Effects of a vinasse-microorganism blend application on a Vertisol with sugarcane

Efectos de aplicación de vinaza mezclada con microrganismos sobre un Vertisol con caña de azúcar

José Gallego-Blanco[1, 2], Elizabeth Muñoz[1], and Leidy Hernández-Ríos[1]

ABSTRACT

The effect of a second dose of vinasse on some physical and chemical properties of a Vertisol was evaluated with cut sugarcane in Valle del Cauca, Colombia. We analyzed the expression of any possible toxicity in foliar tissue samples at the end of the cycle. Vinasse treatments added with two different mixtures of microorganisms were established in a randomized complete block with five replicates: soil without vinasse and no microorganisms; soils with a dose of vinasse, soils with two doses of vinasse; soils with a single dose of vinasse separately evaluated with two different mixtures of microorganisms and soils with two doses of vinasse separately evaluated with two different mixtures of microorganisms. The chemical properties evaluated were pH, soil organic matter content, C, N, P, Ca, Mg, Na, and K content, cation exchange capacity CEC and electrical conductivity EC. The physical properties determined were bulk density, particle density and porosity. There were no significant differences in the physical and chemical properties of the soil for the evaluated cultivation cycle with the application of one or two doses of vinasse with and without microorganisms. Leaf tissue analysis did not show a nutritional imbalance due to the second application.

Key words: *Saccharum officinarum*, efficient microorganisms, physical properties, chemical properties, leaf tissue, toxicity.

RESUMEN

El efecto de una segunda dosis de vinaza sobre algunas propiedades físicas y químicas de un Vertisol, fue evaluado para un corte de caña de azúcar en Valle del Cauca, Colombia. Se analizó la expresión de alguna posible toxicidad en muestras de tejido foliar al final del ciclo. Tratamientos de vinaza adicionada con dos mezclas diferentes de microrganismos se establecieron en bloques completos al azar con cinco repeticiones: suelo sin vinaza y sin ningún microrganismos; suelos con una dosis de vinaza; suelos con dos dosis de vinazas; suelos con una sola dosis de vinaza evaluando dos mezclas diferentes de microorganismos por separado y suelos con dos dosis de vinaza evaluando las dos mezclas diferentes de microorganismos por separado. Las propiedades químicas evaluadas fueron pH, contenidos de materia orgánica, C, N, P, Ca, Mg, Na, K, capacidad de intercambio catiónico CIC y conductividad eléctrica CE. Como propiedades físicas se determinaron densidad aparente, densidad real y porosidad. No hubo diferencias significativas en las propiedades físicas y químicas del suelo para el ciclo de cultivo evaluado, con la aplicación de una o dos dosis de vinazas al suelo con y sin microorganismos. Los análisis de tejido foliar tampoco mostraron algún tipo de desequilibrio nutricional debido a la segunda aplicación.

Palabras clave: *Saccharum officinarum*, microrganismos eficientes, propiedades físicas, propiedades químicas, tejido foliar, toxicidad.

Introduction

Vinasse is the principle waste generated in the distillation of ethanol from sugar mills. Its chemical composition varies considerably from one distillery to another depending on the raw material used in the fermentation, the type and efficiency of fermentation, distillation and the varieties and the degree of ripeness of the cane used (Rao, 1983).

Several researchers have addressed the issue of the use of this waste from different perspectives: its use in the chemical industry of sugar derivatives (Berón, 2006; Wei and Xu, 2004), its biodegradation by microorganisms (Ryznar-Luty *et al.*, 2007), its use in protein production (Díaz *et al.*, 2003; Tauk, 1982), its use in the composting of different materials (Conil, 2006) and more recently, its use as a solid (Irisarri, 2006) or liquid fertilizer for sugar cane and other crops. With regard to the latter form of use, Coelho *et al.* (1985), assessed vinasse as a substitute in the fertirragtion of crops using its high nutrient content, and determined that fertilization with vinasse is economically viable.

