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Effects of Different Soil Management Systems in the Chemical Properties in the Coastal Plains of State Paraiba

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Abstract: This study evaluated the chemical characteristics of soils under different management systems, i.e., the culture of sugar cane with and without vinasse compared to forest area in the Coastal Plains of State Paraiba. For each management system were opened five profiles occurring in the same soil class, dystrophic Ultisol grayish. In each profile, the soil samples were collected at 0-5, 5-10, 10-20 and 20-40 cm depths. These samples, after being air dried and passed through a sieve of 2 mm, were characterized chemically. Data were analyzed using descriptive statistics, analysis of variance and Tukey test at 5% probability. The pH, electrical conductivity, exchangeable aluminum, potential acidity and phosphorus results, in relation to soil management, were significantly affected; in relation to depth, there was a significant effect on the pH results and on the electrical conductivity, calcium, sodium, potassium, potential acidity and P results. However, for area x depths there was a significant difference only for aluminum, potential acidity and phosphorus contents. The results of this study show that treatment with vinasse application promotes improvements in soil chemical properties such as pH increases and the availability of K and P in the surface layers of soil.

Key words: Cane sugar % Vinasse % Soil characteristics

INTRODUCTION

The native vegetation of the unit geo-environmental titled Coastal Plains of region Northeastern, Brazil, is Atlantic Forest. In general, the soils of this environment are of low natural fertility, acidic, with low supply of organic matter, low cation exchange capacity; due to the presence of clay kaolinite in these soils contain high exchangeable Al saturation, low levels of phosphorus and potassium and organic matter provides the greatest amount of soil nitrogen [1].

The Coastal Plains have significant economic and social importance, particularly because the diversity of agricultural production with great emphasis on the production of sugar cane. This production has progressed significantly in this area and in the whole national territory [2].

With the advent of the Pro-Alcohol program in 70 years, ethanol production increased significantly throughout the country and consequently the volume of vinasse.

For a long time vinasse was released into water bodies, but after identifying their property as fertilizer is now used in sugar cane [3]. Changes in soil chemical properties resulting from the application of vinasse in continuous cultivation of sugar cane can provide insight into production on a sustainable basis. The vinasse resulting from the manufacture of ethyl alcohol by fermentation is composed mainly of organic acids and cations such as K, Ca and Mg. When applied properly in the soil can provide positive effects, such as raising the pH, the greater availability of plant nutrients, increased ion exchange capacity and improve soil physical structure, reflecting better water storage, aeration and root

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development, resulting in the significant increase in productivity [4, 5]. The distillery spent wash applied to soil through irrigation with water showed there was enrich in the plant nutrients (N.P.K) in the soil and no adverse effect on other parameters [6].

According to Brito & Rolim [7] and Brito *et al*. [8] increases in potassium content and high pH were the main changes in area that received vinasse more than 20 years. Evaluating forms of phosphorus in a soil cultivated with sugar cane vinasse applied, Busato *et al*. [3] concluded that this addition increased by 48% total phosphorus content in the soil sample of 0-20 cm depth.

Despite the changes that are occurring in production systems and soil management in the Paraiba State, there are few studies carried out in sugar-cane fields, with regard to environmental aspects, mainly related to the practice of fertilizing with vinasse.

A soil's characterization is fundamental to know its quality and potencial to produce agricultural products [9]. Therefore the aim of the present study was to evaluate the chemical characteristics of soils under different management systems, i.e., the culture of sugar cane with and without vinasse compared to forest area in the Coastal Plains of State Paraiba.

MATERIALS AND METHODS

The survey was carried out on the Miriri Alimentos e Bioenergia S/A, Capim, Municipality, State of Paraíba, Brazil (latitude 6°56' South; longitude 35°07' West, 70 m a.s.l.). The regional climate is tropical (hot and humid) with relative humidity around 80% and average annual temperature and rainfall of 28°C and 1,200 mm, respectively. According to Chaves and Farias [10] in this area the soil is typical dystrophic Ultisol grayish with texture ranging from sandy loam to sandy clay loam.

In the study area the different land uses were the following treatments: native Forest considered the reference system; the planting area of sugar cane with and without vinasse application. The exact coordinates of all profiles in the study were obtained through a global positioning system (GPS), ensuring the possibility of sampling again in the exact location (Table 1).

For each management system were opened five profiles occurring in the same soil class. In each profile, the soil samples were collected from March to April 2010, at depths of 0-5, 5-10, 10-20 and 20-40 cm. These samples, after being air dried and passed through a sieve of 2 mm, were characterized chemically according to the methods recommended by Embrapa [11].

