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ESTOQUE DE CARBONO, DENSIDADE, POROSIDADE E NEMATOFAUNA DO SOLO EM ÁREAS COM E SEM APLICAÇÃO DE VINHAÇA[1]

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1 RESUMO

O objetivo deste estudo foi avaliar o estoque de carbono, a nematofauna e algumas propriedades físicas do solo de duas áreas cultivadas com cana-de-açúcar com diferentes manejos (sem e com aplicação de vinhaça). Desta forma, foram analisados a umidade, densidade do solo, porosidade total, estoque de carbono e os fitonematoides do solo das duas áreas. Amostras de solo foram coletadas em quatro pontos de amostragem nas profundidades de 0-10, 10-20, 20-30 e 30-40 cm, em cada área, totalizando 32 amostras. Os dados foram submetidos à análise de variância e as médias comparadas pelo teste Tukey à 5% de probabilidade. Não ocorreu variação significativa da umidade do solo no experimento, como também, não houve interação entre manejo e profundidade do solo para todas as variáveis estudadas. Entre os fitonematoides, *Helicotylenchus* mostrou-se significativamente sensível à aplicação da vinhaça. Ao contrário da porosidade total que foi 13% maior na área com aplicação da vinhaça, a densidade do solo, o estoque de carbono e o nível populacional de *Helicotylenchus* foram significativamente menores na área com aplicação da vinhaça, 7, 51 e 84%, respectivamente.

Palavras-chave: aproveitamento de resíduo, qualidade do solo, *Saccharum* spp.

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CARBON STOCK, SOIL DENSITY, POROSITY AND NEMATODE COMMUNITY IN REAS WITH AND WITHOUT APPLICATION OF VINASSE

2 ABSTRACT

This study aimed to evaluate carbon stock, nematode community, and some soil physical properties of two areas cultivated with sugarcane under different managements (without and with application of vinasse). Thus, soil moisture, bulk density, total porosity, carbon stock and plant parasitic nematodes were assessed. Soil samples were collected in four sampling points at 0-10, 10-20, 20-30 and 30-40 cm depths, totaling 32 samples per area. Data were subjected

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to analysis of variance and mean compared with Tukey test at 5% probability. Soil moisture did not significantly vary within the experiment, neither was significant the interaction between soil depths and management for any study variable. Within the plant-parasitic nematodes, Helicotylenchus was significantly sensitive to the vinasse application. In contrast to total porosity that was 13% higher; soil bulk density, carbon stock and Helicotylenchus populational level were significantly lower in the area with vinasse, 7, 51 and 84%, respectively.

Keywords: residue use, *Saccharum* spp., soil quality.

3 INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is considered one of the most important agricultural crops in Brazil. In Brazil, it is estimated that 592 million tons will be harvested in the 2021/2022 harvest. The sugarcane area to be harvested in the North/Northeast Region is estimated at 53,254 thousand tons, according to Conab (CANA-DE-AÇÚCAR, 2021).

Vinasse, one of the residues generated by the sugar and alcohol agroindustry, has been used in sugarcane-producing regions to improve soil fertility by providing macro- and micronutrients, increasing the organic matter content and preserving the carbon content in the soil, thus increasing crop development and increasing production (BARROS et al., 2010; BARROS et al., 2013; TAVEIRA, et al., 2020).

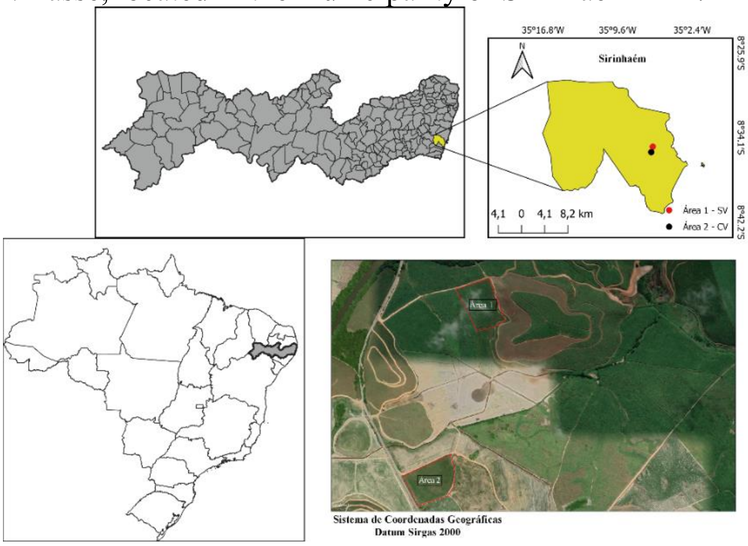
Certain management systems can result in changes in the preservation of organic matter and the physical and biological balance of the soil, which may or may not be favorable for soil conservation and agricultural production. Therefore, it is essential to choose systems that promote productive capacity and the conservation of soil properties (ROZANE et al., 2010).