In South America, Brazil is the country with the greatest experience in research and fertirrigation with vinasse on

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[1] Geades Group, Faculty of Basic Sciences, Universidad Autónoma de Occidente. Cali (Colombia).
[2] Corresponding author. Jmgallego@uao.edu.co

sugarcane. In the 80s, Oscar Braunbeck, a professor from the Agricultural Engineering School at the State University of Campinas and a group of researchers from the Center for Sugarcane Technology in Brazil, discovered the potential use of vinasse as fertilizer and developed a transport system for delivery directly from the distilleries to the fields (Almeida, 2007).

In Colombia, a single dose is regularly applied per cutting of the sugar cane crop, depending on the potassium content in the soil. Vinasse is high in potassium, calcium and organic matter (Jiang *et al.* 2012). Recent studies in Colombia have shown that vinasse with 10% and 55% of total solids or Brix are as efficient as KCl for K supply to growing sugarcane (Quintero, 2008).

Since the beginning of its widespread use as fertilizer, many studies have been conducted to evaluate the actual effects of the application of a single dose of vinasse on physical, chemical and biological soil properties (Rojas *et al*., 2008; Quintero *et al*., 2008; Montenegro *et al*., 2009).

This study aimed to contribute to the investigation of the effects of the application of a second dose of vinasse per cut on the cultivation of sugar cane and some physical and chemical properties of the soil.

Materials and methods

This study was conducted in the municipality of El Cerrito, Valle del Cauca (Colombia) in a vertisol soil, of the Corinthian-Santa Rosa consociation (CT-SH), classified as Typic Haplusterts (Quintero *et al*., 2008). This soil, cultivated with sugarcane *Saccharum officinarum* L. var. CC-8592, was evaluated for the first cut of the 2008 to 2009 growing season.

We used 15.6°Brix vinasse produced in the Ingenio Providencia distillery. This type of vinasse is regularly used by Ingenio for its sugarcane fertirrigation plans.

We implemented a randomized complete block design with seven treatments and five replicates to assess the effects of a second application of vinasse and its degradation in the soil by using two mixtures of efficient microorganisms inoculated into the vinasse before application. For this we analyzed the soil without any application (control), then applied the first dose of vinasse with different mixtures of efficient microorganisms (FDVM1, FDVM2), at mid-cycle, the second vinasse dose was applied with mixtures of microorganisms (SDVM1, SDVM2). Similarly, we also evaluated the effect of the vinasse application without any addition of microorganisms, with one dose (FDVWM) and with two doses (SDVWM).

Two mixtures of efficient microorganisms were used; mixture number one (M1) was a commercial product known as MyM® and mixture number two (M2) was prepared by the authors, with only some of the microorganisms included in the commercial product (Tab. 1). The microorganism strains used to make the second mixture were obtained from commercial offerings of production houses other than the one that supplies the MyM® formulation.

TABLE 1. Efficient microorganisms used in the two test mixtures.

Mixture 1 (M1)	Mixture 2 (M2)
Saccharomyces sp.	*Saccharomyces cerevisiae*
Azospirillum brasilense	*Azospirillum brasilense*
Azotobacter chroccocum	*Paecilomyces lilacinus*
Azospirillum vinelandii	*Trichoderma viride*
Pseudomonas fluorescens	
Lactobacillus casei	
Rhodopseudomonas palustris	
Paecilomyces lilacinus	
Trichoderma sp.	

Each experimental unit consisted of 10 m (six rows) by 10 m plots, with a total area of 100 m^2. The total study area was 2.6 ha. Each of the plots corresponding to the blocks and repetitions were separated by plots of equal size without any treatment, to avoid possible interactions between each of the treatments.

Irrigated vinasse doses depend on the content of exchangeable potassium in different soil types. In this paper, taking into account the high levels of potassium in the soil (greater than 0.40 cmol kg^{-1}), only 6,000 L ha^{-1} of vinasse was applied in each of the doses used.

For the first soil sampling, five composite samples were taken of the total study area; for the second sampling, a composite sample of each experimental unit was taken. All soil samples were taken at a depth of 10 to 20 cm.

