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Full Length Research Paper

Cropping systems evaluation, fertilization, and effects on technological quality and sugarcane productivity

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The scarification has been used in soil descompaction and when combined with fertilizer and harrowing has been called triple operation, which together can change the quality and increase the productivity of sugarcane. In this study we evaluated the influence two cropping systems in ratoon, associated with different forms of fertilization on the technological quality and productivity of sugarcane. The design was randomized blocks, with split plots, with four replications. In the main plots we evaluated two treatments: C/HE=with chisel plow; S/HE=without chisel plow. The subplots were tested for fertilization treatments: M=mineral fertilization; T=M+filter cake; H=M+humic extract; M+T+H. We evaluated the technological analysis and the production of sugarcane. It was observed that the use of the chisel during the period of the 2nd and 3rd ratoon did not cause changes in technological variables and sugarcane productivity. The fertilizers used did not provided increases in the number of stems per meter nor the productivity of sugarcane stems. The values obtained for brix degree of syrup, apparent sucrose, broth purity, fiber, reducing sugars and total reducing sugars were above minimum values defined by the standard the cane quality in all the treatments, but did not increase the number of stems and crop productivity.

Key words: Triple cultivation, scarification, organic fertilization, filter cake.

INTRODUCTION

Current techniques of management of sugarcane culture are based on soil plowing during the preparation and planting, which added to the harvest and the

transshipment production system, have high potential for compression because the traffic is repeated during the crop cycles under different humidity conditions, thereby

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altering the physical, chemical and soil organic matter (Materechera, 2009; Oliveira et al., 2014).

Sugarcane is one of the crops that is most affected by soil compaction, because its root system is formed by rhizomes and fasciculated roots, of which 85% are in the layer 50 cm deep, and 60% in the layer 20-30 cm deep (Oliveira Filho et al., 2015). This compaction creates a less favorable environment for the development of the root system of cane (Otto et al., 2011; Kingwell and Fuchsbichler, 2011).

The subsoiling has been used to break through layers of soil in those agricultural areas that have suffered compaction (Gorucu et al., 2006), however before the new planting plants use scarification between the lines of ratoon cane, which associated with fertilizer and harrowing, it has been called triple cultivation (Camilotti et al., 2005).

These three post-harvest operations have been simultaneously conducted with the purposes of decompression, chemical fertilization and weeds control (Paulino et al., 2004), besides reducing operating costs. Souza et al. (2014) noted that soil scarification enables better development of the roots of sugarcane in depth, causing it to remain stable in dry periods. Plant responses to soil compaction are measures by changes in the development and functioning of roots, which can affect productivity and product quality (Alameda et al., 2012).

With the expansion of sugar-alcohol market and the incorporation of new areas of Savanna to the production process, studies have been conducted with the aim of improving the potential of the varieties making them more productive, what can be obtained through the use of new management techniques and monitoring the nutritional requirements of the plants to achieve economically viable production in these regions (Flores et al., 2012).

Currently, the focus is on the huge amounts of organic waste produced in the sugar cane industry. Among them, there is the filter cake which is a residue coming from the crushed bagasse mixture and decantation sludge, from the sugar clarification process. It is an organic compound rich in calcium, phosphorus, nitrogen and potassium, which generates a volume ranging from 30 to 40 kg per ton of cane crushed, with a variable composition depending on the variety of sugarcane and maturation (Santos et al., 2010). However, it can be noted that phosphorus is the predominant element (Almeida Júnior et al., 2011) because the deficiency of this element results in significant decrease in sucrose accumulation, since the phosphate fertilizer directly affects the amount of sugar and juice purity (Elamin et al., 2007). Rossetto et al. (2008) noted that the filter cake plays key role in agricultural production, fertility and as a soil conditioner.

Another option to increase the absorption of water and nutrients by sugarcane is to stimulate root development and, consequently, the agronomic performance of the

plants. Some mills have been using products based on humic-fulvic substances, however, studies about its efficiency in soil and plant are still scarce.