The experimental design was completely randomized in factorial scheme 4 x 3, with five replicates (five profiles) and four depths (0-5; 5-10; 10-20 and 20-40 cm) and three sites (forest; cane sugar with vinasse; cane sugar without vinasse).

Data were analyzed using descriptive statistics by calculating the maximum, minimum, mean and coefficient of variation. Data were subjected to analysis of variance for repeated measures in space (depth). Analysis of variance and Tukey test at 5% probability were made for comparison of means.

Table 1: Geographic location of soil sampling points

Area	Latitude (South)	Longitude (West)
Forest Profile 1	6°59' 56"	35°07' 12.2"
Forest Profile 2	7°00'40.1"	35°07' 35.3"
Forest Profile 3	7°00' 21.9"	35°07' 33.9"
Forest Profile 4	7°00' 34.7"	35°08' 12.9"
Forest Profile 5	7°00' 58.4"	35°08' 03.8"
Sugar cane with vinasse Profile 1	7°00' 11.1"	35°07' 14.7"
Sugar cane with vinasse Profile 2	7°00' 35.1"	35°07' 33.3"
Sugar cane with vinasse Profile 3	7°00' 34.7"	35°08' 17.5"
Sugar cane with vinasse Profile 4	7°00' 58.4"	35°08' 09.8"
Sugar cane with vinasse Profile 5	7°00' 23.8"	35°07' 30.0"
Sugar cane without vinasse Profile 1	7° 05' 01.0"	35°06' 47.7"
Sugar cane without vinasse Profile 2	7° 05'19.2"	35°06'05.1"
Sugar cane without vinasse Profile 3	7° 05'10.8"	35°05'57.8"
Sugar cane without vinasse Profile 4	7° 05'29.0"	35°06'41.1"
Sugar cane without vinasse Profile 5	7° 05'46.1"	35°07'11.7"

RESULTS AND DISCUSSION

The pH, electrical conductivity (EC), exchangeable aluminum (Al), potential acidity (H + Al) and phosphorus (P) results, in relation to local, were significantly affected ($p < 0.01$); in relation to depth, there was a significant effect on the pH results ($p < 0.05$) and on the EC, calcium (Ca), sodium (Na), potassium (K), potential acidity and P results ($p < 0.01$). However, for area x depths there was a significant difference only for Al, potential acidity ($p < 0.05$) and P contents ($p < 0.01$) (Table 2).

The pH is the mechanism used to identify the soil acidity, or identified through this technique the hydrogen ions concentration in soil solution [12]. Regardless of the depth of soil samples, it was found that soil samples from the area of the forest (M) had high acidity reaction according to the minimum (3.9) and maximum (4.8) pH; in soil samples from areas with sugar cane with vinasse (SCV) ranged from 4.4 to 5.5, classified as high to medium acidity and soil samples from areas with sugar cane without vinasse (SCWV) ranged from 4.2 to 6.9, classified as high to weak acidity (Table 3).

Table 2: Summary of variance analysis for the chemical soil properties

		Mean square								
Source of Variation	DF	pH	CE	Ca	Mg	Na	K	Al	H+Al	P
Local	2	9.08**	133506.23**	0.08	0.82	0.0006	0.035	1.18**	82.37**	35.36**
Res.(a)	12	0.36	1866.43	0.37	0.24	0.0002	0.01	0.15	8.85	3.02
Depths	3	0.42*	3488.35**	1.72**	0.20	0.0005**	0.01**	0.03	11.53**	7.84**
Dep.x Loc.	6	0.22	232.36	0.03	0.05	0.0002	0.005	0.084*	4.53*	1.86**
Res.(b)	36	0.14	388.11	0.14	0.12	0.00009	0.003	0.031	1.71	0.46

*, ** Significant at 5 and 1% (F test), respectively

Table 3: Descriptive statistics for pH and electrical conductivity (EC) of soil samples collected at depths of 0-5 cm, 5-10 cm, 10-20 cm and 20-40 cm in different areas of land use (forest (F); sugar cane with vinasse (SCV), sugar cane without vinasse (SCWV))

