PHYSICAL, CHEMICAL AND MICROBIOLOGICAL PROPERTIES OF A DYSTROPHIC YELLOW LATOSOL USING *MANIPUEIRA*

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ABSTRACT: The study aimed to evaluate chemical, microbiological and hydro-physical changes of a Dystrophic Yellow Latosol, receiver of different levels of *manipueira* (cassava wastewater) application, in the cultivation of 'Terra Maranhão' banana. The experimental design was a randomized block with three replications in a factorial scheme 3 x 4, in which it was considered three soil depths and four levels of *manipueira*. It was evaluated the weighted mean diameter of the aggregate, the percentage of aggregation at different periods, soil density, particle density, porosity and soil saturated hydraulic conductivity, in addition to pH of P (mg dm^{-3}), K (mg dm^{-3}), Ca (cmolc dm^{-3}), Mg (cmolc dm^{-3}), Ca+Mg (cmolc dm^{-3}), Al (cmolc dm^{-3}), Na (cmolc dm^{-3}), H+Al (cmolc dm^{-3}), CEC (cmolc dm^{-3}), V%, OM (g kg^{-1}), soil microbial biomass (Ug Cg^{-1} dry soil), acid phosphatase (Ug PNP g^{-1} h^{-1}). The use of *manipueira* influenced some physical characteristic of the soil, but it was not possible to specify the effect of increasing application dosage. Therefore, the application did not affect the biological indicators assessed in the soil or its pH. The use of *manipueira* as a fertilizer in the doses used in this study showed low increase of K, P, H+Al and Al in the soil and a good increase of Mg, Ca and Ca+Mg, Na, CEC and V%.

KEYWORDS: fertirrigation, water reuse, *Musa* spp.

CARACTERÍSTICAS FÍSICAS, QUÍMICAS E MICROBIOLÓGICAS DE UM LATOSSOLO AMARELO DISTRÓFICO COM USO DE MANIPUEIRA

RESUMO: O trabalho teve por objetivo avaliar as variações das características químicas, microbiológicas e físico-hídricas de um Latossolo Amarelo distrófico receptor de diferentes doses de aplicação de manipueira, em cultivo de banana 'Terra Maranhão'. O delineamento experimental foi em blocos casualizados, com três repetições, em esquema fatorial 3 x 4, no qual se consideraram três profundidades do solo e quatro doses de manipueira. Foram avaliados o diâmetro médio ponderado do agregado, a percentagem de agregação em diferentes períodos, a densidade do solo, a densidade da partícula, a porosidade e a condutividade hidráulica saturada do solo, além do pH, P (mg dm^{-3}), K (mg dm^{-3}), Ca (cmolc dm^{-3}), Mg (cmolc dm^{-3}), Ca+Mg (cmolc dm^{-3}), Al (cmolc dm^{-3}), Na (cmolc dm^{-3}), H+Al (cmolc dm^{-3}), CTC (cmolc dm^{-3}), V%, MO (g kg^{-1}), biomassa microbiana do solo (Ug C.g^{-1} solo seco) de Fosfatase ácida (Ug PNP g^{-1}.h^{-1}). O uso da manipueira influenciou algumas caracteristicas físicas do solo, mas não foi possível precisar o efeito do aumento da dosagem de aplicação. Entretanto, a aplicação não afetou os indicadores biológicos avaliados no solo nem o pH do solo. A utilização de manipueira como fertilizante, nas doses utilizadas no presente trabalho, apresentou baixo incremento de K, P, H+Al e Al no solo e um bom incremento de Mg, Ca e Ca+Mg, Na , CEC e V%.

PALAVRAS-CHAVE: fertirrigação, reúso de água, *Musa* spp.

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INTRODUCTION

Cassava (*Manihot esculenta* Crantz.) is a tuberous crop of South American origin, cultivated in many countries of the world and in almost all Brazil. Because of their adaptability to various climates and soil types, the relatively low level of technology required for its production and the variety of products obtained from it, mainly food, this crop is traditionally associated to small rural properties (SOARES et al., 2008). Cassava performs great social importance as it constitutes the main source of carbohydrates for more than 700 million people, mainly in developing countries (ALVES et al., 2008).