Evaluating the application of humic substances in soil and their influence on technological quality varieties of sugarcane, Rosato et al. (2010) found that these humic substances at a dose of 20 t ha⁻¹ gave positive effect on the accumulation of sucrose in most varieties. Santos et al. (2010) evaluated the vegetative growth and productivity of sugarcane, depending on fertilization with filter cake enriched with soluble phosphate. They found that pie application at planting, promoted an increase in sugarcane stalks and tillering.

Technological variables of sugarcane are important for the industry and for suppliers, which are paid by the quality of the sugarcane produced, which is directly influenced by the fertilizer used in the area (Vischi Filho, 2014). The quality of this raw material can be measured by means of some variables, among them the total solids content in the syrup, sugarcane apparent sucrose, fiber and syrup purity (Larrahondo et al., 2009).

Due to the importance of the sugarcane culture in the country and its expansion in Savanna where medium textured soils and low fertility dominate, besides the need to generate techniques aimed at sustainability management system, this study has been developed aiming to evaluate the influence of two cropping systems in ratoon, associated with different forms of fertilization on the technological quality and productivity of sugarcane.

MATERIALS AND METHODS

The study was conducted at the 'Farm Freedom', in an area of Alcoolvale plant in the city of Aparecida do Taboado-Brazil, which covers an area of 2.750.130 km², representing 0.77% of the state, located between the geographical coordinates 51°13' west longitude and 20°13' south latitude, average altitude of 392 m. The area was planted to pasture (*Urochloa decumbens*) for 35 years and since 2004 sugarcane has been cultivated. Treatments were installed shortly after the mechanical harvesting of sugarcane in November 2006 (2nd ratoon) and 2007 (3rd ratoon), where sugarcane variety RB 867515 was cultivated.

The climate is classified as AW, tropical humid according to the International Classification of Köppen, with rainy season in summer and dry season in winter. Average rainfall is around 1.595 mm (Abranches and Bolonhesi, 2011).

The soil of the experimental area was classified as Oxisol, medium texture, highly weathered, deep and well drained (Embrapa, 2006), which features in the layer of 0.0 to 0.20 m: 180 g kg⁻¹ clay, 770 g kg⁻¹ sand and 50 g kg⁻¹ silt. Before the implementation of the experiment, the soil had pH in water=6.3, P=17 mg dm⁻³, K=96 mg dm⁻³, Ca=1.90 cmol_c dm⁻³, Mg=0.60 cmol_c dm⁻³, H+Al=2.0 cmol_c dm⁻³ and total organic carbon (COT)=9.28 g kg⁻¹. In the preparation of the area, according to the soil analysis, 2.0 t ha⁻¹ dolomitic limestone were applied with 89% relative neutralization total power (PRNT), half the dose before deep plowing and the other half before harrowing of the total area. Before planting 1.0 t ha⁻¹ gypsum surface was applied.

