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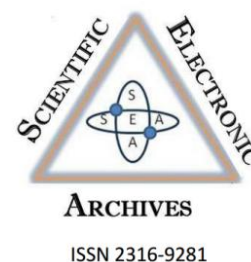
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Productivity and agronomic characteristics of sugarcane under different tillage systems

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Abstract: Sugarcane production has increased in recent years mainly because of the demand for ethanol. Soil preparation in areas where sugarcane has not been planted yet can increase productivity by improving physical and chemical characteristics. The objective of this study was to evaluate the effect of soil tillage on agronomic traits and productivity of sugarcane. The experiment was conducted in the municipality of Goianésia (GO) on a Red-Yellow Latosol of medium texture using the CTC-2 variety. The experimental design was randomized blocks with six treatments and four replications. The treatments were: T1) desiccation + moldboard plow + harrow, T2) moldboard plow + harrow, T3) harrow + moldboard plow + harrow, T4) no-till, T5) subsoiler, and T6) harrow + disc plow + harrow. The number, diameter, height and productivity of stalks were evaluated. The treatment which resulted in the highest number of stalks was harrow + moldboard plow + harrow; however, this treatment was differed only from the treatment with moldboard plow + harrow. The seedbed preparation with desiccation + moldboard plow + harrow and also harrow + disk plow + harrow provided the highest yield of sugarcane stalks. The no-till treatment proved to be a viable alternative, since it did not differ in productivity from treatments that provided the highest yields. It is a more economical form of cultivation when compared to the other treatments studied in this work.

Keywords: ethanol, no-till, soil tillage, *Saccharum spp.*

Introduction

Sugarcane (*Saccharum spp.*) is a very important crop for the Brazilian economy. Brazil is the world's largest producer of sugarcane, accounting for more than half of all sugar sold worldwide. In addition, Brazil is the largest exporter of ethanol. The estimated productivity of the current 2016/17 crop is 76,152 kg ha⁻¹, with an estimated total production of 691 thousand tons of sugarcane, representing a 3.8% increase over the last season (Conab, 2016).

The production of this crop has significantly increased due to the opening of new production areas in several Brazilian states, and also because of higher production capacity attributed to the improvements in management systems, selection of

more productive varieties and the use of irrigation (Simoes et al., 2015).

Strong expansion of the production of sugarcane has been observed in recent years. It is mainly due to the prospect of ethanol production, especially in the Cerrado region where this increase has been occurring more rapidly (Aguiar & Souza, 2014). Expansion areas are those which were previously destined for other crops and are currently cultivated with sugarcane. Areas which were previously cultivated with other crops for a period of two or more than two harvests are also considered expansion areas (Moraes et al., 2016).

The expansion of sugarcane is more intense in regions which typically produce soybean and also in areas with degraded pastures. However, the

growth of sugarcane production has raised some questions about its impact on the environment, the choice of new areas and the increase of productivity in existing areas. Therefore, studies of the economic viability of this crop in relation to production costs, mainly in areas never cultivated with sugarcane, will be crucial for the management decisions in relation to the cultivation of this crop (Carvalho et al., 2011).

The planning of activities directly involved in the cultivation of sugarcane, from planting to harvest, is a very important step in economic management. There is a number of choices to be made such as the selection of agricultural chemicals, machinery, implements, soil amendments and the variety (Silva & Carvalho Junior, 2010).

Soil preparation before planting, including acidity correction and the increase of nutrient content, is a crucial step for the longevity of the crop, because the seedbed will be revolved again only after the fifth or the sixth harvest, depending on the variety (Carvalho et al., 2011). The maximum efficiency of acidity correction and provision of essential nutrients can be ensured by liming, especially when it is distributed homogeneously in the area and well incorporated into the soil. However, soil revolving can cause undesirable losses as the loss of water and organic carbon caused by increased mineralization of organic matter and disaggregation of the soil (Moraes et al., 2016).

