-1}) and relative humidity (%) in the conduction period of the experiment was collected from a weather station (CR10X; Campbell Scientific, Inc.) installed inside from the experimental site. Irrigation management was performed by tensiometry in order to increase the values of soil water tension to that of field capacity, the measurements were performed daily along of the experiment.

The experimental design was completely randomized with 4 blocks in a factorial scheme (2 x 3)+2, made up by two levels of nitrogen (N) (0.6 and 0.9 g pot^{-1}) and three levels of Si (5, 10 and 15 g pot^{-1}). These levels are considered as 100 and 150% for N and 50, 100 and 150% for Si. The source of silicon and nitrogen was cement (15.7% Si) and urea, respectively

The results were submitted to analysis of variance by the Test F and the differences between the water demands were compared by the Tukey test of significance of 5%. Statistical analyzes were performed using software R.

RESULTS AND DISCUSSION

Daily variation of the mean temperature, solar radiation and relative humidity (%) in the period of conduction of the experiment is presented in figure 1, maximum increase in irrigation depth as well as water tension in the soil was observed between 40 and 60 days after planting , DAP (Figure 2).

Increases in N doses had a positive effect on leaf area (cm^2), the best combination was obtained in the treatment of 150% N and 50% Si (Figure 3). Thus, increases in Si levels had a positive effect only within the 100% N treatment, but with increasing doses of N o Si had a negative effect under leaf area. The maximum increase of dry biomass as well as WUE was observed in the combination of 100% N and 100% N (Figures 4 and 5), however for higher nitrogen levels the silicon effect was negative, thus increasing the dose of the latter the tendency to decrease the observed values of all analyzed variables.

The silicon applied in factorial combinations with nitrogen had a significant effect on the leaf area, with better performance observed at higher levels of nitrogen, of the combination where the highest increase was obtained in 150% N and 50% Si, on the other hand , treatments with lower levels of N had no statistical differences between themselves (Figure 6). In contrast, GAO et al. (2005) did not have a significant effect on the addition of silicon under dry weight of the corn plant.

In the case of the silicon effect interaction with the nitrogen under biomass (Figure 7), as in the leaf area, it had better performance in the higher levels of nitrogen, but a better dose was one that combined in equal amounts of silicon and nitrogen i.e., 100 % N and 100% Si.

The differentiated effect of silicon under leaf area and biomass according to AMIN et al., (2014), the different concentrations of Si exogenously increased plant growth and morphological attributes, but high applied silicon levels are statistically significant too effective in the production of plant dry matter. They agreed with CAMARGO; KORNDÖRFER; WYLER, (2014), who recommend low-rate silicate applications (<200kg ha^{-1} Si) as an alternative method for nutritional management for sugarcane production.

Finally, silicon had a positive effect under the WUE (Figure 8), with a combination, as in biomass, the dose that combines the nitrogen and silicon levels in equal proportion. According to GAO et al., (2005) compared to the treatment without Si, the addition of Si significantly increased the WUE of corn plants and the degree of increase was more significant when the plants underwent water stress.

However, it is necessary to consider the presence of Si in the form of cement, which results in an increase in the production of Si (KORNDÖRFER GH et al., 2000). In all cases, the factorial combination that contains the highest dosage of both nitrogen and silicon, did not present the best performance. This could be explained according to KEEPING et al., (2015), whom consider that the combination of silicon and NH_4+, affects the pH of the soil, obtained the highest rates of absorption of Si, under lower pH, as well as Silicon source may have a pH-increasing effect.

Although DE OLIVEIRA et al. (2016) found negative effects of silicon on the profiling and on the number of panicles in rice plants, possibly due to the higher absorption of silicon and lower absorption of phosphorus and nitrogen, favored by chemical similarity (460 and 490 mg dm^{-3} Si), there may have been higher absorption of silicon and less absorption of these two elements, which are essential for lamination and panicle formation. This subject is worthy of further study at the soil chemistry level.

CONCLUSION

Sugarcane responded to silicon applied in factorial combinations with nitrogen, being more significant for leaf area than for biomass and WUE. The best combination was composed of 0.6 g pot^{-1} of N and 10 g pot^{-1} of Si.

In high nitrogen applications (0.9 g pot^{-1}) as urea, increases in silicon levels had a negative effect on biomass and WUE.

