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Micronutrients application on cultivation of sugarcane billets

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The production of sugarcane is constantly growing in Brazil, and by the 2016/2017 season, it is estimated to have reached 691 million tons. However, productivity has not shown significant increase, this is due largely to inadequate nutritional supplementation of sugarcane plantations, especially the micronutrients. The aim of this study was to evaluate the effect of micronutrients application on the billets and quality of sugarcane in the groove of sugarcane plantation. The experiment was carried out in randomized blocks of six treatments, with application of micronutrients sources in the planting furrow, with 4 repetitions. Number of stems, leaf nutrient content, sugarcane yield and total recoverable sugar (ATR) of sugarcane were evaluated. The use of micronutrients Cu, Mn and Zn chelated associated with sources of K_2O, B and Mo promoted increased productivity of billets (TCH) 10 and 15% with doses of 1.0 and 1.5 L ha^{-1} complex nutrient respectively. The exclusive application of Boric Acid and Zinc Sulphate in dosages of 2.03 kg ha^{-1} did not increase the productivity of sugarcane. Nutrient sources applied on billets did not result in increases in technological quality of sugarcane, assessed by ATR.

Key words: *Saccharum* spp, boron, copper, zinc, manganese, molybdenum, fertilization, soil fertility.

INTRODUCTION

The sugarcane industry is of great economic, social and strategic importance to Brazil, and the world at large due to the sustainable use of biomass energy (Agrianual, 2015). Projection for the crop production in Brazil in 2016/2017 was around 30 billion liters, slightly lower than production in the previous harvest, because of climatic factors and nutrition of sugarcane plantations. Domestic consumption for 2018 is projected at 30.3 billion liters and exports at 11.3 billion (Agrianual, 2015). There are many agronomic techniques used in the production of sugarcane, such as the choice of suitable varieties of the soil and climate, conservation and chemical correction of soil, pests and weeds control, etc. The search for the most appropriate fertilizer, as well as the most balanced fertilization for the purpose of maximum productivity is on constant increase. The fertilization of sugarcane should

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be performed with the application of macro and micronutrients needed to trigger the physiological processes of plants, which determine the final crop yield. The micronutrients perform vital functions in plant metabolism or as part of compounds responsible for metabolic and/or physiological processes as enzyme activators (Malavolta et al., 1974; Epstein, 1975). Although most of the work carried out in the Center-South of Brazil did not show responses of sugarcane to the application of micronutrients (Alvarez and Wutke, 1963; Espironelo 1972, Alvarez et al., 1979; Siqueira et al., 1979 and Azeredo and Bolsanello, 1981) in some studies in São Paulo, there was a significant effect on production of stems in a Oxisol Dark, sandy phase, with the application of Cu and Zn in the form of chelates (Alvarez, 1984) and a Yellow Red Latosol, sandy phase, with the application of Zn (Cambria et al., 1989). In the country's northeast region, symptoms of micronutrient deficiencies have been common, with responses to the application of Cu and Zn (Marinhoe Albuquerque, 1981). Regarding boron, Alvarez and Wutke (1963) studied the application of various micronutrients to sugarcane, planted in Argisol Red Yellow and Purple Latosol, and getting positive reaction of boron on the first floor. According Orlando Filho et al., (2001), sugarcane often presents the phenomenon of "hidden hunger" in relation to micronutrients, this means when there is deficiency which economically limits productivity, but the plant has no visible symptoms. Several factors influence the absorption of micronutrients by sugarcane, the main soil type, crop variety, and plant age (Orlando Filho et al., 1983). The export of micronutrients by sugarcane is given in the following order: iron (Fe) > manganese (Mn) > zinc (Zn) > copper (Cu) > boron (B) > molybdenum (Mo). In this context, the objective was to evaluate the effect of application of different sources of micronutrients in productivity and quality of sugarcane.