The use of organic matter can be effective in controlling plant nematodes. Therefore, vinasse has significant potential as a management alternative because of its high organic matter content. Soil physical properties are also crucial for nematode survival. Any change that affects plant composition or physiological properties caused by changes in soil properties can affect species diversity (CAIXETA et al., 2011). Therefore, this study aimed to evaluate soil carbon stocks, nematode fauna, and some soil physical properties in two areas cultivated with sugarcane, with and without vinasse application.

4 MATERIALS AND METHODS

The study was carried out in the municipality of Sirinhaém, PE, in two areas cultivated with sugarcane located on the southern coast of the state of Pernambuco, at the Trapiche SA mill. The area without vinasse (SV) was located between coordinates 08°34'57.41 ”S and 35°06'11.53” W, and the area with vinasse application (CV) for five years was located at coordinates 08°35'29 ”S and 35°6'20.98” W. The sugarcane variety cultivated in both areas was B8008 (Figure 1). The climate of the region is humid tropical of the As' type or pseudotropical, according to the Koppen climate classification (1948), which is hot and humid, with rainfall from autumn to winter and average annual temperatures varying approximately 24°C.

Figure 1. Delimitation of the study areas, without (Area 1 - SV) and with application (Area 2 - CV) of vinasse, located in the municipality of Sirinhaém - PE.



Source: Authors (2021).

In each study area, a 10 m² square was delimited, and samples were collected at the corners of each square in the 0–10, 10–20, 20–30, and 30–40 cm layers, totaling 32 samples. These samples were collected with the aid of an undisturbed sample auger for physical analysis. For nematological analyses, samples of approximately 600 cm³ of soil were collected with the aid of a digger at each of the four depths. Composite sampling was also performed from each of the areas for physical and chemical soil characterization (Table 1).

Table 1. Physical and chemical characterization of the soil in the studied areas.

Sand	Silt	Clay	MO	pH $_{H2O}$	Textural classification
	g kg $^{-1}$		(%)		
			Area without vinasse		
507.1	101.5	391.4	15.37	5.32	Clay–sandy
			Area with vinasse		
442.9	223.5	333.6	9.7	5.23	Clay–sandy loam

MO: Organic matter.

After collection, the soil samples were placed in plastic bags and taken to the Soil Mechanics and Waste Utilization Laboratory and the Phytonematology Laboratory, belonging to the Federal Rural University of Pernambuco, for physical, chemical and nematological analyses.

The moisture, soil density and total porosity were determined via analyses following the methodology proposed by Embrapa (1997), and the soil carbon stock was calculated via the following expression (VELDKAMP, 1994):

$$Est\ C = \frac{(CO \times Ds \times e)}{10} \quad (1)$$

where Est C = organic C stock at depth (Mg ha $^{-1}$); CO = total organic C content at depth (g kg $^{-1}$); Ds = soil density at depth (kg dm $^{-3}$); and e = thickness of the layer considered (cm).

Analyses were performed by extracting nematodes from 300 cm³ of soil from each sample via the centrifugal flotation method in sucrose solution (JENKINS, 1964). Plant parasite population estimates were performed by counting samples on a Peters slide via an optical microscope, with two readings per sample. The results are expressed as the number of samples per 300 cm³ of soil. The plant parasites were identified to the genus level (MAI et al., 1996).

