



Reduced planting system influencing on soil nutrient contents and sugarcane yield: a study in Nova Alvorada do Sul, MS

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INFO

Keywords

preparation systems
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ABSTRACT

The benefits of the non-revolving soil system for grain cultivation are widely known. This study aims to monitor the effect of planting systems on sugarcane yield and quality, and its influences on soil nutrient contents. A study was carried out during 2019 and 2020, and compared three sugarcane planting systems based on: (i) conventional planting, (ii) reduced planting, (iii) and planting without soil disturbance. Data collections of soil and sugarcane samples (yield and quality parameters) were carried out in the first year of harvest (plant cane) and the first ratoon. Results showed that the reduced planting system promoted an increase in sugarcane yield in short term than conventional planting and planting without soil disturbance. The quality parameters of sugarcane were not affected by planting systems. More studies are requested to compare and explain the sugarcane planting systems and their effect on soil conditions, mainly in long term.

RESUMO

Sistema de plantio reduzido influenciando nos teores de nutrientes do solo e na produtividade da cana-de-açúcar: um estudo em Nova Alvorada do Sul, MS

Os benefícios do sistema de plantio sem o revolvimento do solo para o cultivo de grãos são amplamente conhecidos. Este estudo tem como objetivo monitorar o efeito dos sistemas de plantio na produtividade e qualidade da cana-de-açúcar e suas influências nos teores de nutrientes do solo. Foi realizado um estudo durante 2019 e 2020, comparando três sistemas de plantio de cana-de-açúcar baseados em: (i) plantio convencional, (ii) plantio reduzido, (iii) e plantio sem revolvimento do solo. A coleta de dados de amostras de solo e cana-de-açúcar (parâmetros de produtividade e qualidade) foi realizada no primeiro ano de colheita (cana planta) e na primeira soca. Os resultados demonstraram que o sistema de plantio reduzido promoveu um aumento na produtividade da cana-de-açúcar em curto prazo do que o plantio convencional e o plantio sem revolvimento do solo. Os parâmetros de qualidade da cana-de-açúcar não foram afetados pelos sistemas de plantio. Mais estudos são necessários para comparar e explicar os sistemas de plantio de cana-de-açúcar e seus efeitos nas condições do solo, principalmente no longo prazo.

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INTRODUCTION

Sugarcane (*Saccharum* sp.) is an important source for the production of ethanol and energy generation. In Brazil, sugarcane occupies about 8.4 million hectares, considered the third crop in the cultivated area, behind the soybean and corn areas (CONAB, 2021). Sugarcane production is characterized by a system consisting of mechanized processes, where agricultural machinery is used from preparation to harvesting the crop (Baquero et al., 2012). Production system requires modern machines that perform with maximum efficiency and lower cost in a satisfactory quantity and quality (Souza et al., 2012).

The main tillage systems are conventional, reduced tillage, and planting without soil disturbance. The reduced tillage and planting without soil disturbance can vary depending on the type of soil, moisture condition (time of the year), presence or no weeds and soil pests, need for soil physical and/or chemical correction, availability of tools and machinery, among others. For example, an area that needs in-depth chemical recovery should be prepared in the conventional system, using mainly the plow, to enable the deep incorporation of correctives and seeds.

The conventional tillage system uses a sequence of operations with plowing, harrowing, subsoiling, and deep furrowing (Silva Junior et al., 2013). The use of the subsoiler is indicated for areas where in-depth chemical recovery has already been carried out. Areas properly chemically recovered and without biological restriction (pests at a controlled level) can be directed to reduced preparation or planting without disturbance. Therefore, it can be seen that in the plants, a global assessment of the system is necessary to choose the most adequate soil preparation system for the conditions of the areas (Arcoverde, 2019a).