	Depth, cm											
Statistic	0-5	5-10	10-20	20-40	0-5	5-10	10-20	20-40	0-5	5-10	10-20	20-40
	pH											
	Forest				SCV				SCWV			
Minimum	3.9	4.0	4.1	4.1	4.8	4.7	4.4	4.5	5.0	4.2	5.2	5.0
Maximum	4.8	4.7	4.7	4.8	5.5	5.1	5.4	5.5	6.9	6.4	5.8	5.6
Mean	4.4	4.3	4.3	4.5	5.0	4.7	4.9	4.9	6.2	5.4	5.6	5.4
CV (%)	8	6	7	7	6	5	9	9	11	16	4	5
	Aluminum, $cmol_c\ kg^{-1}$											
	Forest				SCV				SCWV			
Minimum	0.20	0.20	0.40	0.20	0.00	0.20	0.20	0.20	0.00	0.00	0.00	0.20
Maximum	1.40	1.40	1.00	0.60	0.20	0.60	0.60	0.60	0.20	0.00	0.20	0.80
Mean	0.60	0.72	0.64	0.44	0.16	0.28	0.28	0.32	0.04	0.00	0.16	0.32
CV (%)	85	61	41	38	56	64	64	56	224	-	56	84
	Potential Acidity (H + Al), $cmol_c\ kg^{-1}$											
	Forest				SCV				SCWV			
Minimum	2.31	2.09	1.70	1.32	2.01	1.73	1.02	0.61	0.18	0.26	0.54	0.36
Maximum	7.92	14.82	6.52	3.71	4.45	4.77	4.21	2.57	1.88	1.65	1.58	0.84
Mean	5.15	7.17	4.23	2.63	2.94	2.88	2.09	1.46	0.71	0.86	0.90	0.59
CV (%)	42	70	53	38	35	41	60	59	97	67	44	29
	Electrical conductivity, $\mu S\ cm^{-1}$											
	Forest				SCV				SCWV			
Minimum	66.9	54.6	53.3	50.9	123.9	98.9	73.3	80.7	56.7	62.7	62.4	59.8
Maximum	93.0	87.9	63.2	64.2	195.6	138.6	109.6	113.9	216.8	154.1	136.9	72.5
Mean	78.8	66.1	58.3	57.8	145.6	117.6	96.6	92.9	98.3	90.5	83.2	68.2
CV (%)	13	20	8	10	20	15	15	14	68	41	37	7

CV= coefficient of variation

Table 4: Mean values of soil pH and electrical conductivity (E.C.) depending on the type of activity (or area) and depth

	Type of activity (or area)		
Attributes	Forest	SCV	SCWV
pH	4.38c	4.94b	5.72a
E.C. (µS/cm)	64.05b	115.66a	84.53ba

	Depth (cm)			
	0 - 5	5 - 10	10 - 20	20 - 40
pH	5.26a	4.88b	4.96ab	4.95ab
E.C (µS/cm)	107.55a	91.39ab	81.59bc	71.78c

pH= soil pH; E.C.= electrical conductivity; SCV= sugar cane with vinasse; SCWV= sugar cane without vinasse.

Means followed by same letters in the lines do not differ by Tukey test to 5% probability.

The aluminum (Al) average levels in soil samples from Forest areas were classified as medium (0.4 to 1.0 $cmol_c\ kg^{-1}$) [13] despite the maximum values of this element in the 0 to 20 cm depths were classified as high; in other soil samples were classified as low (0 a 0, 3 $cmol_c\ kg^{-1}$) (Table 2). In other words, the largest and lower aluminum levels occurred in the forest and in sugar cane area, respectively, following changes in pH [14, 15]. Studying soils submitted to the cultivation of sugar cane, Severiano *et al*. [16] and Portugal *et al*. [15] found the mean levels of Al, 0.1 to 1.1 $cmol_c\ dm^{-3}$ and 0.60 to 0.83 $cmol_c\ dm^{-3}$, respectively, similar to results found by this research.

The potential acidity values (H^+ Al) ranged between type of activity presented behavior similar to that shown by Al^{3+}, with the highest values observed in the Forest classified as low (0 a 2.5 $cmol_c\ kg^{-1}$) to high (>5.0 $cmol_c\ kg^{-1}$) [13] and lowest in the area of sugar cane without vinasse, classified as low (Table 2), corroborating with Portugal *et al*. [15].

The coefficients of variation of pH values were low (CV < 12%) [17], except for treatment without vinasse in the 5-10 cm depth which was classified as medium, confirming several studies in the literature and later, with Chaves *et al.* [18]. Since the coefficients of variation (CV) of the Al and potential acidity levels were classified as medium (12% < CV < 62%) and, with some exceptions, such as high (> 62%), generally, at 0 -5 cm and 50-10 cm depths (Table 3).