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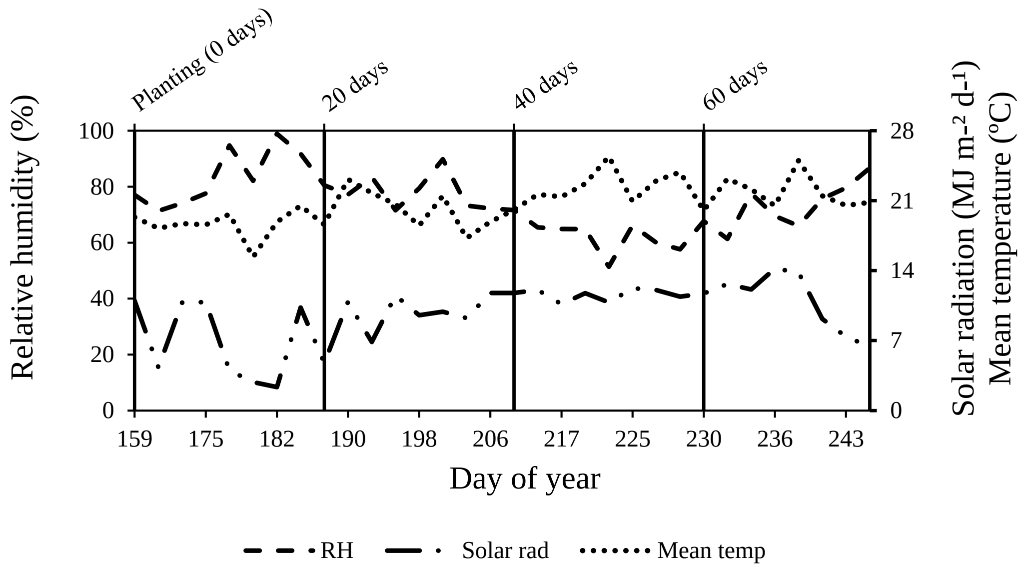

Figure 1. Daily variation of the mean temperature (ºC), solar radiation (MJ m^{-2} d^{-1}) and relative humidity (%) in the conduction period of the experiment.

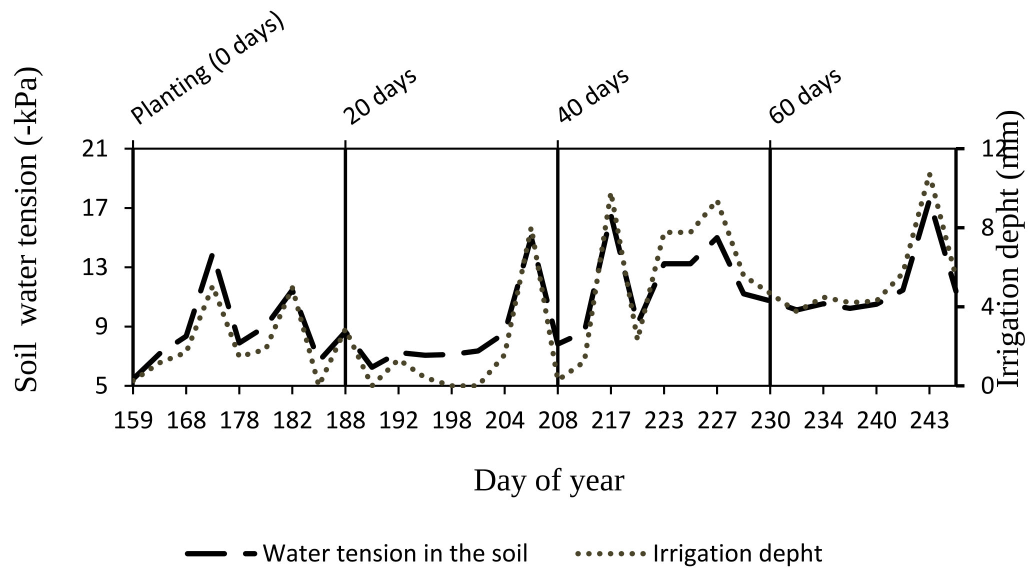

Figure 2. Irrigation depht applied (mm) and soil water tension in the soil (KPa) in the period of conduction of the experiment.