The fundamental role of tillage is to create ideal conditions for root development. In sugarcane this initial management practice can profoundly

influence the yield of consecutive harvests when the tillage is not conducted with appropriate operations for each type of soil. Tillage affects the physical and chemical properties of the soil by changing the absorption of nutrients and water infiltration, which helps control erosion (Tavares et al., 2010).

In areas previously cultivated with grains (soybeans and corn) the need for conventional tillage has been questioned because usually these soils have good fertility and are without physical restrictions. Some mills have opted for minimum tillage using the subsoiler in order to ensure the incorporation of lime and gypsum into the deeper layers of the profile (Carvalho et al., 2011).

In this context, the objective of this study was to evaluate the effect of different tillage systems on agronomic characteristics and the productivity of sugarcane in an expansion area.

Methods

The experiment was conducted in the municipality of Goianésia, Goiás on the property of the Jalles Machado mill located at coordinates 15°10'S and 49°15' W at the average altitude of 640 m in the Cerrado. The climate of the region is classified as Aw (tropical savanna) according to the Köppen, typically hot and humid with rainy summers. Before the implementation of the treatments the area was occupied by *Brachiaria brizantha*.

Soil sampling in the experimental area was conducted at depths of 20 cm and 40 cm for the chemical (Table 1) and physical (Table 2) analysis. The soil in the area was classified as Red-Yellow Latosol (Embrapa, 2006).

Table 1. Soil chemical characterization before planting in the expansion area of sugarcane at the depths 0 - 0.20 m and 0.20-0.40 m.

Depth (m)	pH (CaCl ₂)	Ca	Mg	Al	P	K	H+Al	T	V	m	OM
			cmol _c dm ⁻³		mg . dm ⁻³		cmol _c dm ⁻³		-----%-----		g. kg ⁻¹
0-0.2	4.01	0.45	0.29	1.65	1.4	78	8.25	9.19	10.25	63	16.2
0.2-0.4	3.97	0.23	0.15	2.0	0.7	19.2	8.70	9.12	4.8	82	10.4

pH in CaCl₂; Ca, Mg, Al, (KCl 1 mol L⁻¹); P; K = (HCl 0.05 mol L⁻¹ + H₂SO₄ 0.0125 mol L⁻¹) available P (Mehlich⁻¹ extractor); H + Al = (Buffer – SMP at pH 7.5); CEC at pH 7.0; V = Base saturation; m = Al saturation, M.O. = Colorimetric method (Embrapa, 2009).

Table 2. Soil texture in the expansion area of sugarcane at depths 0 - 0.20 m and 0.20-0.40 m.

Depth (m)	CS	FS	Silt	Clay	Texture ¹
	-----g kg ⁻¹ -----				
0 to 0.20	77	284	159	480	clayey
0.20 to 0.40	122	206	139	533	clayey

CS = coarse sand; FS = fine sand.¹ Pipette Method, (Embrapa, 2009).

Six treatments were carried out as described in Table 3. A randomized block design was used. Each block consisted of six plots, each 50 m long and 19.5 m wide with 13 sugarcane rows spaced 1.5 m apart. The blocks and the plots were separated by technical paths each 5.0 m wide to facilitate the operation of machines and implements. Thus, the

area of each plot was approximately 1000m² and the total area of the experiment 2.4 hectares.

Broad-spectrum herbicides (glyphosate + 2.4-D) at doses 3.0 and 2.0 L ha⁻¹ respectively, were applied 30 days before the implantation of the experiment (Table 3).

Liming with a single dose 3.5 t ha⁻¹ of dolomitic limestone PRNT 85% was performed

before the implementation of the treatments on the entire area. Shortly after the implantation of the treatments, but before the planting, gypsum (0.8 t ha^{-1}) was applied also on the entire area of the experiment.