Planting without soil disturbance promotes the maintenance of soil cover with residues and mobilizes the soil only in the planting furrow (Carvalho et al., 2011). Before planting without turning over, two phases are necessary: implantation and establishment. For the implantation, there is soil mobilization with chemical and physical correction and elimination of compacted or thickened layers. While the establishment is based on cultural treatments and crop rotation throughout the cycles (Santos Junior et al., 2015). Over time, soil without disturbance improves soil's physical, chemical, and biological

quality (Almeida et al., 2016). However, despite the known benefits of soil without disturbance, there is a need for information about the impacts of soil management systems for sugarcane cultivation to establish a relationship between the effects of compaction on the soil's physical attributes and plant development (Arcoverde et al., 2019a).

The hypothesis is that low soil turnover in the reduced planting system contributes to increase sugarcane yield and quality as a result of better soil conditions in the region of Nova Alvorada do Sul/MS. This study aims to monitor the effect of planting systems on sugarcane yield and quality, and its influences on soil nutrient contents.

MATERIAL AND METHODS

A study was carried out in the region of Nova Alvorada do Sul, Mato Grosso do Sul (21° 58'64" S; 54° 11'04"W; altitude of 407 m), during 2019 and 2020. The region has a climate classified as dry winter, with an annual average of 1,300 mm of rain. During the study, the total precipitation presented an average of 1,429 mm. The study compared three sugarcane planting systems based on: (i) conventional planting (CP), reduced planting (RP), and planting without soil disturbance (PNoD).

The experimental area was prepared and planted between February and March 2019, considering a planting period of 18 months. In CP, heavy harrowing, intermediate harrowing, subsoiling, and leveling harrowing were used, followed by furrowing in the planting lines. While, PNoD, there was no soil disturbance, the only opening of furrows in the planting line. In the reduced preparation, heavy harrowing, intermediate harrowing, leveling harrowing, and furrowing were performed.

The experimental area has a 12-year history of sugarcane farming, where before the sugarcane cycle, it was cultivated with pasture. Before soil preparation, sampling was carried out in the 0 – 20 and 0.20 – 0.40 cm layers to characterize the soil attributes (Table 1). Phosphorus, potassium, calcium, and magnesium were determined in resin; sulfur was monitored in calcium phosphate solution (0.01 mol L⁻¹), and aluminum was determined in KCl solution (1 mol L⁻¹). The soil has a predominance of sand with clay content between 10 to 25% (between the blocks), classifying it as a sandy texture with a soil classified as Latossolo in the Brazilian soil classification.

Table 1 – Soil characterization in the experimental area located in Nova Alvorada do Sul, Mato Grosso do Sul.

Soil layers (m)	OM g kg ⁻¹	pH CaCl ₂	P mg dm ⁻³	S	K	Ca	Mg	Al mmol _c dm ⁻³	H+Al	CEC
0.0 - 0.2	25.0	5.2	11.0	5.1	2.5	32.0	12.0	<1.0	38.0	69.3
0.2 - 0.4	23.0	5.2	4.2	6.0	2.0	29.0	10.0	<1.0	34.0	52.7

Organic matter (OM); pH in CaCl₂ (0.01 mol L⁻¹); phosphorus (P); potassium (K); calcium (Ca); magnesium (Mg); sulfur (S); aluminum (Al); hydrogen plus aluminum (H + Al); cation exchange capacity (CEC).

In the year of planting, lime, gypsum, and phosphate were applied to soil correction and phosphate fertilization with a furrow bottom using the formulated fertilizer 08-30-10 (nitrogen, phosphorus, and potassium). The area did not receive a vinasse application, as it is 30 km away from the planting. In the 2019/20 season, an application of filter cake (25 tons ha⁻¹) was broadcast as supplement fertilization. Sugarcane seedlings (RB966928) were mechanically planted with a spacing of 1.50 cm between rows. The design of the study was based on the randomized block where each experimental unit (total of five replications) had an area of 87 ha of conventional planting, 74 ha of planting without tillage, and 112 ha of reduced tillage, totaling a crop reform area of 273 ha.

Data collection and analysis

Data collection was carried out in the first year of harvest (plant cane) and the first ratoon. The collection of stalks was carried out in a mechanized manner in April 2020 (plant cane) and May 2021 (first ratoon), in the entire production area. All stalks were weighted to determine the total sugarcane yield.