The experimental design was of randomized blocks in a split plot

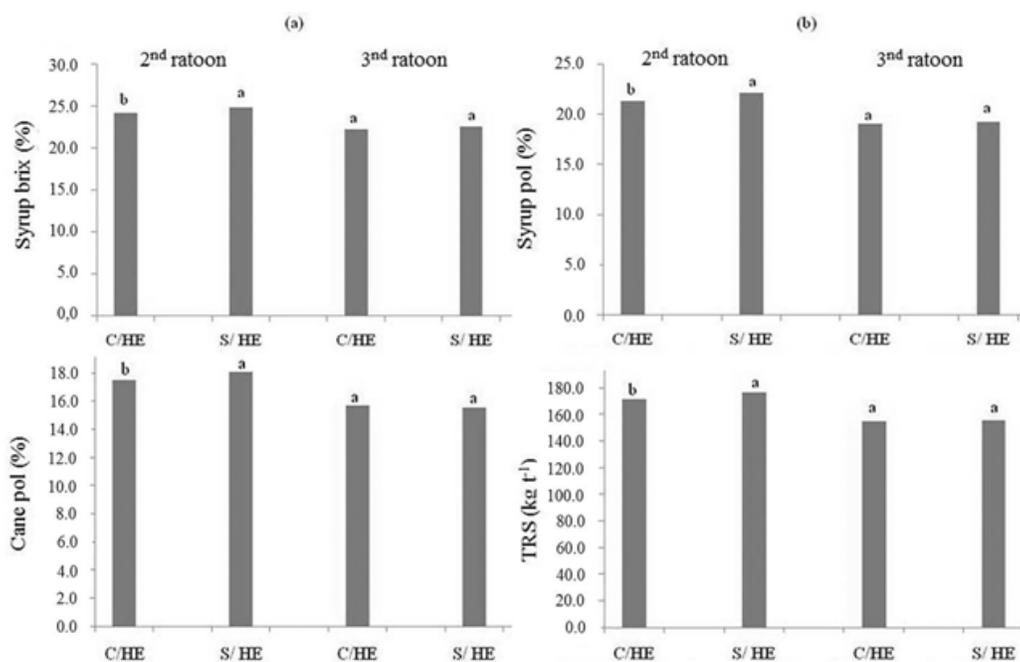


Figure 1. Treatments with (C/HE) and without chisel plow (S/HE), and technological variables in sugarcane of 2nd and 3rd ratoon in Aparecida do Taboado-Brazil, in 2006 and 2007, respectively. The same letters do not differ significantly from each other, by Tukey test ($p > 0.05$).

design with four replications. The main plots received two treatments: C/HE=with chisel plow; S/HE=without chisel plow. In the subplots four forms of fertilization were estimated: M=mineral fertilizer (control); T=mineral fertilization+filter cake; H=mineral fertilization+humic extract; M+T+M=mineral fertilization+pie filter+humic extract.

Treatments in the main plots were represented by cropping systems with chisel plow (C/HE), which associated with fertilization and cultivation is called triple operation in dealing with ratoon, and without the use of the chisel plow (S/HE) and fertilization. This operation was conducted with a cultivator of seven branches, DMB model attached to a tractor of 110 hp and traction 4 × 4, where two lines at a time were grown at 0.25 m deep.

The experimental plots consisted of five lines of sugarcane 10 m long, spaced 1.40 m, totaling 70 m² per plot with dividers of 2.0 m between plots, and 3.0 m between blocks. The experiment was conducted in the 2nd and 3rd ratoon of sugarcane cultivation.

The mineral fertilizer was conducted by applying applying 90 kg ha⁻¹ of N, 30 kg ha⁻¹ of P₂O₅ and 120 kg ha⁻¹ of K₂O, while for the filter cake in natura 13 t ha⁻¹ (dry base) and 20 L ha⁻¹ humic extract were applied in the subplots, using the triple operation in the area with scarification. In the main plot where the triple operation was not carried out, the distribution of fertilizer was made with the suspension of the chisel plow, only applying fertilizer between rows, without the incorporation of mineral fertilizer, filter cake and humic extract to the ground.

The chemical characterization of the filter cake presented temperature between 60-65 °C and humidity of 5.35%, water pH=7.2; N=12.75 g kg⁻¹; P=4.15 g kg⁻¹; K=91.6 g kg⁻¹; Ca=23.60 g kg⁻¹; Mg=3.0 g kg⁻¹; organic carbon=423 g kg⁻¹, with C/N ratio of 33.3%. These data were provided by the Laboratory of the Agronomic Institute Soil Center of Campinas. The filter cake used had a water content of 0.58 kg kg⁻¹ at the time of the experiment.

The characterization of the humic extract was of 12% humic acids, 3% fulvic acids, 4% K₂O and 8% of total nitrogen, data on the product showed on the label of Tradecorp Company. Samples for determining the quality of the syrup were established of ten stems of sugarcane collected in sequence on the center line of the field but excluding the first three meters on each side. After the collection the green and dried leaves were taken out and stripping occurred in the apex bud. We analyzed: brix degree of syrup (°Brix), purity, apparent percentage of sucrose in syrup (Syrup Pol), apparent percentage of sucrose in sugarcane (Cane Pol), percentage of reducing sugars in syrup (Syrup RS), percentage of reducing sugars in the cane (cane RS), sugarcane fiber and total recoverable sugars (TRS), according to Consecana method (2006).