The data were subjected to analysis of variance, and the means, when necessary, were compared via the Tukey test at 5% probability. Furthermore, Pearson's correlation coefficient at 5% probability was used to determine the degree of simple linear correlation between the variables. The analyses were performed via R 4.1.0 software (R CORE TEAM, 2021).

5 RESULTS AND DISCUSSION

Vinasse application significantly affected the soil density, total porosity, and carbon stock. The variation in density and total porosity throughout the soil profile was significant. No significant effect of any of the factors on soil moisture was found, nor was there any interaction effect between management and soil depth for the variables analyzed (Table 2).

Table 2. Analysis of variance for the effects of vinasse application management and soil depth on moisture (U), density (Ds), total porosity (Pt) and carbon stock (EC) in areas cultivated with sugarcane.

FV	GL	U	Ds	PT	EC
		Mean Square			
Management (M)	1	0.0006 ^{ns}	0.0880 *	202,793 *	545.92 **
Depth (P)	3	0.0001 ^{ns}	0.0879 *	89,192 *	21.99 ^{us}
M x P	3	0.0002 ^{ns}	0.0023 ^{ns}	7,344 ^{ns}	11.69 ^{ns}
Residue	24	0.0009	0.0194	29,270	60.99
Total	31				

FV: source of variation; GL: degree of freedom; **, *, * and ^{ns}: significant at $p < 0.01$, $p < 0.05$ and not significant, respectively.

With respect to phytonematodes (Table 3), only vinasse application significantly affected the *Helicotylenchus community*. There was no interaction effect between vinasse application and soil depth for any of the genera analyzed.

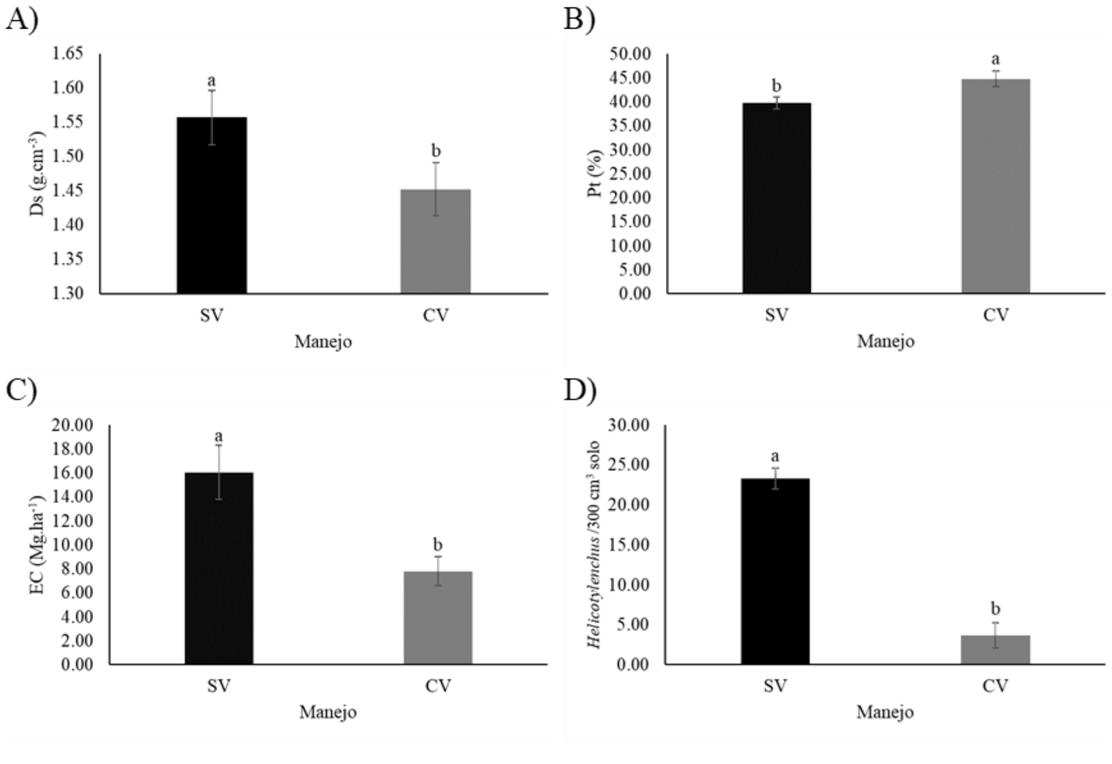
Table 3. Analysis of variance for the effects of vinasse application management and soil depth on the communities of *Meloidogyne* (Melo), *Pratylenchus* (Praty), *Helicotylenchus* (Heli), *Trichodorus* (Tricho) and *Criconemoides* (Crico) in areas cultivated with sugarcane.