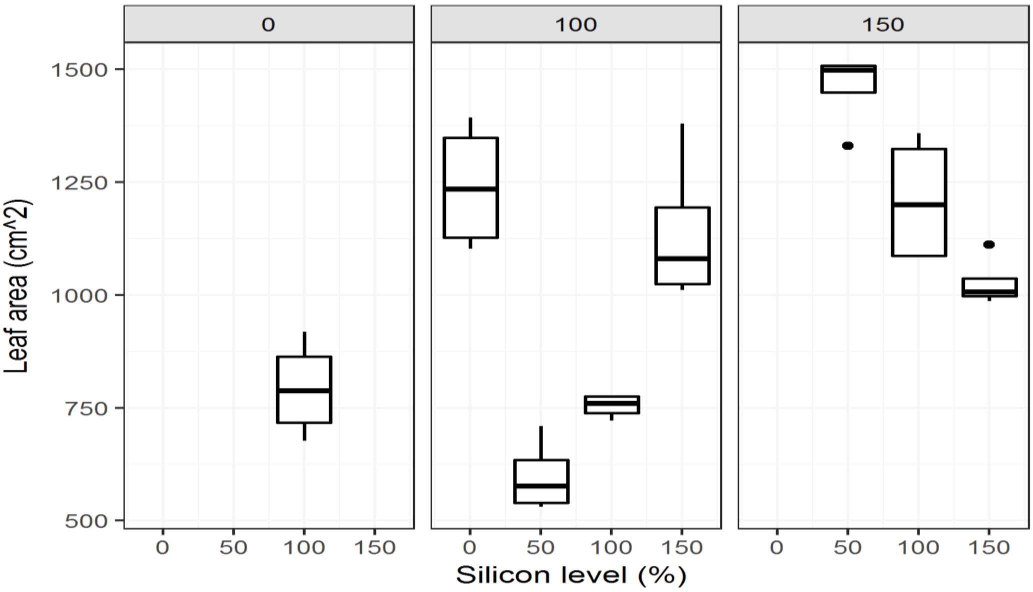

Figure 3. Effects of four silicon level (%) under leaf area (cm^2) the sugarcane. Grey label are nitrogen level. Horizontal lines represent the median for each leaf area, the boxes represent data from the 25th to the 75th percentile, and the dots are data points beyond this boundary. Significance is $p < 0.05$.

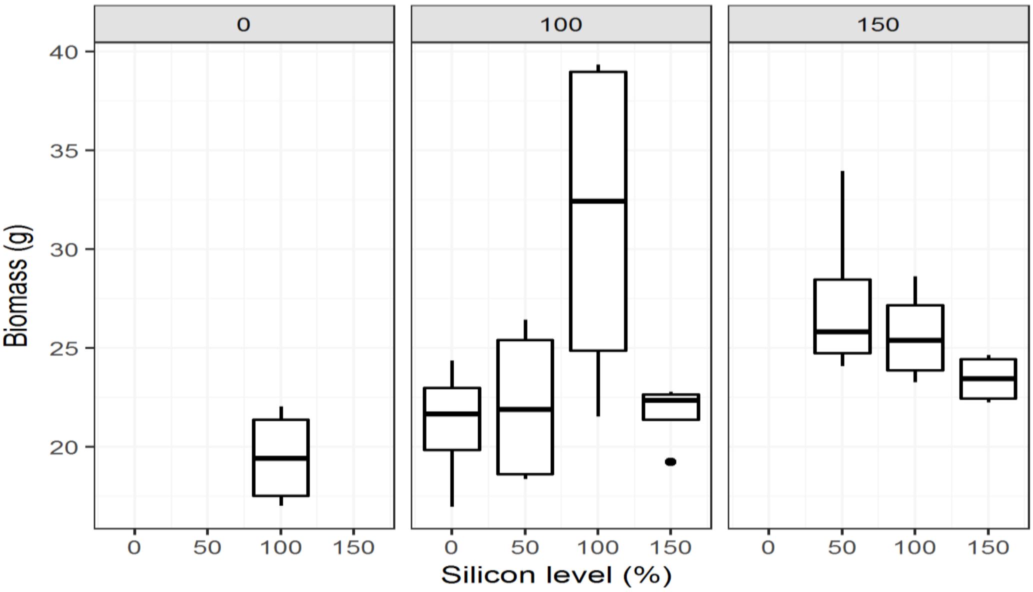

Figure 4. Effects of four silicon level (%) under dry biomass (g) the sugarcane. Grey label are nitrogen level. Horizontal lines represent the median for each leaf area, the boxes represent data from the 25th to the 75th percentile, and the dots are data points beyond this boundary. Significance is $p < 0.05$.