Stalks also were collected to determine the quality parameters of sugarcane (theoretical recoverable sugar - TRS, pol, fiber, and Brix), according to Fernandes (2003), using a mechanized manner, with a volume of 30% stalk sampled. The soil was collected 30 days after planting in the 0-0.2 m soil layer, to monitor the soil nutrient contents according to Embrapa (2017). Phosphorus, potassium, calcium, and magnesium were determined in resin; sulfur was monitored in calcium phosphate solution (0.01 mol L⁻¹), and aluminum was determined in KCl solution (1 mol

L⁻¹).

Data was evaluated using descriptive statistics (means, deviations, and standard errors), the normality of the data (Shapiro-Wilk test), and the homogeneity of the variance (O'Neill and Mathew's test). Each planting system was treated with a population and the means were compared using the t test (Student; p<0.05).

Data of yield was correlated with soil nutrient contents (phosphorus, potassium, calcium, magnesium, organic matter) and values of aluminum, hydrogen plus aluminum, and pH using Pearson's correlation (p<0.05). The results were represented in layers with (i) the root layer represented by sugarcane yield; (ii) and the first layer represented by soil contents in each planting system.

RESULTS AND DISCUSSION

In both years, the reduced planting system promoted an increase in sugarcane yield by an average of 79.0 (year 1) and 71.2 Mg ha⁻¹ (year 2), considered a gain of 8 and 5% higher than conventional planting and planting without soil disturbance, respectively (Figure 1). In the reduced preparation, heavy harrowing, intermediate harrowing, leveling harrowing, and furrowing were performed to better the physical conditions of the soil. Arcoverde et al. (2019a) verified that lower resistance to mechanical penetration of the soil and higher soil moisture impacted positively in sugarcane yield. In-plant cane, Arcoverde et al. (2019b) verified in no-tillage sugarcane higher values of density and resistance to penetration compared to the reduced system, demonstrating greater compaction up to 0.10 m in depth, caused by mechanical operations in sugarcane areas.