FV	GL	Melo	Praty	Heli	Tricho	Crico
		Mean Square				
Management (M)	1	60.50 ^{ns}	3300.8 ^{ns}	3081.13 *	24.50 ^{ns}	0.34 ^{ns}
Depth (P)	3	146.46 ^{ns}	4835.5 ^{ns}	234.17 ^{ns}	92.21 ^{ns}	4.02 ^{ns}
M x P	3	67.50 ^{ns}	840.1 ^{ns}	230.12 ^{ns}	39.75 ^{ns}	8.63 ^{ns}
Residue	24	81.44	2195.0	722.00	50.27	7.22
Total	31					

FV: source of variation; GL: degree of freedom; **, *, * and ^{ns}: significant at $p < 0.01$, $p < 0.05$ and not significant, respectively.

The values of the soil bulk density, carbon stock, and *Helicotylenchus community* in the area with vinasse application were 7%, 51%, and 84% lower, respectively, than those in the area without vinasse application, differing statistically. On the other hand, the total porosity was 13% greater in the area with vinasse application (Figure 2).

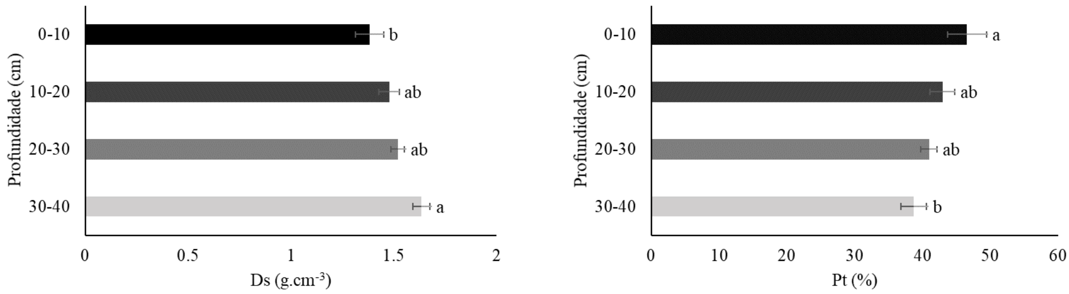
Figure 2. Test of means for soil density (A), total porosity (B), carbon stock (C) and *Helicotylenchus community* (D) in areas cultivated with sugarcane without (SV) and with (CV) vinasse application.



Analyzing the layers of the soil profile, the highest average soil density was observed at depths of 30 - 40 cm, corresponding to 1.64 $g.cm^{-3}$, differing statistically from the upper layer (0 - 10 cm), where the lowest soil density of 1.38 $g.cm^{-3}$ was found. Conversely, the highest soil porosity was found in the 0–10 cm layer (46.6%), which differed from the lowest soil layer (30–40 cm), which had the lowest total porosity (38.7%), reflecting the significant difference in soil density (Figure 3).

Figure 3. Density (A) and total porosity (B) in the soil layers of areas cultivated with sugarcane. Means followed by the same letter do not differ statistically according to the Tukey test (0.05 < p).