According to Santana *et al*. [19] the electrical conductivity expresses of the salts amount present in the soil solution. Thus the greater the salts amounts present in the solution the greater the electrical conductivity value. According to the classification of Warrick and Nielsen [17], the coefficients of variation were classified as low (CV < 12%) in treatments Forest, 10-20 cm and 20-40 cm depths and SCWV at 20 -40 cm depth; at 0-5 cm and 5-10 cm depths of the Forest, at all depths of the SCV and at 5-10 cm and 10-20 cm depths from the SCWV, the coefficients of variation were classified as mean (12 < CV < 62%); finally, at 0-5 cm depth of the SCWV, the coefficient was classified as high (CV > 62%) (Table 3).

The areas under cultivation with sugar cane showed the highest pH values (Table 4), probably as a result of residual effects of liming taken over the cycles of this crop, corroborating Portugal *et al*. [15] and Vasconcelos *et al*. [20]. And no matter what type of activity, there is a trend of decreasing pH with increasing depth in the soil profile, as Corá *et al.* [21] and Portugal *et al*. [15] (Table 4).

The pH values of Forest and SCV areas are less than the SCWV area (Table 4) due to increased presence of organic matter in these two areas mentioned above; according to Costa Junior [22], the decomposition of plant residues promotes the release of H^+ ion with the consequent decrease in pH values.

The electrical conductivity value was higher in SCV area, however, no significant difference between this area with SCWV; likewise no significant difference between the Forest and SCWV values. When did the comparison of EC values in relation to the depths, there was a progressive decrease with increasing depth (Table 4).

In the statistical analysis, observed significant difference among the Al and acidity potential contents of different locations and depths ($p< 0.01$) and the interaction between these parameters ($p< 0.05$) (Table 5).

The Al and potential acidity contents in the Forest area were more significant among the type of activity in all depths followed by sugar cane with and without vinasse area (Table 5) corroborating Portugal *et al*. [15] and Vasconcelos *et al*. [20]. However, with respect to depth, there was a significant difference only in the potential acidity amounts in the Forest area. According to Silva-Olaya [23] the decrease in the potential acidity values occurred with increasing depth in the profile is the result of the decrease in pH values with increasing depth (Table 4).

Table 5: Mean aluminum and potential acidity contents as a function of depth in management system

	Type of activity (or area)		
Depth (cm)	Forest	SCV	SCWV
	Aluminum, $cmol_c\ kg^{-1}$		
0-5	0.6 aA	0.16 aAB	0.04 aB
5-10	0.72 aA	0.28 aAB	0.00 aB
10-20	0.64 aA	0.28 aAB	0.16 aB
20-40	0.44 aA	0.32 aA	0.32 aA
	Potential Acidity, $cmol_c\ kg^{-1}$		
0-5	5.15 abA	2.94 aAB	0.72 aB
5-10	7.17 aA	2.88 aB	0.86 aB
10-20	4.23 bA	2.09 aA	0.90 aA
20-40	2.63 bA	1.46 aA	0.60 aA

SCV= sugar cane with vinasse; SCWV= sugar cane without vinasse. Means followed by same lowercase letters in columns and capital letters in lines do not differ by Tukey test to 5% probability

Table 6: Descriptive statistics for calcium, magnesium, sodium, potassium and phosphorus of soil samples collected at depths of 0-5 cm, 5-10 cm, 10-20 cm and 20-40 cm in different areas of land use (Forest (F); sugar cane with vinasse (SCV), sugar cane without vinasse (SCWV))