The first sampling was performed before planting sugarcane and established the baselines. The second was performed one month after the first application of vinasse (plant age of 4.5). The third sampling was performed one month after the second application of vinasse (6.5 months).

At the start of the experiment, the soil showed very uniform physical and chemical properties, as seen in the small standard deviations of the data (Tab. 2A). This would imply that any difference in physical or chemical properties of the soil during the test would be attributable to the evaluated treatments rather than the soil heterogeneity.

Samples for measuring physical and chemical properties were taken according to the methodology recommended in ICA (1992). The properties evaluated were: pH (potentiometry, water 1:1), percentage of organic matter, C and N (Walkley and Black), phosphorus (Bray II), exchangeable cations and cation exchange capacity (ammonium acetate 1N - pH 7), Boron (Hunter colorimeter) and electrical conductivity (potentiometer) according to SSSA (1996). Bulk density (core method), particle density (pycnometer) and porosity (mathematical formula) in accordance with the methodology proposed by SSSA (1986).

Nutrient analysis was performed on leaf tissue samples composed of 25 leaves per plot; each leaf was referenced to the first with a visible neck or leaf TVD. The upper and lower thirds and the central vein were removed from each leaf, leaving only the middle third for analysis, approximately 40 cm in length. Nitrogen (Kjeldahl), phosphorus (Colorimeter), calcium, magnesium, potassium (atomic absorption spectroscopy), iron, copper, manganese, zinc (atomic absorption spectroscopy [nitric-perchloric mixture]), sulphur (turbidimeter), boro (colorimeter [azomethine-H]) were evaluated. Results underwent analysis of variance (ANOVA) and Pearson correlation coefficients were established by Statgraphics® software version 16:1.

Results and discussion

Physical properties

Bulk density is the mass of a unit volume of dry soil, within this volume are both solids and pore spaces included. The porosity is the ratio between bulk density and particle density of the soil expressed in percentage. Consequently, any factor that influences the pore space of a soil affects its bulk density (Brady and Weil, 2008).

After the second application of vinasse to the soil, there were no significant differences in bulk density or particle density in the evaluated treatments (Tab. 2B). The application of one or two doses of vinasse of 15.66°Brix, evaluated only in the first cutting of cane in a vertisol and under field conditions, did not cause significant effects on the evaluated properties.

These results differ with the findings of Jiang *et al*. (2012). These authors found a decrease of between 0.06 Mg m^{-3} and 0.07 Mg m^{-3} in the bulk density of soil consecutively treated with vinasse for a period of three years. This could indicate that this variable, when subjected to field

TABLE 2. Soil physical properties before (A) and after (B) applying the treatments and standard deviation in parentheses (the data correspond to five samples).

A

Texture	
Clay (%)	42.34 (3.75)
Lime (%)	35.34 (2.08)
Sand (%)	22.32 (4.60)
Particle density Mg m^{-3}	2.25 (0.1)
Bulk density Mg m^{-3}	1.21 (0.1)
Porosity (%)	46.22 (0.1)

B

Texture	Control	FDVM1	FDVM2	SDVM1	SDVM2	FDVWM	SDVWM
Clay (%)	44.7 (3.77)	42.7 (2.18)	43.5 (2.85)	43.1 (3)	42.16 (3.74)	43.76 (0.9)	46.56 (6.54)
Lime (%)	30 (0.51)	31.6 (1.33)	30 (1.92)	30.4 (3.43)	31.92 (2.28)	32.32 (0.9)	29.12 (9.32)
Sand (%)	25.3 (3.77)	25.7 (2.32)	26.5 (3.7)	26.5 (5.32)	25.92 (3.35)	23.92 (1.8)	24.12 (3)
Particle density Mg m^{-3}	2.44 (0.1)	2.47 (0.09)	2.52 (0.09)	2.4 (0.1)	2.47 (0.13)	2.36 (0.1)	2.41 (0.08)
Bulk density Mg m^{-3}	1.31 (0.13)	1.38 (0.1)	1.51 (0.1)	1.4 (0.09)	1.45 (0.25)	1.41 (0.15)	1.26 (0.06)
Porosity (%)	46.62 (3.18)	43.86 (3.11)	39.97 (5.93)	41.34 (4.2)	40.97 (12)	40.29 (5.85)	47.66 (2.9)

experiments, requires at least three years to be considered a good indicator of the effect of the application of a second dose of vinasse for the cane growing cycle.