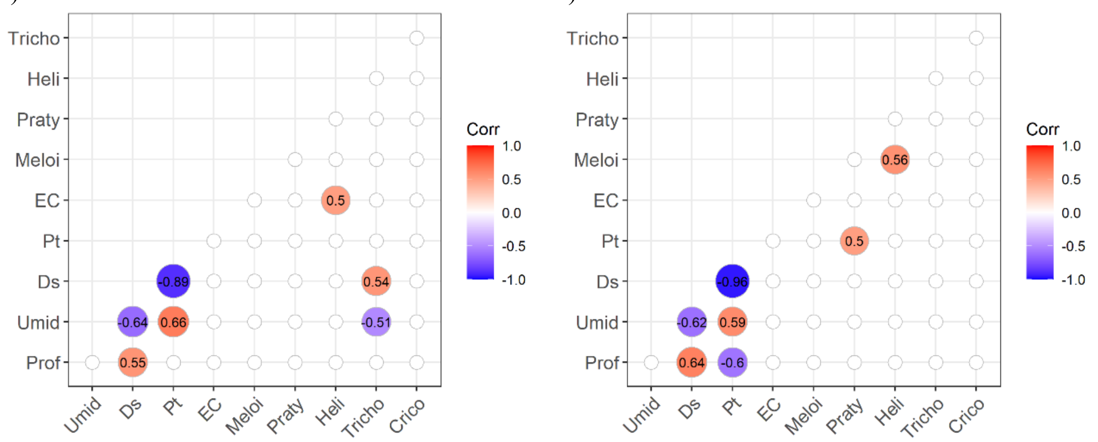
A) B)



In general, the soil physical properties were correlated with each other in both study areas (Figure 4). Analyzing the correlations involving plant nematodes in the area cultivated without vinasse addition (Figure 4A), the *Trichodorus community was* correlated with soil moisture (negatively) and bulk density. Furthermore, there was a correlation between *Helicotylenchus* and the soil carbon stock. In the area with vinasse addition (Figure 4B), the number of correlations involving plant nematodes was lower. There were positive correlations between *Pratylenchus* and total soil porosity and between *Helicotylenchus* and *Meloidogyne*. In both areas, no significant correlations were observed *with Criconemoides*.

Figure 4. Correlation coefficients of soil physical properties, carbon stocks and plant nematodes in areas without (A) and with (B) vinasse application.

A) B)



Prof: Depth; Umid: moisture; Ds: soil density; Pt: total porosity; EC: carbon stock; Meloi: *Meloidogyne*; Praty: *Pratylenchus*; Heli: *Helicotylenchus*; Tricho: *Trichodorus*; Crico: *Criconemoides*.

The higher density values and, consequently, the lower total porosity values in the deeper soil layers indicate that cultivation activities are affecting these areas. Similarly, Silva, Cabeda, and Lima (2005) reported lower soil density in areas cultivated with sugarcane irrigated with vinasse than in other management systems. Dos Santos et al. (2017), analyzing changes in soil physical properties after fertigation with vinasse in an area cultivated with sugarcane, reported that the soil density was significantly lower in the 0–10 cm layer, in addition to a reduction in soil porosity from the 20 cm layer onward.

In contrast to the results of this study, Barros et al. (2013) reported reductions in soil carbon stocks in areas cultivated with sugarcane with and without vinasse application, although this difference was not significant. Similarly, Canellas et al. (2007), who analyzed the stocks and quality of organic matter in soil cultivated with sugarcane for a long period (55 years), reported no significant differences in carbon stocks when tillage management with and without vinasse application at a depth of 20–40 cm was compared.

Matos et al. (2011), evaluating the relationships between nematofauna and soil chemical properties cultivated with sugarcane with vinasse application, reported a reduction in the number of phytonematodes in areas irrigated with vinasse compared with nonirrigated areas. Similar to the results reported in this study, Miranda et al. (2012) reported a reduction in the abundance of *Helicotylenchus* between evaluations carried out before and 10 days after vinasse application in an area cultivated with sugarcane.

The results of this study, those described by Matos et al. (2011), Miranda et al. (2012), and others cited in the literature, revealed the suppressive effect of vinasse on phytonematodes. Rodriguez-Kábana (1986) explained that the decomposition of organic matter by bacteria and fungi produces organic acids that can overcome the cuticle of nematodes, causing the death of phytonematodes.

6 CONCLUSION

The addition of vinasse to the sugarcane management system promoted a reduction in carbon stocks and soil bulk density, with an increase in total porosity. Among the plant-parasitic nematodes present in the soil, only the *Helicotylenchus* community was significantly sensitive to vinasse application. Soil moisture was not affected by the different management systems across the soil profile.

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