	Depth, cm											
Statistic	0-5	5-10	10-20	20-40	0-5	5-10	10-20	20-40	0-5	5-10	10-20	20-40
	Calcium, $cmol_c\ kg^{-1}$											
	Forest				SCV				SCWV			
Minimum	0.29	0.37	0.20	0.18	0.64	0.34	0.40	0.24	0.73	0.57	0.24	0.25
Maximum	2.16	1.82	0.77	0.65	2.13	1.61	0.68	0.66	1.95	1.38	1.39	0.65
Mean	1.12	0.86	0.55	0.40	1.22	0.84	0.57	0.45	1.31	0.87	0.83	0.42
CV (%)	80	70	41	47	46	60	19	42	33	38	50	35
	Magnesium, $cmol_c\ kg^{-1}$											
	Forest Mata				SCV				SCWV			
Minimum	0.54	0.32	0.75	0.40	0.47	0.17	0.39	0.31	0.96	0.99	0.85	0.66
Maximum	1.54	2.09	0.96	1.54	1.32	1.34	1.31	1.04	1.56	2.06	1.34	1.47
Mean	1.12	0.95	0.84	0.84	0.89	0.74	0.85	0.70	1.32	1.38	1.09	1.00
CV (%)	39	72	10	54	42	68	38	44	18	30	21	32
	Sodium, $cmol_c\ kg^{-1}$											
	Forest				SCV				SCWV			
Minimum	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Máximo	0.04	0.03	0.02	0.03	0.06	0.04	0.01	0.01	0.01	0.02	0.03	0.01
Mean	0.03	0.02	0.01	0.01	0.03	0.02	0.01	0.01	0.00	0.01	0.01	0.00
CV (%)	30	40	30	120	77	99	62	62	93	78	120	93
	Potassium, $cmol_c\ kg^{-1}$											
	Forest				SCV				SCWV			
Minimum	0.05	0.05	0.04	0.04	0.07	0.05	0.04	0.05	0.04	0.04	0.02	0.04
Maximum	0.09	0.09	0.07	0.05	0.55	0.37	0.18	0.07	0.13	0.11	0.05	0.04
Mean	0.07	0.07	0.05	0.05	0.20	0.15	0.09	0.06	0.06	0.06	0.04	0.04
CV (%)	21	21	23	15	96	82	62	14	59	50	34	0.00
	Phosphorus, $mg\ dm^{-3}$											
	Forest				SCV				SCWV			
Minimum	1.8	0.9	0.5	0.0	27.5	5.2	5.6	1.1	2.8	2.2	1.5	3.6
Maximum	3.6	3.7	2.6	1.6	52.8	44.3	33.3	50.2	47.6	26.6	18.5	18.3
Mean	2.6	2.0	1.3	0.5	44.7	32.2	17.1	18.7	24.2	16.0	7.9	7.6
CV (%)	26	55	67	122	23	44	65	110	68	64	83	81

CV= coefficient of variation

Changes in calcium (Ca) levels was medium to low in Forest and sugar cane with vinasse management systems at 0-5 cm depth and in Forest at 5-10 cm depth (Table 6). In other depths and in all management systems, the levels were low, with lower values, in general, in Forest, corroborating Portugal *et al*. [15]. In Yellow dystrophic Ultisol, cultivated with sugar cane, Neto *et al*. [24] found that Ca average concentration was 0.90 $cmol_c$ dm^{-3}, values similar to those found in this research. Considering that levels 2 to 3 $cmol_c$ kg^{-1} of Ca are suitable for crop development, it can be said that in areas of study of this element there are deficiencies in most crops, related to the nature of the soil. According to the data presented in Table 6, it was observed that the highest coefficients of variation (CV) values corresponded to 0-5 and 5-10 cm depths in the Forest management system, classified as high (CV > 62%); other values were classified as medium (12% < CV < 62%) [17].

Apparently the Ca results the results of Ca in the areas of sugar cane without vinasse are higher than in other studied areas, however, these results in terms of management systems, no significant difference (Table 7) disagreeing Vasconcelos *et al*. [20] that showed significant difference in terms of their data management systems. When comparing the four depths was observed that there was a decrease in calcium content with increasing depth (Table 7). According to Silva-Olaya [23] the highest concentrations of this element in the surface layers is due to the cycling of nutrients through the decomposition of crop residues on the soil surface, besides the fact that the application of lime in areas under cultivation of sugar cane.

The soil magnesium (Mg) levels were varied (Table 6), however, the levels were predominantly classified as medium [13]. The coefficients of variation (CV) of these levels were classified as medium (12% < CV < 62%) [17] except in the 5-10 cm depth in forest and sugar cane with vinasse systems. Although the Mg levels were slightly higher in the area of sugar cane without vinasse and have decreased with the depth they showed no significant difference (Table 7), disagreeing with Vasconcelos *et al*. [20] who found higher levels in the cropping systems under application of vinasse compared to the management system under irrigation. Whereas the magnesium content sufficient for most crops is about 0.4 $cmol_c$ kg^{-1} and the concentration of 0.8 $cmol_c$ kg^{-1} is considered high [25], we can say that in study area in general has no deficiency of this element since the soil samples showed levels around 0.8 $cmol_c$ kg^{-1}. These results agree with Diogenes *et al*. [26] that found in Oxisol soil in the 0-20 cm and 20-40 cm depths medium Mg content of 0.82 $cmol^{-1}$ dm^{-3} and 0.63 $cmol^{-1}$ dm^{-3}, respectively.