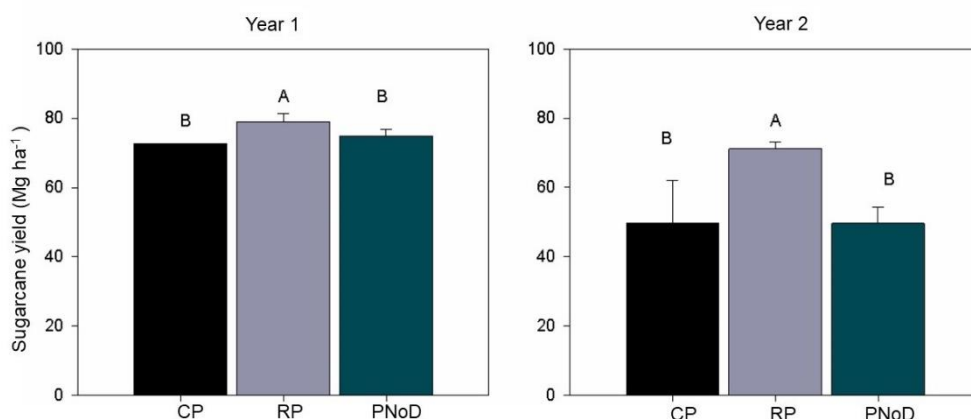


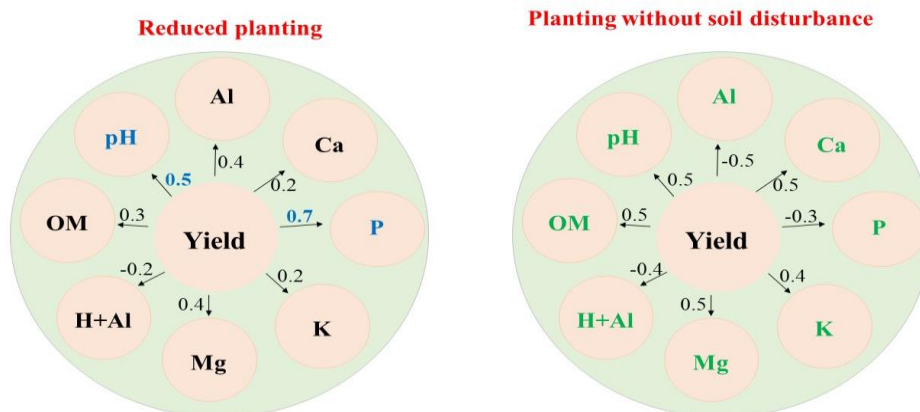
Figure 1 - Sugarcane yield (Mg ha⁻¹) with conventional planting (CP), reduced planting (RP), and planting without soil disturbance (PNoD) in the region of Nova Alvorada do Sul, Mato Grosso do Sul. Means compared according to the t test (student; p<0.05); bars identified with different capital letters represent the difference between systems.

In the reduced planting system, the increase in yield was associated with an increase in pH (r: 0.50; p<0.05) and phosphorus in soil (r: 0.70; p<0.05). The positive effect of phosphorus contents is explained by applying fertilizer using the formulation 08-30-10 and an application of filter cake (25 tons/hectare) as supplement fertilization. Interestingly, the P efficiency on yield was more evident just in the reduced planting system. Lopes et al. (2021) showed that the application of filter cake contributed to increasing the sugarcane yield (up to 6%), β-glucosidase activity (up to 15%), and soil P contents when compared to mineral control.

In the planting without soil disturbance, there was no significant correlation between yields and soil contents. While, in conventional planting organic matter was associated with a higher yield and an r of 0.7 (p<0.05) (Figure 2). This increase is

explained by the soil revolving, which promotes a higher contact between soil and residues with the rapid mineralization of nutrients. Sugarcane residue incorporated in the soil can directly promote soil carbon due to soil organic matter inputs (Almeida et al., 2019). The positive effect of conventional planting on soil nutrition is commonly observed in Year 1, with a reduction of soil protection in the subsequent years

In year 2, there was higher soil P content with planting without soil disturbance which presents an average similar to the conventional planting. While, reduced planting presented the lowest contents of phosphorus in soil. For the others nutrients, there was no difference in both years (Table 2).



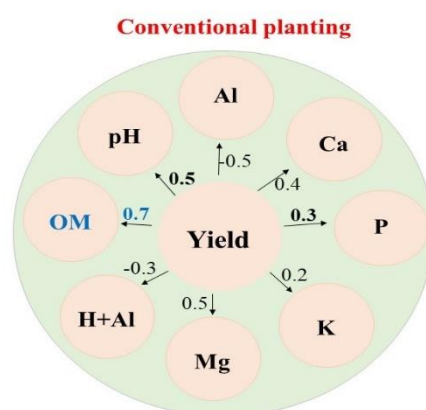


Figure 2 - Sugarcane yield correlation with phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), organic matter (OM), aluminum (Al), Hydrogen plus aluminum (H+Al), and pH in conventional planting (CP), reduced planting (RP) and planting without soil disturbance (PNoD) in the region of Nova Alvorada do Sul, Mato Grosso do Sul.

The yield and soil contents were correlated by Pearson's correlation ($P < 0.05$), using a population of teen samples (2 years) for each planting system.

Table 2 - Contents of organic matter (OM), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), aluminum (Al), hydrogen plus aluminum (H + Al), and pH in conventional planting (CP), reduced planting (RP) and planting without soil disturbance (PNoD) in the region of Nova Alvorada do Sul, Mato Grosso do South.