The CTC-2 variety was used. The cane seeds were planted manually 15 to 20 sets per meter into furrows 0.30-0.40 m deep. Fertilization at planting was the same for all treatments with 250 kg ha^{-1} of monoammonium phosphate (MAP) applied into furrows, equivalent to 120 kg ha^{-1} of P_2O_5 , and 28 kg ha^{-1} of N.

After the distribution of the cane sets the furrows were covered. Topdressing fertilization was performed 8 months after planting by applying a liquid fertilizer 05-00-13 + 0.3% Zn + 0.3% B at a dose of 1000 L ha^{-1} .

The agronomic evaluated traits were: the diameter, height and the number of stalks. Ten

stalks per plot were selected in sequence from the central row of the plot a week before the harvest. The diameter of the third internode from the base was measured with a digital caliper while the height was measured with a tape from the soil base to the leaf +1. The evaluation of the number of stalks was performed ten months after planting, counting all stalks within 50 meters of the five central rows. The total evaluated area was 375 m^2 .

To determine the mass of the stalks per hectare (TCH), the cane was harvested manually. The mass of stalks was determined considering 50 m in the five central rows of the plot, with a total area of 375 m^2 per plot. The weighing was carried out using a dynamometer (Técnica D-10000) attached to a tractor hydraulic lift system. The data were subjected to analysis of variance by F test at 5% probability, and the averages compared by Tukey test with 0.05 significance.

Table 3. Tillage operations for the implementation of the experiment in Goianésia – Goiás.

Treatments	Operations
T1	Desiccation (Glyphosate and 2,4-D at doses 3.0 and 2.0 L ha^{-1} , respectively) + moldboard plow (the average depth 0.40 m) + light harrow (the average depth 0.15 m) - (DMPH)
T2	Moldboard plow (the average depth 0.40 m) + light harrow (the average depth 0.15 m) - (MPH)
T3	Intermediate harrow (0.20 m) + moldboard plow (the average depth 0.40 m) + light harrow (the average depth 0.15 m) - (PC)
T4	Desiccation (Glyphosate and 2,4-D at doses 3.0 and 2.0 L ha^{-1} , respectively) + No-till - (NT)
T5	Desiccation (Glyphosate and 2,4-D at doses 3.0 and 2.0 L ha^{-1} , respectively) + Subsoiler (the average depth 0.40 m) - (SU)
T6	Intermediate harrow (the average depth 0.20 m) + discs plow (the average depth 0.30 m) + light harrow (the average depth 0.15 m) - (PCDH)

Results and discussion

The number of stalks was different among the treatments (Table 4). The number of stems per meter was lower in the treatment with moldboard plow + harrow. It was probably due to the turning of the fertile soil which limited the availability of nutrients. The treatment which produced the highest number of stems was harrow + moldboard plow + harrow; however, this treatment only differed in the number of stalks from the treatment with moldboard plow + harrow, and did not differ from the other treatments. Because the treatment harrow + moldboard plow + harrow turned and homogenized the soil more efficiently, it may have favored a better distribution of nutrients and less soil compaction.

The no-till system was not different from the treatment with the highest number of stems. Therefore, economically speaking it may be a better option than the other systems, and it also better preserves physical and chemical characteristics of the soil by limiting soil disturbance.

The treatments with more intense soil disturbance, as desiccation + plowing + harrowing

and harrowing + disc plowing + harrowing, induced the highest yields (Figure 1). However, these two treatments did not differ in productivity from the treatments with moldboard plow + harrow and no-till. The use of subsoiler promoted the lowest (Figure 1) productivity, approximately 100 t ha^{-1} . Grange et al. (2005) evaluated five soil tillage treatments in Thailand on an area of 80 m^2 of sugarcane for eight seasons (plant cane - expansion + three ratoon harvests - plant cane - replanting + two ratoon crops and plant cane - replanting) and also found the lowest yields with the use of subsoiler.