MATERIALS AND METHODS

The experiment was conducted in the municipality of Rafard-SP (23° 00 '43 "S, 47° 31' 37" O) in Retiro site in an area cultivated with the crop of sugarcane variety SP 83-2847. Before the experiment was setup, soil sampling was performed at 0 to 20 and 20 to 40 cm, removing 15 sub-samples for each of the two composite samples for the purpose of characterization (physical and chemical parameters) of the second experimental area recommendations (Raij and Cantarella, 1997), (Table 1). The experimental area received of N, P and K_2O, respectively. The area application of 1 t ha^{-1} of limestone, two months before the experiment and 500 kg ha-1 of magnesium thermophosphate without micronutrients in total area. Fertilization was carried out at planting with the application of 40, 100 and 100 kg ha^{-1} received the application of 300 g ha^{-1} Regent® (Fipronil) and 6.5 L ha^{-1} Furadan® (Carbofuran) in the planting furrow at the time of mating of the seedlings. The experimental design was randomized blocks with 6 treatments and 4 replications, totaling 24 experimental units. Each experimental unit consisted of 14 lines of 10 m with 1.4 m line spacing, totaling 196 m^2. The treatments consisted of application of micronutrients on billets at planting of sugarcane. Treatments applied in the planting furrow were 1.0 L ha^{-1} Wuxal Semillion® (T1); 1.5 L ha^{-1} Wuxal Semillion® (T2); 2 L ha^{-1} Wuxal Semillion® (T3); 1 L ha^{-1} Wuxal Semillion® + 600 g ha^{-1} of Zn (zinc sulfate) + 350 g ha^{-1} B (boric acid) (T4); 600 g ha^{-1} of Zn (zinc sulfate) + 350 g ha^{-1} B (boric acid) (T5) and control treatment (T6). The guarantee of complex micronutrient applied in the treatments. The guarantee of complex micronutrient applied in the treatments were: Wuxal Semilon®: K_2O: 150 g L^{-1}; 39 g L^{-1}; B: 15 g L^{-1}; Cu: 7.5 g L^{-1}; Mn: 15 g L^{-1}; Mo: 22.5 g L^{-1}; Zn: 22.5 g L^{-1}; Wuxal Polimicro®: B: 25 g L^{-1}; Mn: 25 g L^{-1}; Mo: 25 g L^{-1}; Zn: 49 g L^{-1}; S: 15 g L^{-1}. The number of stems in two meters in the three main lines of the experiment at 120 days after the beginning of the experiment was determined. The harvest of stalk was performed at 10 meters from the centerlines of each experimental unit, so that each of the ends of the lines was discarded. The stems were weighed using truck transshipment fitted with load cell. Prior to harvest, 10 culms were randomly retired, tied identified and then sent to the plant laboratory to determine the technological parameters. The results were submitted to analysis of variance (ANOVA) using the F test at 5% probability. When there was significance in ANOVA was made average comparison test by Tukey test (p = 0.05 and 0.10) using the statistical program SAS (2002).

RESULTS AND DISCUSSION

The number of culms was not affected by the application of micronutrient sources on the sugarcane stalks (Table 2). The number of culms is a biometric variable that mostly affects the productivity of sugarcane. Many studies which evaluate fertilization with macronutrients, especially nitrogen; show high correlation between number of stems, and yield of sugarcane (Vale et al., 2012). It is noteworthy that the average number of stems found in this study (11.9 tillers per meter) is adequate and sufficient to ensure high productivity (Weber et al., 2001).Different letters differ according to Tukey's test at 5% probability. T1: 1.0 L ha^{-1} Wuxal Semillion®; T2: 1.5 L ha^{-1} Wuxal Semillion®); T3: 2 L ha^{-1} Wuxal Semillion®; T4: 1 L ha^{-1} Wuxal Semillion® + 600 g ha^{-1} Zn (zinc sulfate) + 350 g ha^{-1} B (boric acid); T5: 600 g ha^{-1} of Zn (zinc sulfate) + 350 g ha^{-1} B (boric acid) and T6: Treatment control. The nutrient content in leaf +1 sugar cane, except manganese, showed no effect of the application of micronutrient sources on the billets (Table 3).

Different letters in the same column differ according to Tukey's test at 5% probability. T1: 1.0 L ha^{-1} Wuxal Semillion®; T2: 1.5 L ha^{-1} Wuxal Semillion®); T3: 2 L ha^{-1} Wuxal Semillion®; T4: 1 L ha^{-1} Wuxal Semillion® + 600 g ha^{-1} Zn (zinc sulfate) + 350 g ha^{-1} B (boric acid); T5: 600 g ha^{-1} of Zn (zinc sulfate) + 350 g ha^{-1} B (boric acid) and T6: Treatment control.Although there was no effect of the application of micronutrients in the planting furrow in the leaf content of these essential elements, the importance of nutrition culture, such as borate ion like complex sugars, should be noted, indicating the

Table 1. Chemical and physical properties of the soil before the experiment.