Manipueira is the liquid resulting from the pressing of the grated dough for the production of flour (DAMASCENO, 1999), generated in mean volume of 450 L per t of processed cassava. In soil, finely particulated organic matter present in *manipueira* may be easily biodegraded releasing appreciable amounts of nutrients (KIEHL, 1985).

Studies of effects of using cassava as fertilizer has been reported, with results being positive or not to the crop productivity (MARINI & MARINHO, 2011). In the case of effects on soil physical properties, few studies have been reported in the literature, and it does not address the behavior of the properties of interest in water management in soil, such as bulk density, particles and saturated hydraulic conductivity.

The production of waste originating from diverse activities has raised great concern, primarily due to the impacts it causes to the environment, especially with regard to contamination of soil, surface and underground water sources for various processes. The care with environmental preservation has grown in parallel with the increase of waste production generated by agribusiness, which may be used in agriculture as a form of partially replace synthetic commercial fertilizers (SANTOS et al., 2010).

CAOVILLA et al. (2010) states that the use of wastewater is not a new concept and has long been practiced around the world, earning nowadays importance to the reduction of availability of good quality water resources. According to MEDEIROS et al. (2008) the biggest advantages of the use of wastewater are conservation of the water available, the great availability of wastewaters, possibility of intake and nutrient recycling (reducing the need for chemical fertilizers) as well as contributing to preserving the environment.

The disposition of wastewater in the soil-plant system, when done without agronomic and environmental criteria, may cause problems of contamination of soil, surface water and groundwater, and toxicity to plants. On the other hand, if well planned, this application may bring benefits, such as source of nutrients and water for plants, reduction in the use of fertilizers and their pollution potential (ERTHAL et al., 2010). The reuse of water for irrigation is a practice widely studied and recommended by many researchers as a viable alternative to meet the water needs and, largely, the nutritional needs of the plants (ALVES et al., 2009).

Thus, the search for rational alternatives that enable water reuse becomes increasingly more necessary, both from the standpoint of the environmental and economic point of view, especially in arid and semi-arid regions where water resources are scarce. The Brazilian Northeast region is an example, commonly plagued by long periods of dry spells and almost periodic droughts (BEZERRA & FIDELIS FILHO, 2009).

This study aimed to evaluate the impact of the use of *manipueira* on chemical, physical and microbiological characteristics of a typical dystrophic Yellow Latosol from the Coastal Tablelands in Recôncavo Baiano, state of Bahia, Brazil, receiving different doses of *manipueira*.

MATERIAL AND METHODS

The experiment was conducted in the experimental fields of Embrapa Cassava & Fruits, in Cruz das Almas, State of Bahia, which geographic coordinates are: 12º48'S and 36º06'23"W, at an altitude of 225 m. The climate is Aw to Am, according to Köeppen classification; the annual medium pluviosity of 1,170 mm. The soil is classified as typical dystrophic Yellow Latosol (SOUZA & SOUZA, 2001) and presents textural classification according to Table 1.

TABLE 1. Textural characteristics of the soil of experimental area.

Depth (m)	Total of Sand ($g\ kg^{-1}$)	Silt ($g\ kg^{-1}$)	Clay ($g\ kg^{-1}$)
0 - 0.20 m	623	94	283
0.20 - 0.40 m	493	92	415
0.40 m - 0.60 m	490	95	415

The experiment was conducted in an experimental area planted with 'Terra Maranhão' banana, spaced 2.0 x 2.5 m, drip irrigated, with three emitters per plant. The characterization of the chemical composition of the wastewater (*manipueira*) was performed in the Laboratory of Soils and Plant Nutrition of Embrapa Cassava & Tropical Fruits. It was determined the concentrations of phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg) and sodium (Na). To determine the concentration of the elements, it was used nitropercloric digestion. *Manipueira* showed 327.7 mg L^{-1} of P, 3456.26 mg L^{-1} of K, 278.29 mg L^{-1} of Ca, 617.18 mg L^{-1} of Mg, and 22.06 mg L^{-1} of Na.