Montenegro *et al.* (2009), assessing the effects of the application of two doses of vinasse on a maize crop sown in pots under greenhouse conditions, also found a reduction in the bulk density of a clay loam soil. However, these authors found an increase in bulk density when evaluated in soil with a sandy clay loam texture.

The bulk density, taking into account the soil pore space depends on the organization exhibited by the solid phase, is directly affected by texture (Jaramillo, 2002). While the tested soil, clay texture, did not present significant changes in bulk density for the treatments, soils with different textural classes may have changes in bulk density for the evaluated time period.

The porosity of the soil after the second application of vinasse showed no significant changes in the treatments. This differs from that reported by Gemtos *et al.* (1999) and Jiang *et al.* (2012). Because of its relationship with soil bulk density, it is likely that this variable also needs a period longer than 3 years for evaluation as an indicator of the effect of the addition of a second dose of vinasse to the soil.

Chemical properties

The evaluated soil (Tab. 3) showed a pH near neutrality (6.95). The organic matter content was medium considering the thermal floor (ICA, 1992). The contents of C, N and total C/N ratio were considered normal in the soil. The C/N ratio of the organic matter in the topsoil of agricultural soil usually presents average values near 12 (Brady and Weil, 2008). P contents were very high. The values of Ca and Mg were high but the C / Mg (1.94) ratio was within the recommended range (Brady and Weil, 2008). The contents of soil K (0.53 cmolc kg^{-1}) were high (Quintero, 2008). The Na content was suitable. The CEC is high and may result from high clay content in the soil (> 40%). The electrical conductivity was adequate, indicating that soil salinity was not a problem (ICA, 1992).

Soil pH for the time period evaluated did not present any significant change with the application of the two doses of vinasse per crop cycle. Increases in this variable during the test did not amount to a unit for any of the tested treatments (Tab. 3). This behavior is consistent with that reported by Jiang *et al.* (2012) who said that after three years of continuous application, the pH of the soil treated with vinasse only changed between 0.07 and 0.25 units as compared to soil without vinasse treatments.

Other authors, however, have reported changes in pH when conducting soil vinasse applications. Montenegro *et al.* (2009) found a near to unit change when a dose of vinasse was applied to two soils with different textures. Thus, we find authors who reported no changes and authors who reported changes in soil pH after application of vinasse.

TABLE 3. Soil chemical properties before (A) and after (B) applying the treatments and standard deviation in parentheses (the data correspond to five samples).