Tavares et al. (2010) and Carvalho et al. (2010) found no differences among treatments regarding productivity using different methods of soil preparation in sugarcane. This may have been due to the small size of the sample area in order to determine the productivity, which generates a large coefficient of variation not allowing the detection of differences between treatments (Moraes, 2016).

Camilotti et al. (2005) evaluated four treatments of soil preparation, one of which they called minimum tillage. It only consisted of planting

the cane seeds into the furrows, while the other treatments involved soil disturbance including furrowing during the planting. Those authors found no differences among the treatments regarding the productivity in sugarcane.

In conclusion, the treatments desiccation + moldboard plow + harrow and harrow + disc plow + harrow on the expansion area of sugarcane achieved the highest yields (Figure 1). However, as the no-till treatment did not show a difference in

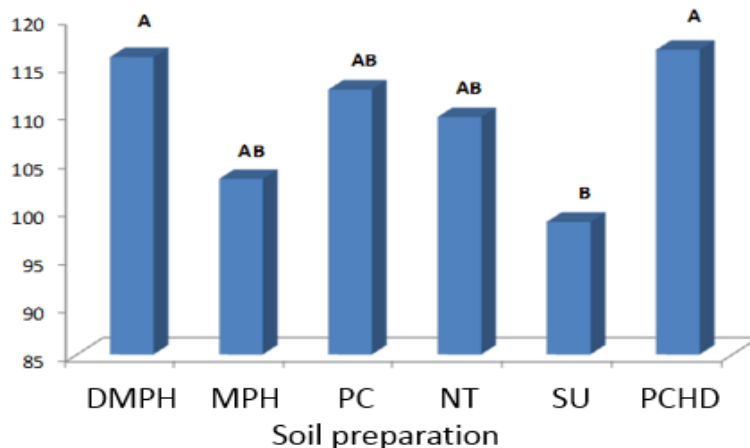
productivity in relation to the other treatments, it may be a good option taking into account the costs of soil preparation which each treatment generates. Carvalho et al. (2011), when evaluating no-till system in sugarcane found favorable economic result using no-till compared to conventional tillage which involved heavy disk harrowing 0.20 m deep, in addition to an intermediate harrowing followed by plowing and harrowing again.

Table 4. Agronomic traits of sugarcane under different soil tillage treatments

Treatment	Stalk diameter (cm)*	Height (m)*	Number of stalks m ⁻¹
DMPH	2,75 a	2,0 a	16,95 ab
MPH	2,50 a	2,5 a	16,00 b
PC	3,0 a	2,2 a	18,50 a
NT	2,9 a	2,2 a	16,30 ab
SU	3,0 a	2,5 a	16,85 ab
PCDH	3,0 a	2,0 a	17,12 ab
CV (%)	10,97	20,95	5,30

DMPH - (desiccation + moldboard plow + harrow); MPH - (moldboard plow + harrow); PC - (harrow + moldboard plow + harrow); NT - (no-till); SU - (subsoiler); PCDH - (harrow + disc plow + harrow). Means followed by the same lowercase letters in the column do not differ by Tukey test at 5%. * Not significant.

Figure 1. Productivity of sugarcane (t ha⁻¹) grown on expansion area as a function of different forms of soil preparation.



DMPH - (desiccation + moldboard plow + harrow); MPH - (moldboard plow + harrow); PC - (harrow + moldboard plow + harrow); NT - (no-till); SU - (subsoiler); PCDH - (harrow + disc plow + harrow). Means followed by the same uppercase letters in the column do not differ by Tukey test at 5%. CV = 6,02%.

Conclusions

The use of harrow + moldboard plow + harrow provides more stalks of sugarcane.

Different tillage systems do not affect plant height and the diameter of sugarcane stalks.

The treatments desiccation + moldboard plow + harrow and harrow + disc plow + harrow provide the highest yields of sugarcane.

The no-till system proved to be a viable alternative in the cultivation of sugarcane.

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