To determine the yield (t ha⁻¹), the authors collected 45 stems of the three center lines in diagonal arrangement, following the methodology of Gheller et al. (1999). The results were analyzed for normality and homogeneity of data through Lilliefors, Cochran and Bartlett tests, respectively. Variance analysis was made using the statistical program SISVAR, and the F test was applied for significance. Averages were compared by Tukey test ($p < 0.05$).

RESULTS AND DISCUSSION

Analyzing data obtained in the treatments with and without the use of chisel plow in ratoon cane in the second year, it was observed that the average values for °Brix, syrup Pol, cane Pol and TRS were higher for growing system without chisel plow while in the third year ratoon cane, there were no differences between treatments for the variables analyzed (Figure 1). These

results evidence that the stages of sugarcane 2nd and 3rd ratoon scarification operation is unnecessary because it did not change the technological quality of sugarcane. According to Carvalho et al. (2011) °Brix, syrup Pol and TRS variables are among the most important for the sugar industry where the best rates in the area were evidenced without the use of the chisel plow since they are related to the amount of raw materials produced by agriculture that are available for manufacturing sugar or alcohol.

Soil scarification is a minimum preparation operation, which is used alone in order to reduce soil density and its mechanical resistance to root penetration, and increase soil permeability, through the breakup of compacted soil layers, especially in fifth or sixth cut of the cane (Paulino et al., 2004). However, when associated with topdressing and harrowing (triple cultivation), serves to incorporate the fertilizer and control infestations of invasive plants.

The results proved that the application of fertilizers carried out on the soil surface and the control of invasive plants, without the use of soil scarification, did not significantly alter sugarcane technological quality in the most important variables. Consequently, you can save fuel and speed up the operation. Probably in these areas of 2th and 3rd cut the compression levels should not be causing restriction to root growth.

Similar results were observed by Chiba et al. (2008) evaluating the sugarcane cultivation in Argisol treated with sewage sludge. They found that the incorporation of the product through the triple operating equipment did not increase the °Brix values, cane Pol and total reducing sugars in agricultural period of 2003/04. Souza et al. (2005) studied the management of cane straw harvested without burning, the sugarcane productivity and the quality of the syrup. They found that scarification up to 0.30 m, carried out with the Coopersucar model with two winged Ikeda rods, did not promote increased fiber content, purity, apparent sucrose in syrup or reducing syrup sugars.

Analyzing the influence of forms of fertilizer on the technological variables in the 2nd ratoon in 2006 they did not notice differences among the treatments tested (Figure 2), just as there were no differences between S/HE and C/HE (Figure 1). In general, °Brix values, sugarcane apparent sucrose (Pol), syrup purity, fiber, reducing sugars (RS) and total reducing sugars (TRS) were above the minimum values recommended as quality standards (Figure 1), being they > 18%, > 14%, > 85%, 11-13%, <1% 121.96 kg t⁻¹ (Consecana, 2006). That can be explained by the forms of fertilizer used that provided all the nutrients necessary so that cane variety RB 867515 expresses its genetic potential.

Analyzed 18 varieties of sugarcane in the state of São Paulo, Souza et al. (2005) found average values of fiber, purity and syrup apparent sucrose of 91, 11 and 18%, respectively, for management conditions of straw

maintained on the soil surface or incorporated with ripper.

The °Brix values ranged between 22.23 and 24.85%. These values are above the limits mentioned in the literature as the minimum necessary for the sugarcane to present conditions to be sampled in order to conduct a detailed technological analysis, to characterize the degree of maturation. Santos et al. (2010) studied the productivity of sugarcane under fertilization with filter cake enriched with soluble phosphate. They found that the filter cake doses and their combinations with phosphate did not alter the quality of cane syrup, when evaluating the syrup °Brix at harvest.

Analyzing the influence of the forms of fertilization on the technological variables in the 3rd ratoon in 2007 they verified difference ($p > 0.05$) to the syrup Pol and total recoverable sugars (TRS), which on treatment with mineral fertilizer + filter cake showed higher value of sucrose in syrup, differing only from treatment with mineral fertilizer (Figure 3).