Planting	pH ^{Ns}	OM ^{Ns}	P	K ^{Ns}	Ca ^{Ns}	Mg ^{Ns}	H+Al ^{Ns}	Al ^{Ns}
	CaCl ₂	g kg ⁻¹	mg dm ⁻³				mmol _c dm ⁻³	
Year 1								
CP	5.7±0.2	11.0±1.9	12.7±5.3	0.5±0.1	18.8±8.0	9.5±2.0	12.2±2.0	0.0±0.0
RP	5.5±0.2	9.4±0.9	11.9±3.0	0.5±0.2	12.7±4.0	6.3±2.6	12.6±1.5	0.2±0.3
PNoD	5.6±0.3	10.5±1.9	11.0±0.0	0.4±0.3	12.7±2.8	5.9±2.1	12.3±1.9	0.0±0.0
Average	5.6±0.2	10.3±1.3	11.9±2.8	0.5±0.2	14.7±4.9	7.2±2.2	12.4±1.8	0.1±0.1
ANOVA								
p value	0.3	0.2	0.6	0.8	0.2	0.1	0.8	-
CV (%)	3.5	12.6	28.7	28.1	31.0	31.6	9.9	-
Year 2								
CP	4.9±0.2	8.0±0.8	10.7±2.8A	0.4±0.1	6.6±1.8	3.4±1.0	15.7±2.9	2.8±1.3
RP	4.8±0.2	7.5±1.6	7.4±1.0B	0.3±0.2	6.2±2.3	2.8±1.0	15.7±2.5	2.1±1.1
PNoD	4.7±0.3	7.8±0.7	12.5±4.3A	0.3±0.0	5.6±2.2	2.7±1.2	18.1±2.8	2.9±1.1
Average	4.8±0.2	7.8±1.0	9.8±2.7	0.3±0.1	6.1±2.1	3.0±1.1	16.5±2.7	2.6±1.2
ANOVA								
p value	0.7	0.7	0.03	0.85	0.7	0.7	0.6	-
CV	6,4	10.8	31.9	53.2	27.5	22.9	22.6	-

The number of five replications. Coefficient of variation (CV). Means were compared according to the t test (student; $p < 0.05$); columns identified with different capital letters represent the difference between systems; Ns: no significant difference.

In Year 2, soil nutrient contents were lower compared to the first year. The reductions in nutrients and pH in soil were expected due to nutrient demands by sugarcane in each sugarcane cycle. Oliveira et al. (2010) showed that sugarcane exports 92; 15; 188; 187; and 66 kg ha⁻¹ of nitrogen, phosphorus, potassium, calcium, and magnesium, respectively, using cultivars irrigated in a clay loam soil.

There was an increase of Al in soil from Year 1 to Year 2 associated with pH reduction (Table 2). This result is accorded with the role of Al in soil acidity, with a positive correlation between Al content and pH reduction (Otto et al., 2020).

Sugarcane yield and quality

In both years, the planting system's quality

parameters were not affected with an overall average of 17.58; 14.79; 84.10; and 124.7 Brix, pol, purity, and TRS, respectively (Figure 2). Some studies have shown the absence of significant difference between treatments related to these quality parameters (Marangoni et al., 2019). The lack of results may be related to the high adaptive capacity of RB966928 in different managements, compared to other commercial cultivars, as observed by Arcoverde et al. (2019b) studying two management systems with eight sugarcane cultivars.

In the first year, TRS was 124.6 kg Mg⁻¹ increasing to 142.2 kg Mg⁻¹ in the second year but without difference between planting systems (Figure 3). Arcoverde et al. (2019c) verified better results for the technological parameters of sugarcane under no-tillage than under reduced tillage, finding some positive correlations between the parameters with yield in both soil management systems. The sugarcane yield was associated positively with all quality parameters (Brix, pol, theoretical recoverable sugar), Table 3.