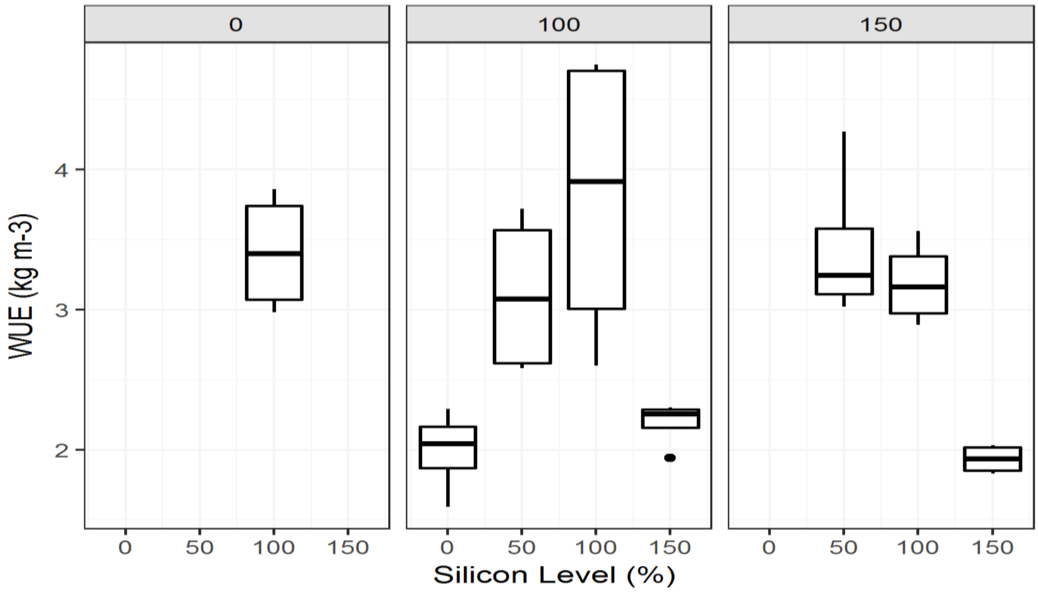

Figure 5. Effects of four silicon level (%) under WUE (kg m^{-3}) the sugarcane. Grey label are nitrogen level. Horizontal lines represent the median for each leaf area, the boxes represent data from the 25th to the 75th percentile, and the dots are data points beyond this boundary. Significance is p <0.05.

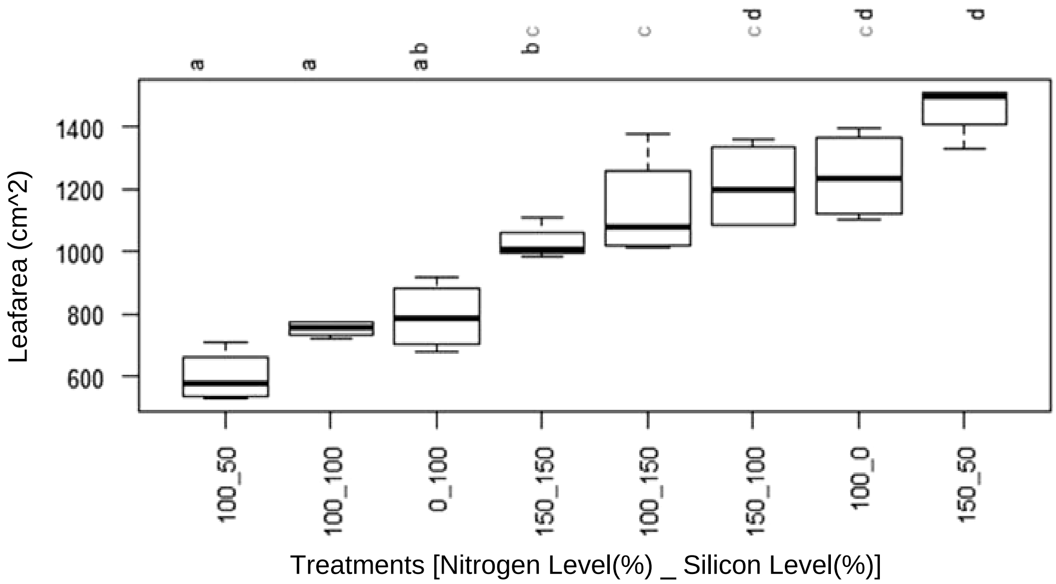

Figure 6. Effects of the combinations of nitrogen and silicon levels (%) under leaf area (cm^2) for sugarcane, the presence of the same letter in the upper indicates a lack of significant difference by Tukey test , p <0.05.