Depth	MO	pH	P	S	K	H	Mg	Al	H	H + Al	SB	CTC	V
cm	gdm $^{-3}$	$CaCl_2$	mg dm $^{-3}$				mmol dm $^{-3}$						%
0-20	10	4.4	10	32	1.1	13	3	5	21.9	27	17.3	44.2	39
20-40	9	4.4	7	30	0.5	7	2	6	22.0	28	9.7	37.7	26
Depth	B	Cu	Fe	Mn	Zn					Clay	Silt	Sand	-
cm		mg dm $^{-3}$									g kg $^{-1}$		-
0-20	0.13	0.3	64	6.0	0.5					146	124	731	-
20-40	0.10	0.3	37	2.6	0.4					133	144	724	-

Table 2. Average number of stems per meter depending on the application of micronutrient sources in the planting furrow.

Treatment	Number of culms
1	12.6
2	12.1
3	11.6
4	11.6
5	11.7
6	12.1
DMS	1.8
CV (%)	9.0

Table 3. Macro Foliar and sugarcane micronutrients due to the application of micronutrient sources in the planting furrow.

Treatments	N	P	K	Ca	Mg	S	B	Zn	Mn	Fe	Cu
			g kg $^{-1}$						mg kg $^{-1}$		
T1	17.1	0.9	5.8	2.8	1.3	2.2	6.3	15.8	40.0 ^{b}	110.6	5.8
T2	17.4	0.9	6.2	2.8	1.5	1.9	6.9	13.4	43.8 ^{b}	118.1	5.1
T3	16.7	0.8	6.4	2.6	1.3	2.2	7.1	14.6	48.8 ^{ab}	117.5	5.4
T4	17.7	0.8	6.0	3.0	1.7	1.6	7.3	14.9	50.6 ^{a}	116.9	5.9
T5	17.3	0.9	6.0	2.8	1.4	1.7	6.7	14.7	50.0 ^{a}	122.5	5.7
T6	18.2	0.9	5.2	3.2	1.6	1.7	7.5	14.4	47.5 ^{ab}	118.1	5.4
DMS	1.55	0.11	1.32	0.69	0.32	0.50	1.06	2.72	11.4	12.99	1.70
CV (%)	5.5	7.9	13.9	15.2	13.9	16.9	9.6	11.7	15.4	6.9	14.4

likelihood of their participation in the transport of carbohydrates from the leaves toother organs, a fact important in the culture of sugarcane (Orlando Filho et al., 2001). Furthermore, it is suggested that boron acts in the division, cell maturation and differentiation, lignification of cell walls and inhibition of starch formation by boron combination with the active site of phosphorylase, which prevents excessive polymerization of sugars in their local synthesis (Sobral and Weber, 1983). Copper is one of the most important micronutrients for sugarcane, acting as an activator of several enzymes, such as the fenolase, laccase, polifenoxolidase, etc. It also operates in the process of photosynthesis, presenting important role in electron transport via plastocyanin (Taiz and Zeiger, 2004). Manganese plays important role, participating in various reactions of the Krebs cycle, in protein synthesis, cell proliferation, photosynthesis and enzyme activation of

Table 4. Average cane yield (TCH), total recoverable sugars (ATR) due to the application of micronutrient sources in the planting furrow.

Treatment	Productivity (t ha^{-1})	ATR (kg.t^{-1})	Relative Yield (%)
1	150.9^{a}	146.4	110.6
2	156.9^{a}	149.7	115.0
3	147.7^{b}	144.9	108.3
4	146.8^{b}	143.4	107.6
5	147.8^{b}	142.9	108.4
6	136.4^{b}	146.9	100.0
Average	147.8	145.7	
DMS	13.2	6.9	
CV (%)	12.0	5.8	