The sodium (Na) values were very low for all treatments ranging from 0.00 to 0.03 $cmol_c$ kg^{-1} (Table 6). When comparing these values can be seen that practically there was no variation for all values. According to statistical analysis, the Na levels had significant differences in relation to depth, being higher in subsurface layers (Table 7). Still, Na levels were not relevant in all soil samples analyzed.

According to the potassium (K) data, most of the soil samples were low (<0.12 $cmol_c$ kg^{-1}) (Table 6) corroborating Neto *et al*. [24], who observed in soils

Table 7: Mean values of the attributes of soil calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K) depending on the type of activity (or área) and depth.

	Type of activity (or area)		
Attributes	Forest	SCV	SCWV
Ca ($cmol_c$ kg^{-1})	0.73a	0.77a	0.86a
Mg ($cmol_c$ kg^{-1})	0.84a	0.80a	1.20a
Na ($cmol_c$ kg^{-1})	0.02a	0.02a	0.01a
K ($cmol_c$ kg^{-1})	0.06a	0.13a	0.05a

	Depth (cm)			
	0 - 5	5 - 10	10 - 20	20 - 40
Ca($cmol_c$ kg^{-1})	1.22a	0.86ab	0.64bc	0.42c
Mg($cmol_c$ kg^{-1})	1.11a	1.03a	0.93a	0.84a
Na($cmol_c$ kg^{-1})	0.02a	0.02ab	0.01b	0.008b
K($cmol_c$ kg^{-1})	0.11a	0.09ab	0.06b	0.04b

Means followed by same letters in the lines do not differ by Tukey test to 5% probability.

Table 8: Mean phosphorus values (mg dm^{-3}) as a function of depth in management system

	Type of activity (or area)		
Depth (cm)	Forest	SCV	SCWV
0-5	2.6 aA	44.7 aB	24.2 aAB
5-10	2.0 aA	32.2 abB	16.0 abAB
10-20	1.3 aA	17.1 cB	7.9 bA
20-40	0.5 aA	18.7 bcA	7.6 bA

Means followed by same lowercase letters in columns and capital letters in lines do not differ by Tukey test to 5% probability

cultivated with sugar cane, similar K levels, ie, 0.07 and 0.1 $cmol_c$ dm^{-3}, respectively; the mean K levels (0.12 to 0.38 $cmol_c$ kg^{-1}) were found only in the system sugar cane with vinasse and at 0-5 cm and 5-10 cm depths.

Following the classification of the CV proposed by Warrick and Nielsen [16] observed that the K levels in the system management sugar cane with vinasse in the first two depths, showed high variability (CV > 62%) and in other soil samples from all management systems, the K showed moderate variability (12% < CV < 62%).

The K results, depending on the depths, showed a significant difference (Table 7) with the lowest levels in layers below 10 cm depth, corroborating Ferreira *et al*. [27] and Vasconcelos *et al*. [20]; however, according to the management system, there was no significant difference, despite higher K levels were observed in the area with sugar cane with vinasse (Table 7). These data were discordant in Portugal *et al*. [15] showing that the K^+, Ca^{2+} and Mg^{2+} varied significantly between the different land uses with higher levels observed in sugarcane fields over the forest. According Camilotti *et al*. [28] showed the efficiency of vinasse as K source in the productivity of sugar cane.

In general, the P available levels in the surface layers (0-10 cm) of the three management systems ranged from low (2.0 - 2.6 mg dm^{-3}), in the Forest, to high (32.2 to 44.7 mg dm^{-3}) in the sugar cane with vinasse, presenting mean values (24.2 to 16.0 mg dm^{-3}) in sugar cane without vinasse [11]; in layers subsurface (10-40 cm) the element levels were all low (Table 6). According Zalamena [29] phosphorus is more concentrated in the surface soil due to deposition of crop residues and low mobility in the soil profile.

Following the classification of the CV proposed by Warrick and Nielsen [17] observed that the P levels in Forest management systems and sugar cane with vinasse in the first two depths, showed moderate variability (12% < CV < 62%) corroborating, in part, with the results presented by Corá *et al.* [21]. In the other soil samples of these two management systems and the other from the area with sugar cane without vinasse, the phosphorus concentration showed high variability (CV > 62%).

In relation to management systems, it was observed the highest levels of phosphorus in the system of sugar cane with vinasse, followed by sugar cane without vinasse and forest, which showed significant difference (Table 8). These higher values can be attributed to frequent applications of fertilizer, mainly by the vinasse, over time in the area. This behavior was similar to that reported by Portugal *et al*. [15] showing that the levels of P remaining on the plantation were higher in both depths, than in Forest.