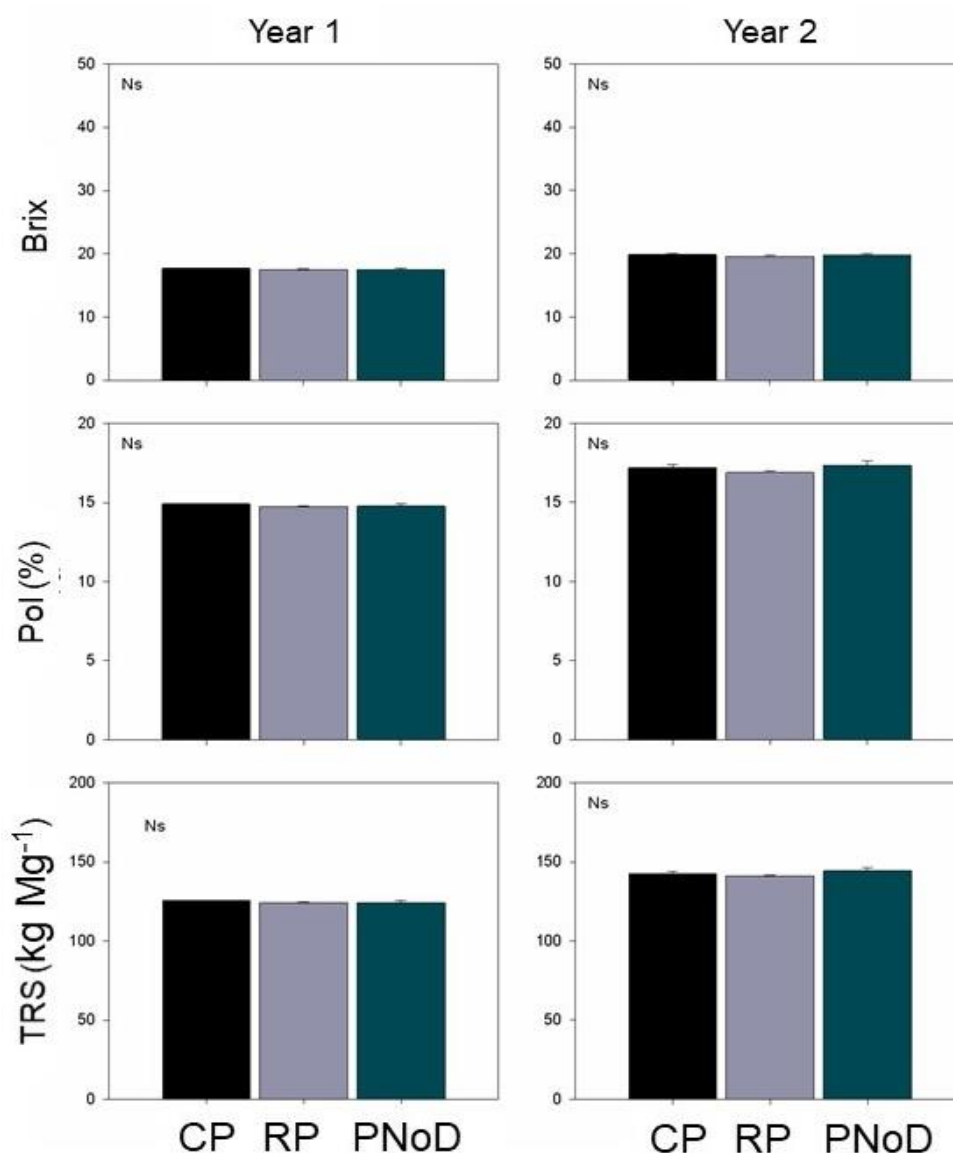


Figure 3 - Brix, pol (%), theoretical recoverable sugar, TRS (kg Mg⁻¹) with conventional planting (CP), reduced planting (RP) and planting without soil disturbance (PNoD) in the region of Nova Alvorada do Sul, Mato Grosso do South.

Means were compared according to the t test (student; $p < 0.05$); bars identified with different capital letters represent the difference between systems; Ns: no significant difference.

Table 3 - Sugarcane yield correlation with Brix, pol, theoretical recoverable sugar (TRS), and yield in Nova Alvorada do Sul, Mato Grosso do South.

	Brix	Pol	Yield
TRS	-0,57	-0,59	-0,60
Brix	-	0,99	0,98
Pol	-	-	0,99

The yield and sugarcane quality were correlated by Pearson's correlation ($p < 0.05$).

CONCLUSION

In short term, the reduced planting system promoted an increase in sugarcane yield than conventional planting and planting without soil disturbance. The quality parameters of sugarcane were not affected by planting systems. More studies are requested to compare and explain the sugarcane planting systems and their effect on soil conditions, mainly in long term.

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