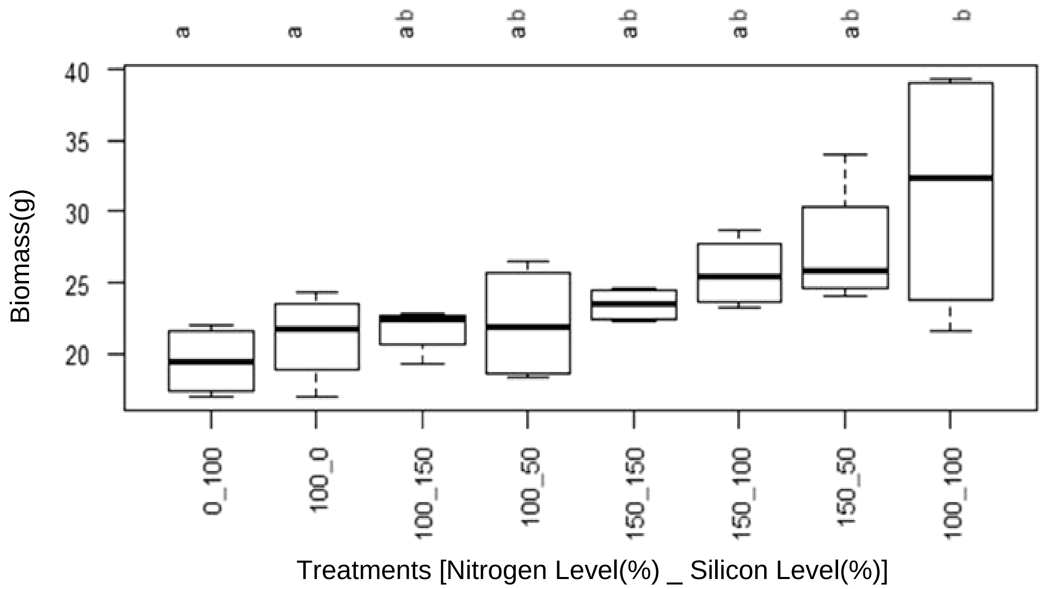

Figure 7. Effects of the combinations of nitrogen and silicon levels (%) under biomass (g) for sugarcane, the presence of the same letter in the upper indicates a lack of significant difference by Tukey test , p <0.05.

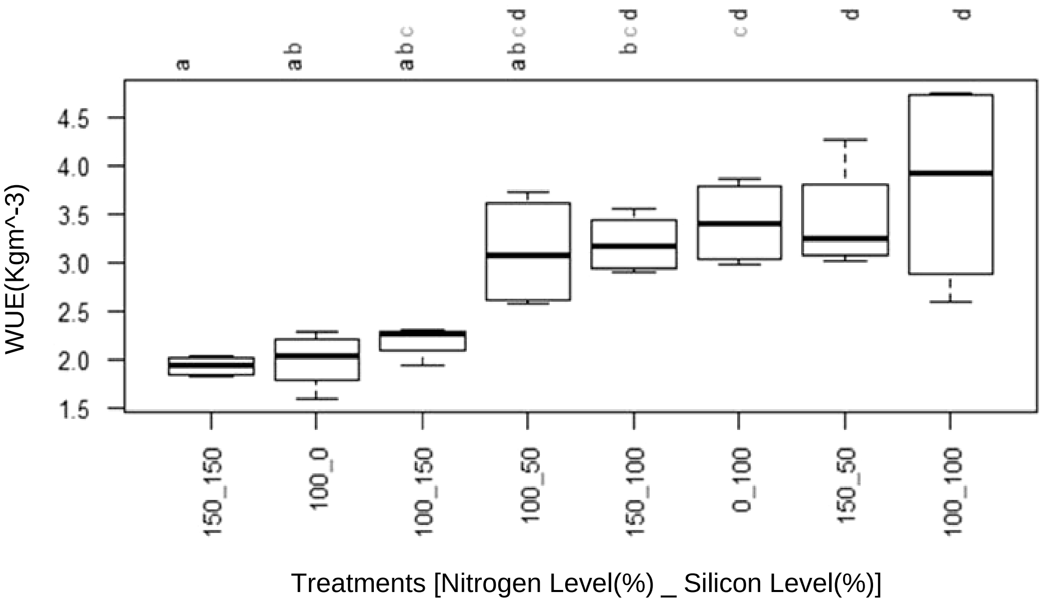

Figure 8. Effects of the combinations of nitrogen and silicon levels (%) under Water-use efficiency (WUE) by sugarcane (kg m^{-3}), the presence of the same letter in the upper indicates a lack of significant difference by Tukey test , p <0.05.