A	pH	MO	C	N	C/N	P	Ca	Mg	K	Na	CEC	EC
	1:1	------ % ------				mg kg^{-1}			cmolc kg^{-1}			mmhos cm^{-1}
	6.95 (0.35)	2.58 (0.28)	1.49 (0.2)	0.13 (0)	11.51 (0.2)	29.81 (7.2)	24.69 (3.6)	12.50 (1.3)	0.53 (0.12)	0.17 (0.02)	39.66 (13.6)	0.34 (0.1)
B	**pH**	**MO**	**C**	**N**	**C/N**	**P**	**Ca**	**Mg**	**K**	**Na**	**CEC**	**EC**
	1:1	------ % ------				mg kg^{-1}			cmolc kg^{-1}			mmhos cm^{-1}
Control	7.24 (0.35)	2.71 (0.17)	1.57 (0.1)	0.14 (0)	11.74 (0.29)	30.88 (11.4)	27.08 (2.92)	12.60 (0.64)	0.54 (0.02)	0.14 (0.01)	46.19 (5.2)	0.31 (0.05)
FDVM1	7.22 (0.5)	2.52 (0.33)	1.46 (0.2)	0.13 (0)	11.83 (0.24)	9.60 (11.4)	26.25 (1.7)	12.62 (1.3)	0.55 (0.02)	0.14 (0.01)	45.41 (11)	0.33 (0.05)
FDVM2	7.36 (0.5)	2.47 (0.33)	1.43 (0.2)	0.12 (0)	11.38 (0.12)	28.42 (7.1)	28.04 (4.5)	12.61 (0.7)	0.52 (0.03)	0.15 (0.01)	44.80 (5)	0.35 (0.12)
SDVM1	7.30 (0.3)	2.59 (0.16)	1.50 (0.1)	0.13 (0)	11.60 (0.28)	32.79 (10.4)	26.71 (2.1)	12.51 (0.76)	0.56 (0.02)	0.15 (0.01)	38.97 (4.6)	0.31 (0.06)
SDVM2	7.54 (0.25)	2.60 (0.18)	1.51 (0.1)	0.13 (0)	11.61 (0.3)	28.44 (5.1)	25.91 (3.6)	13.42 (0.52)	0.55 (0.06)	0.16 (0.01)	39.22 (11.9)	0.3 (0.04)
FDVWM	7.58 (0.2)	2.55 (0.23)	1.48 (0.1)	0.13 (0)	11.59 (0.2)	26.24 (5.5)	28.40 (1.74)	13.45 (0.8)	0.54 (0.05)	0.16 (0.02)	34.93 (4.1)	0.32 (0.06)
SDVWM	7.42 (0.25)	2.51 (0.33)	1.46 (0.2)	0.13 (0)	11.77 (0.23)	26.22 (7.6)	26.49 (4.1)	13.09 (1)	0.55 (0.05)	0.15 (0.01)	49.94 (7.8)	0.3 (0.05)

Control, without vinasse; FDVM1, first dose vinasse and efficient microorganisms1; FDVM2, first dose vinasse and efficient microorganisms2; SDVM1, second dose vinasse and efficient microorganisms1; SDVM2, second dose vinasse and efficient microorganisms2; FDVWM, first dose vinasse without efficient microorganisms, SDVWM, second dose vinasse without efficient microorganisms.

The contents of organic matter, total C and N in the soil are variables that require relatively long periods of time, at least four years, to show a significant change over time (Labrador, 2001 and Abbott and Murphy 2007). However, in this study, because of the nature of vinasse with a potentially high input of organic matter in the form of amino acids, proteins, sugars and lignin among others according to Berón (2006), it is estimated that this parameter could express a change responsive to the time period corresponding to the duration of the test, a cutting cycle of one year. The chemical characterization of the vinasse used in the present study is seen in Tab. 4.

However, the organic matter content of the soil was similar for all treatments and these values were found to be near to the initial ones (2.58%).

TABLE 4. Chemical characterization of the vinasse used in the study and standard deviation in parentheses (the data correspond to four samples).

Parameter	Value
°Brix	15.66 (0.91)
pH	4.27 (0.11)
MO (%)	5.75 (0.45)
NT (kg m^{-3})	2.5 (0.02)
P_2O_5 (kg m^{-3})	0.6 (0.01)
CaO (kg m^{-3})	4.3 (0.08)
MgO (kg m^{-3})	3.2 (0.03)
K_2O (kg m^{-3})	13.8 (0.05)
Na_2O (kg m^{-3})	0.9 (0.02)
S (kg m^{-3})	3.3 (0.02)
B (mg L^{-1})	3.3 (1.13)
Cu (mg L^{-1})	17.46 (10.6)
Fe (mg L^{-1})	181.7 (56.6)
Mn (mg L^{-1})	69.7 (16.6)
Zn (mg L^{-1})	18.42 (4.9)

Montenegro *et al.* (2009) also found no significant changes in the percentages of organic matter soil content after application of vinasse. Quintero (2008), after 20 years of vinasse application to mollisols and vertisols soils, found little change in the values of organic matter. Clearly then, in a much shorter time period, such as the one year duration of this trial, these changes are even less noticeable and significant, proving the statements by Labrador, (2001) and Abbott and Murphy (2007).