sugarcane (Sobral and Weber, 1983). Molybdenum has a direct effect on nitrogenase enzymes and nitrate reductase, which makes proper nutrition with this important micronutrient for the occurrence of biological nitrogen fixation by sugarcane and assimilation of NO_3 in organic compounds (Sobral and Weber, 1983; Orlando Filho et al., 2001). Zinc directly affects the growth of sugarcane plants, since the nutrient is essential for the synthesis of tryptophan which is a precursor of indole acetic acid (IAA), which will form the enzymes responsible for cell growth and elongation. This micronutrient is also involved in the activation of various enzymes (Sobral and Weber, 1983; Orlando Filho et al., 2001; Taiz and Zeiger, 2004). The differences between the observed levels and the ones reported in the literature can be justified due to the sampling time, and was considered sampling at 4 months after planting while according to Raij and Cantarella (1997), sampling refer to full development of culture, which occurs after 4 months of sprouting and also to other factors, such as cultivars soil and climatic conditions, different productivities and the dilution effect portrayed by Jarrell and Beverly (1981), where the concentration of nutrients is diluted with the greatest growth plant. Gomez Alvarez (1974), adds that the concentration of nutrients in the leaves of sugarcane is affected by the age of the culture, climate variations (especially cloudiness) and even the time of day, which indicates as ideal from 6 to 8 h in the morning. Thus, it appears that several factors can influence the nutrient content, thus explaining the differences between the levels found and the ones recorded in the literature. The sugarcane yield had the effect of the application of micronutrients on bill at planting (Table 4). However the levels of total recoverable sugars (ATR) do not have this management (Table 4). Applying Wuxal Semillion at a dose of 1.0 and 1.5 L ha^{-1}, provided yields of 10 and 15% higher respectively compared to the control (Table 4). Studies evaluating the effect of the application of micronutrients in sugarcane began in the 60s, where Alvarez and Wutke (1963) found positive responses in Argisol for isolated applications B, Mo, Fe and Cu which increased production of sugarcane in 21.6; 12.1; 1.6 and 8.3 t ha^{-1} respectively. Alvarez (1984) observed an increase in the production of stems in Rhodic, sandy texture, with the application of copper and zinc in the form of chelates. Azeredo and Bolsanello (1981), had increases of 30% in productivity of sugar cane plant with the use of 5 kg ha-1 of Mn in the groove or spraying with a solution containing 5 g L^{-1} of micronutrient. Different letters in the same column differ according to Tukey's test at 5% probability. T1: 1.0 L ha^{-1} Wuxal Semillion®; T2: 1.5 L ha^{-1} Wuxal Semillion®); T3: 2 L ha^{-1} Wuxal Semillion®; T4: 1 L ha^{-1} Wuxal Semillion® + 600 g ha^{-1} Zn (zinc sulfate) + 350 g ha^{-1} B (boric acid); T5: 600 g ha^{-1} of Zn (zinc sulfate) + 350 g ha^{-1} B (boric acid) and T6: Treatment control. Regarding the application of B and Zn, Franco et al. (2011), found that the application of 2 and 4 kg ha^{-1} of B in planting caused a rise in the production of stem in plant cane. But the authors found that the Zn did not promote increased productivity in plant cane, but increased productivity (14 t ha^{-1} in the control) and the ATR of ratoon. Malavolta (1990), with two foliar applications of 0.175 kg ha^{-1} (of B could increase the order of 18% in the productivity of sugarcane. Mellis et al., 2008), evaluated the response of plant cane for Cu, Zn, Mn and Mo in eight major producing regions of sugarcane states of Sao Paulo and found significant responses for Zn, Mn, Mo and Cu, checking 18% increase in the production of stems and the highest responses were obtained to Zn and Mo. Significant responses were observed in these ratoon stalk production due to the application of Zn, Cu, Mn and Mo. These results demonstrate that the application of micronutrients in the planting furrow may be the most viable way to manage micronutrients in the culture of sugarcane (Mellis et al., 2010).

Conclusions

The use of the micronutrient source of Cu, Mn and Zn chelate associated with sources of K2O, B and Mo increased the productivity of stems (TCH) 10 and 15% when applied at doses of 1.0 and 1.5 L ha^{-1} respectively. The exclusive application of Boric Acid and Zinc Sulphate in dosages of 2:03 kg ha^{-1} did not result in increased sugarcane productivity. Micronutrient sources applied on the stems did not result in significant increases in the content of total recoverable sugars from sugarcane.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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