The effect of the filter cake on the variable of the syrup Pol can be attributed in large scale to the benefits provided by organic matter from the filter cake and the nutrients found in it, especially phosphorus and nitrogen. This result is in agreement with Santos et al. (2011) who studied the isolated or combined effect of organic and mineral fertilizers. They noted that the mineral fertilizer, combined with the organic one, promoted increases in sucrose content in the cane syrup.

Evaluating the effect of humic substances on technological quality of varieties of sugarcane, Rosato et al. (2010) found a positive effect of humic substances (HSs) on the accumulation of sucrose as HSs can be an important technique for improving the quality of raw materials and for the varietal management. The average amount of total recoverable sugars (TRS) at the end of the 2010/2011 Brazilian crop was of 140.86 kg Mg⁻¹, indicating that the data presented in this study were in accordance with the national commercial production standards.

For °Brix, cane Pol, purity, syrup and sugarcane RS, and fiber there were no significant difference between the treatments with fertilization (Figures 2 and 3). That is in agreement with the results obtained by Fravet et al. (2010) which found that the °Brix and syrup Pol variables fell on their values with increasing application of filter cake. The authors cited found that smaller Pol and °Brix values occurred in the treatment, where filter cake was applied, could be explained by the high content of organic matter and high water retention capacity provided by the application of the pie along the root system, compromising the induction of maturation.

Souza et al. (2014) studied the control of agricultural traffic and its effect on soil physical properties and technological quality of sugarcane. They did not observed effects of treatments on °Brix values, purity, fiber or TRS.