Consistent with the behavior of the organic matter content of the soil, the contents of total C, N and C/N ratio of the soil before and after applications of vinasse presented no change. Regarding the contents of total N, this trend is consistent with that reported by Jiang *et al.* (2012), who found no significant changes in this variable after three years of continuous application of vinasse. However, Gemtos *et al.* (2009) found an increase in this variable when a dose of vinasse was applied in a wheat crop cycle.

The reserve of total N in soil is constituted more by organic N fractions than by inorganic N fractions. Organic N represents 95 to 99% of total N in soils (Labrador, 2001; Sylvia *et al.*, 2005; Brady and Weil, 2008). One suggested explanation for the behavior of the total soil N is that due to the relatively short time period of the test duration, it is possible that the potential contribution of organic matter from vinasse could not degrade to form part of the final reserve of organic soil N, and consequently did not significantly influence the total N content of the soil. Confirmation of this explanation will be the subject of study or research in future projects.

The content of phosphorus in the soil before and after application of vinasse showed no statistically significant changes. The values of this element always remained classified as very high. The same trend in this element was reported by Jiang *et al.* (2012), the authors found no significant changes between soils fertilized with vinasse and unfertilized soils.

The exchangeable bases Ca and Mg showed no statistically significant differences between treatments. This behavior is consistent with the views expressed by Montenegro *et al.* (2009), the authors found no changes in the content of these bases after application of vinasse to the soil. However, Quintero (2008) takes the opposite view in stating that the consecutive application of vinasse for 20 years slightly increased contents of Ca and Mg in the soil.

The K content in the soil had no significant difference with the addition of two doses of vinasse for the cane growing cycle. It was expected that additions of vinasse, rich in K, would increase the content of this element in the soil, however, under the conditions of this trial that did not happen. This trend is different from that reported by Quintero (2008); Gemtos *et al.* (2009) and Montenegro *et al.* (2009). The authors reported that the K content increased markedly after adding vinasse to the soil. Jiang *et al.* (2012) found that the K content in soils treated with vinasse was significantly higher than in soils without any treatment. The authors stated that high concentrations of K in the vinasse make this a useful byproduct as a fertilizer in all soil types. It is possible that in this study changes in soil K content were not able to manifest due to the short time of evaluation.

Regarding the influence of the application of vinasse on soil EC, there was not a significant difference between soils with and without addition of vinasse. The same happened to Na content and the Sodium Absorption Ratio SAR. This differs from that reported by Montenegro *et al*. (2009), who related major changes in Na content and RAS with vinasse application. Gemtos *et al*. (2009) also reported increases in the content of exchangeable Na after applying vinasse to the soil. Quintero (2008) found that applying vinasse for 20 years lead to a slightly increased soil content of exchangeable Na. Correlation analysis showed that the most strongly related variables were CN-MO, as might be expected.

Leaf tissue

Measurements of leaf tissue in the sugar cane plant are used to diagnose mineral deficiencies or plant nutrient disorders, conduct a survey of the nutritional status and make recommendations within fertilization programs in line with the real needs of the crop (Cháves, 1999). In the present study, the purpose of this analysis was only to determine the absorption and accumulation of nutrients by the cane plant, presenting the differences in the evaluated treatments and relating them to the nutrient content from the soil after being irrigated with vinasse.

However, prescribing an accurate diagnosis on the chemical analysis of leaf tissue is complex because the concentration of nutrients in the plant is highly variable and depends on factors associated with the plant and soil, with direct and indirect involvement. Some factors are associated with the plant variety, age, moisture content and the development and condition (stability) of its root system. Factors associated with soil are the agro-ecological zone, moisture content, physical and chemical properties and management practices in the field, among others.

Cháves (1999) presented an overview of the optimal concentrations of the major macro and micronutrients in sugarcane leaf tissue. Tab. 5 presents the nutritional contents of foliar tissue samples for each treatment.