Phosphorus levels decreased significantly with depth, with the exception of the P levels observed in the Forest area (Table 8); the fact of the P moving into the soil by diffusion, which causes little mobility, contributes to its accumulation in the soil in the surface layers where fertilizers are applied.

CONCLUSIONS

In general, low levels of nutrients in the Forest soil can be explained partly by the fact that in this environment, most of the nutrients is allocated in the vegetation, beyond poverty Ultisol chemistry and its high degree of weathering. Despite the improved chemical obtained from the management system with the planting of sugar cane have dystrophic character, probably due to the large export of nutrients by crops, as well as losses by leaching or erosion. These results suggest that liming and fertilization practices are necessary to maintain soil productivity in this, since he has no way to replenish these nutrients naturally. For some high levels, such as phosphorus, are attributed, as already mentioned, for frequent fertilizers applications, mainly by vinasse.

REFERENCES

1. Sobral, L.F., K.R. Silveira and R.D. Viana, 2008. Comparison of Resin, Mehlich-1 and Mehlich-3 extractants for phosphorus and potassium, in Coastal Tableland soils. Bulletin of Research and Development 33. Aracaju: Embrapa Tabuleiros Costeiros.

2. Costa, O.V., R.B. Cantarutti, L.E.F. Fontes, L.M. Costa, P.G.S. Nacif and J.C. Faria, 2009. Soil carbon stocks under pasture in costal Tableland areas in southern Bahia state, Brazil. Brazilian J. Soil Sci., 33: 1137-1145.
3. Busato, J.G., L.P. Canellas and A.C.X. Velloso, 2005. Phosphorus in an Inceptsoil under long-term sugarcane. I - Sequential fractionation. Brazilian J. Soil Sci., 29: 935-944.
4. Leal, J.R., N.M.B. Amaral Sobrinho, A.C.X. Vellosom and R.O.P. Rossielo, 1983. Redox potencial and pH: a variation in soil treated with vinasse. Brazilian J. Soil Sci., 7: 257-261.
5. Silva, M.A.S., N.P. Griebeler and L.C. Borges, 2007. Use of stillage and its impact on soil properties and groundwater. Brazilian J. Agricultural and Environmental Engineering, 11: 108-114.
6. Chidankumar, C.S., S. Chandraju and R. Nagendraswamy, 2009. Impact of distillery spent wash irrigation on the yields of top vegetables (Creepers). World Applied Sciences J., 6: 1270-1273.
7. Brito, F.L. and M.M. Rolim, 2005. Comportment of effluent and soil fertirrigated with vinasse. Agropecuária Técnica, 26: 60-67.
8. Brito, F.L., M.M. Rolim and E.M.R. Pedrosa, 2009. Effect of vinasse application in chemical characteristics of soils from forest zone of\Pernambuco. Brazilian J. Agricultural Sci., 4: 456-462.
9. Prieto-Méndez, J., H. Rubio-Arias, F. Prieto-García, A.D. Roman-Gutiérrez, M.A. Mendez-Marzo and O.A. Acevedo-Sandoval, 2011. Soil quality in terms of physical-chemical-metal properties for barely (*Hordeum vulgare*) production in the State of Hidalgo, Mexico. American-Eurasian J. Agricultural & Environmental Sci., 10: 230-237.
10. Chaves, L.H.G. and C.H.A. Farias, 2008. Spatial variability of carbon stocks in the Coastal Tablelands of Paraiba state, Brazil: Soil cultivated with sugarcane. Brazilian J. Agricultural Sci., 3: 20-25.
11. EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária. Centro Nacional de Pesquisa de Solo, 1977. Manual methods of soil analysis. 2 ed. Rio de Janeiro: EMBRAPA. Serviço Nacional de Levantamento e Conservação de Solo, pp: 212.
12. Belizário, M.H., 2008. Changes in the soil carbon stocks due to agricultural land use in the Southwest Amazonian. 96f. Dissertation (MSc in Soils and Plant Nutrition) - São Paulo University, Piracicaba-SP.
13. Lopes, A.S. and J.A. Guidolin, 1989. Interpretation of soil analysis: concepts and applications. 2.ed. São Paulo: Comitê de Pesquisa/Técnico/ANDA, pp: 64.
14. Souza, D.M.G., L.N. Miranda and S.A. Oliveira, 2007. Soil acidity and its correction. In: Novais, R.F., V.H. Alvarez V.N.F. Barros, R.L.F. Fontes, R.B. Cantarutti and J.C.L. Neves, Soils Fertility. Viçosa, MG, Brazilian Soil Science Society, pp: 991.
15. Portugal, A.F., O.D.A.V. Costa and L.M. Costa, 2010. Physical and chemical properties of a soil under different production systems and forest in the zona da Mata region of Minas Gerais state (Brazil). Brazilian J. Soil Sci., 34: 575-585.
16. Severiano, E.C., G.C. Oliveira, N. Curi and M.S.D. Júnior, 2009. Use potential and structural quality of two soils under sugarcane production in goianésia, Goiás State, Brazil. Brazilian J. Soil Sci., 33: 159-168.
17. Warrick, A.W. and D.R. Nielsen, 1980. Spatial variability of soil physical properties the soil. In: Hill, D. (Ed.) Applications of soil Physics. New York: Academic Press, cap, 13: 319-344.
18. Chaves, L.H.G., G.A. Tito, A.D. Barros and H.O.C. Guerra, 2007. Soil chemical properties of the Sume irrigated perimeter, Paraíba State, Brazil. Caatinga J., 20: 110-115.
19. Santana, M.J., J.A. Carvalho, K.J. Souza, A.M.G. Sousa, C.L. Vasconcelos and L.A.B. Andrade, 2007. Effects of irrigation water salinity upon the sprouting and initial development of sugar cane (Saccharum spp) and on soils with different textural levels. Ciência e Agrotecnologia, 31: 1470-1476.
20. Vasconcelos, R.F.B., J.R.B. Cantalice, V.S. Oliveira, Y.D.J. Costa and D.M. Cavalcante, 2010. Aggregate stability in a dystrophic cohesive Yellow latosol of a costal plain under different sugarcane residue application. Brazilian J. Soil Sci., 34: 309-316.
21. Corá, J.E., A.V. Araujo, G.T. Pereira and J.M.G. Beraldo, 2004. Assessment of spatial variability of soil attributes as a basis for the adoption of precision agriculture in sugarcane plantations. Brazilian J. Soil Sci., 28: 1013-1021.
22. Costa Junior, C., 2008. Carbon and nitrogen stocks and soil aggregation under different managements in Rio Verde (Goiás State, Brazil). 140f. Dissertation (MSc in Chemistry in Agriculture and Environment) - São Paulo University, Piracicaba-SP.