With regard to the parameters evaluated for number of

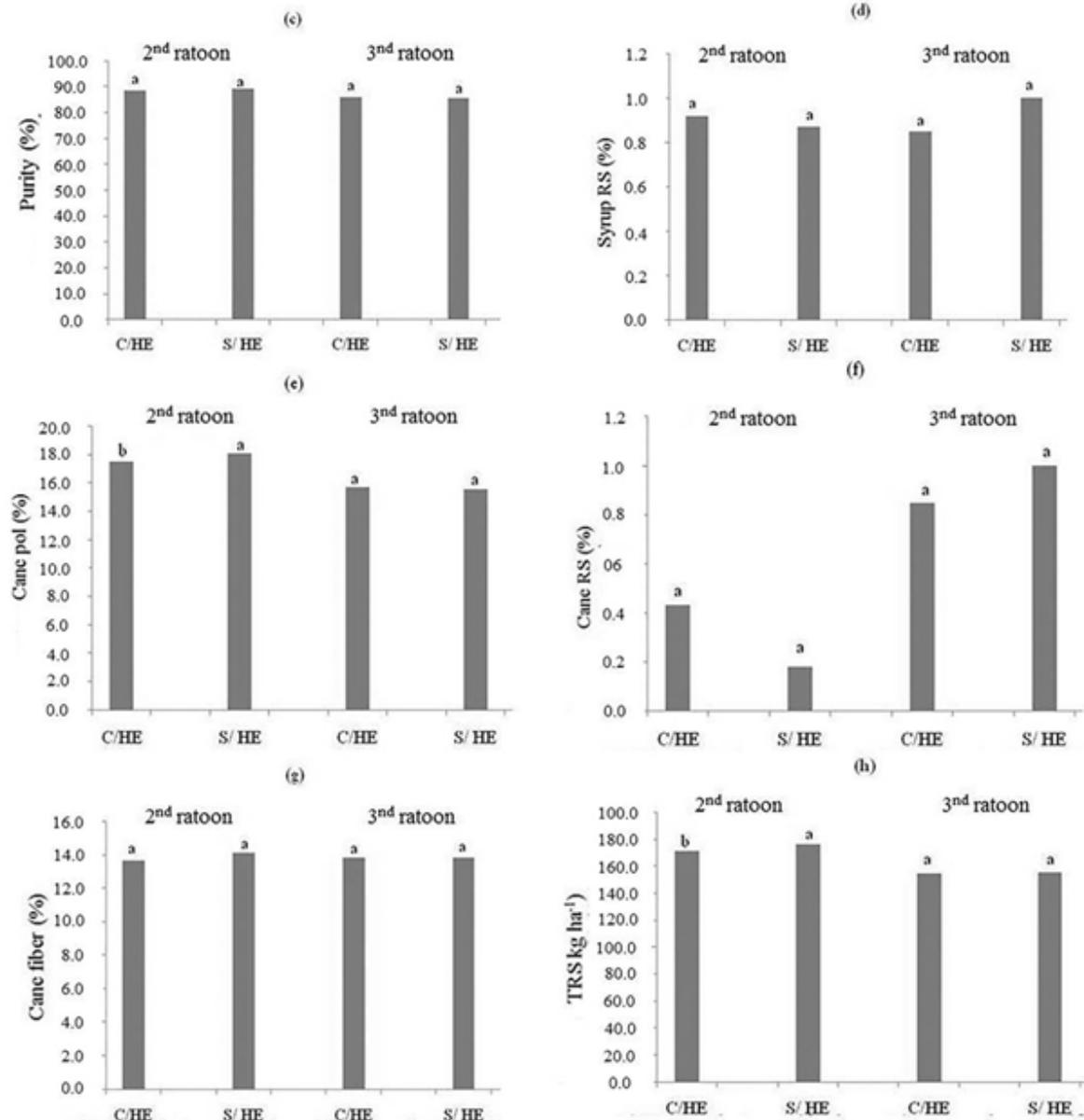


Figure 2. Influence of ways of fertilization on the technological variables in sugarcane of 2nd ratoon in the city of Aparecida do Taboado-Brazil, in 2006. M=mineral fertilizer; T=Mineral fertilization+filter cake; H=Mineral fertilization+humic extract; M+T+M=Mineral fertilization+pie filter+humic extract. The same letters do not differ significantly from each other, by Tukey test ($p > 0.05$).

stems per meter of furrow and productivity there were no differences ($p > 0.05$) between treatments C/HE and S/HE in cane of 2nd and 3rd ratoon (Figure 4).

These results are similar to those obtained by Pauline et al. (2004) who studied the effect of the triple operation with scarification to the depth of 0.15 to 0.30 m between the lines of ratoon of sugarcane, and observed that these post-harvest management practices did not differ as to productivity. Souza et al. (2014) affirm that the use of the

leading disk harrow cultivation compared to the fallow system is not important in the production and quality of stems.

There were no differences ($p > 0.05$) between forms of fertilization on sugarcane of 2nd and 3rd ratoon. Yet the treatments with humic extract, mineral+filter cake+humic extract and mineral+filter cake, produced, respectively, 8, 7 and 6% more in tons of sugarcane than the treatment with mineral fertilizers (Figure 4).

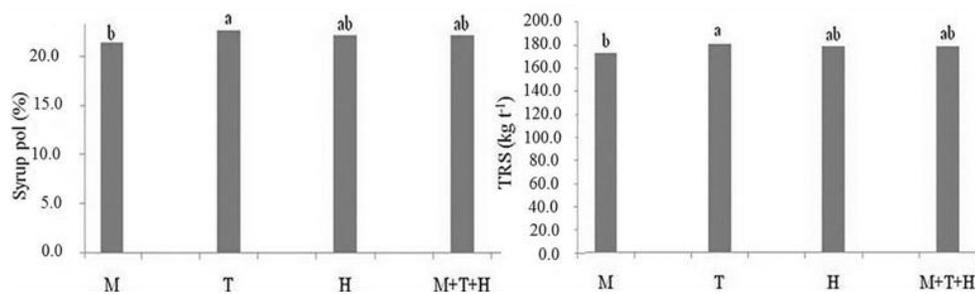


Figure 3. Influence of ways of fertilization on the technological variables in sugarcane of 2nd ratoon in the city of Aparecida do Taboado-Brazil, in 2007. M=Mineral fertilizer; T=Mineral fertilization+filter cake; H=Mineral fertilization+humic extract; M+T+H=Mineral fertilization+pie filter+humic extract. The same letters do not differ significantly from each other, by Tukey test ($p>0.05$).