According to Cháves (1999), the levels of P, K, Ca, Mg, Fe, Mn, Cu and B are within the proper range or sufficient, while Zn and N have low concentrations. However, for all evaluated treatments, plant nutrients were found to be within the proper range taking into account age and variety, the physical and chemical characteristics of the soil and the crop agro-ecological zone.

Foliar K content, the most abundant element in vinasse, did not show an effect, accumulation or toxicity for the cane for the evaluated cutting. Analysis of variance showed no significant differences with respect to the nutritional content of the plant (Tab. 5). One might infer that a second application of vinasse with a concentration of 15.66°Brix, irrigated in the doses and time of the test, in the variety CC-8592, caused no nutritional imbalance that could be seen through the leaf tissue analysis.

This contrasts with the findings of Quintero (2008), who after applying different doses of vinasse for 20 consecutive years, found that in nine-month-old CC-8592 varieties, foliar contents of N, Ca and Mg decreased, and foliar K content increased, and furthermore, there was no effect on foliar P content.

These differences between the two tests could be explained by the short evaluation period of this study, compared with that of Quintero (2008).

Conclusions

Vinasse applications under the conditions used in this trial did not affect the physicochemical properties evaluated for a single cut of the sugar cane cultivation in a vertisol soil in Valle del Cauca, Colombia. However, since soil is

TABLE 5. Concentration of macro and micronutrients in evaluated leaf tissue.

	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	B
					------ % ------					
Control	1.32	0.21	1.06	0.39	0.25	184.72	28.18	7.40	15.92	4.69
FDVM1	1.28	0.19	1.09	0.35	0.24	179.24	26.92	7.48	19.52	4.05
FDVM2	1.26	0.20	1.09	0.34	0.24	191.96	29.40	7.68	15.50	5.18
SDVM1	1.26	0.20	1.13	0.33	0.23	156.60	28.72	7.86	16.44	4.12
SDVM2	1.20	0.21	1.20	0.30	0.21	154.26	38.98	7.22	17.92	5.25
FDVWM	1.27	0.20	1.09	0.32	0.24	136.72	39.24	7.28	18.82	5.19
SDVWM	1.27	0.20	1.16	0.32	0.22	151.30	30.06	7.00	16.32	5.14

Control, without vinasse; FDVM1, first dose vinasse and efficient microorganisms1; FDVM2, first dose vinasse and efficient microorganisms2; SDVM1, second dose vinasse and efficient microorganisms1; SDVM2, second dose vinasse and efficient microorganisms2; FDVWM, first dose vinasse without efficient microorganisms, SDVWM, second dose vinasse without efficient microorganisms.

a complex and comprehensive resource of these production systems, its physicochemical characterizations and evaluations must always be accompanied by an efficient indicator of the biological properties of the soil. Therefore, these and other results should be taken only as an approximation of the behavior of soils when treated with these types of additives.

Vinasse applied in one or two doses does not make a significant contribution to the soil organic matter readily observable in one crop cutting. New ways of using this additive should be explored, mixed with different materials for example, in order to get medium term significant changes in the percentages of organic matter in the treated soil.

Similarly, it would be important to future studies of both individually applied vinasse and vinasse mixed with different materials and in different proportions to determine the coefficients of mineralization and humification and thus define more precisely the forms, dose and time of application to properly synchronize with the phenological stage of the crop to take full advantage of this method.

A second vinasse application of 15.66°Brix in soils cultivated with the sugar cane variety CC-8592 did not influence the nutrient content in leaf tissue samples taken from 9.5-month-old plants, in the first cut. It would be important to determine the behavior of these parameters for a complete cycle consisting of four or five cuts depending on the variety of the sugarcane cultivated in this type of soil in Valle del Cauca.

All studies evaluating the addition of two doses of vinasse on a sugarcane crop cycle must be carried out for a period of at least 4 years, allowing the studied variables enough time to express themselves and so produce more conclusive results.

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