23. Silva-Olaya, A.M., 2010. Dioxide carbon emission from different soil tillage in the sugarcane plantation. 103f. Dissertation (MSc in Soils and Plant Nutrition) - São Paulo University, Piracicaba-SP.
24. Neto, D.E.S., A.C. Oliveira, F.J. Freire, M.B.G.S. Freire, C.W.A. Nascimento and A.T. Rocha, 2009. Extraction of phosphorus in soils cultivated with sugarcane and relationship with buffer capacity of the soil. Brazilian J. Agricultural and Environmental Engineering, 13: 840-848.
25. Raij B. Van, 1981. Soil Fertility Diagnosis. Piracicaba: Instituto da Potassa & Fosfato, Instituto Internacional da Potassa, pp: 42.
26. Diógenes, L.C., J.F.L. Filho, J.L. Silva, J.C.A. Nóbrega, L.P. Pacheco, A.S.A. Júnior and R.S.A. Nóbrega, 2010. Carbon stock in Oxisol with livestock farming system integration in the Alvorada do Gurguéia, Piauí State. In: Brazilian Meeting on Management and Conservation of Soil and Water, 18, 2010, Teresina. Abstracts... Teresina: EMBRAPA Meio-Norte, CDRom.
27. Ferreira, E.V.O., I. Anghinoni, P.C.F. Carvalho, S.E.V.G.A. Costa and E.G. Cao, 2009. Soil potassium content in an integrated crop-livestock system under no-tillage with different grazing intensities. Brazilian J. Soil Sci., 33: 1675-1684.
28. Camilotti, F., I. Andrioli, M.O. Marques, A.R. Silva, L.C. Tasso Junior and F.O. Nobile, 2006. Physical atributes of oxisol cultivated with sugar cane after applications of sewage sludge and vinasse. Agricultural Engineering J., 26: 738-747.
29. Zalamena, J., 2008. Land use impact on soil chemical and physical atributes of the sul-riograndense plateau border. 79f. Dissertation (MSc in Soil Science) - Federal University of Santa Maria, Santa Maria.