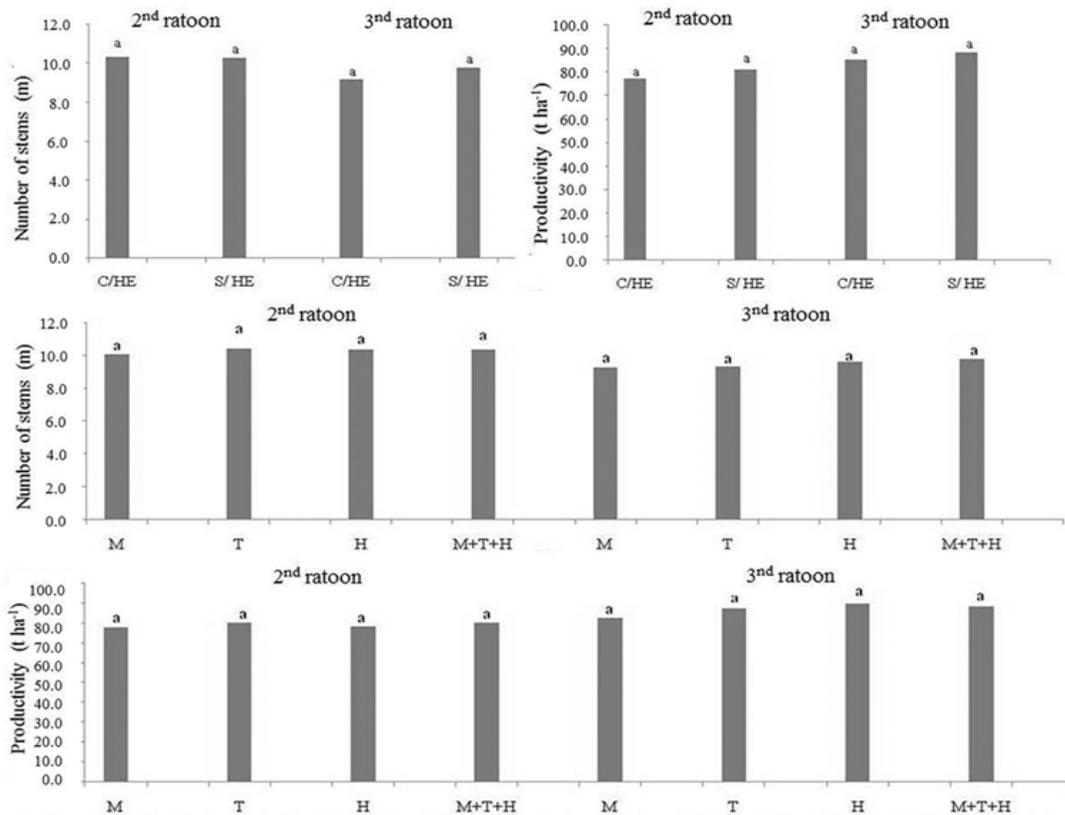


Figure 4. Number of stems per meter and stem yield ($t\ ha^{-1}$) of sugarcane at 11 months of application in treatments with (C/HE) and without using the chisel plow (S/HE), and forms of fertilization for the 2nd and 3rd ratoon. M=Mineral fertilizer; T=Mineral fertilization+filter cake; H=Mineral fertilization+humic extract; M+T+H=Mineral fertilization+pie filter+humic extract. The same letters do not differ significantly from each other, by Tukey test ($p>0.05$).

According to Nardin (2007), the use of filter cake in clay was not enough for significant differences on the productivity of sugarcane, regardless of application.

Fravet et al. (2010) in studies on the filter cake and its effects on some attributes of sugarcane, found an effect of the application of this by-product in stem yield.

Conclusion

Using the chisel plow to incorporate the fertilizer in the post-harvest period in the 2nd and 3rd ratoon cane did not cause changes in technological variables or sugarcane crop yield. The values obtained for brix degree of syrup, apparent sucrose sugarcane, broth purity, fiber, reducing sugars and total reducing sugars were above minimum values defined by the standard of the cane quality in all the treatments, but did not increase the number of stems and crop productivity.

Conflict of Interest

The author(s) have not declared any conflict of interest.

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