The experimental design was in randomized blocks with three replications in a factorial design, in which it was considered three depths (Z1-0 - 0.10 m; Z2 - 0.10 to 0.30 m, and Z3 - 0.30 to 0.50 m) and five doses of *manipueira* (D1 - application of 6 L of *manipueira* per plant per month, without mineral fertilization; D2 - application of 2 L of *manipueira* per plant per month with mineral fertilizer; D3 - application of 4 L of *manipueira* per plant per month with mineral fertilizer; and D4 - application of 6 L of *manipueira* per plant per month with mineral fertilizer). The mineral fertilization was done through fertirrigation with the application of urea and potassium chloride, with split of the total amount of nitrogen and potassium to maintain the same monthly percentage of the total applied.

TABLE 2. Soil chemical properties of the experimental area.

Depth	pH	P	K	Ca	Mg	Na	Al	H+Al	CEC	V	M.O
(cm)	(H_2O)	mg dm^{-3}	---------------------------- cmolc dm^{-3} ----------------------							(%)	g kg^{-1}
0 -20	5.17	4.33	0.26	1.17	1.27	0.14	0.30	3.15	5.60	47	7.54
20-40	5.27	4.33	0.13	1.30	1.10	0.15	0.70	3.45	5.00	48	7.31

The effect of the use of *manipueira* in hydro-physical properties in soil was evaluated through analysis of saturated hydraulic conductivity (Ko) by the constant head permeameter method, soil bulk density (ρ_b) volumetric ring method, particles (ρ_p), volumetric flask method, total porosity (η) from the bulk density (ρ_b) and particles (ρ_p), available soil water (AW) and aggregate analysis by wet manner.

Undisturbed samples were taken with an Uhland soil sampler, and disturbed samples in trenches in depths of 0-0.10, 0.10-0.30 and 0.30-0.50 m. These samples were collected in three periods, one before the implementation of *manipueira*, another at four months in beginning of the experiment and the last at 12 months after implementation. The data of available soil water (AW), density of bulk and particles, total porosity, weighted mean diameter (WMD) and percentage of aggregation (% AGREG) collected 14 months after the start of the experiment, submitted to variance analysis and to compare the averages, it was used the Tukey's test, adopting a level of significance of 10%.

The microbiological evaluations were performed at the end of the banana cycle in the Nematology Laboratory of Soil Microbiology of Embrapa Cassava & Fruit. The samples were submitted to analysis of microbial biomass (BM-C) by the fumigation-extraction method (VANCE et al. 1987, mentioned by ALMEIDA et al., 2008) and, acid phosphatase, based on the reading in spectrophotometer of p-nitrophenol, resulting from the enzymatic activity of acid phosphatase, according to the methodology described by DICK et al. (1996). The chemical evaluations were also made at the end of the crop cycle in the Laboratory of Soils and Plant Nutrition of Embrapa Cassava & Fruit. The chemical analyzes included the determination of exchangeable calcium (Ca^{2+}), Magnesium (Mg^{2+}) and Aluminum (Al^{3+}), extracted in solution of potassium chloride 1 mol L^{-1} and H+Al extracted in a solution of calcium acetate 0.5 mol L^{-1} dosed by titrimetry; available phosphorus by colorimetry; exchangeable sodium (Na^{+}) and potassium (K^{+}) extracted in solution of Mehlich 1 dosed by flame photometry, organic carbon and pH in water. We calculated potential cation-exchange capacity (CEC) and base saturation (V). The chemical and microbiological parameters were submitted to analysis of variance, and, to compare the averages, it was used the Tukey's test with significance level of 5%.

RESULTS AND DISCUSSION

Variance analysis of data collected 14 months after the start of the experiment showed no effect of depth and doses of *manipueira* for available soil water (AW), weighted mean diameter (WMD), and percentage of aggregates (AGREG%) (Table 3).

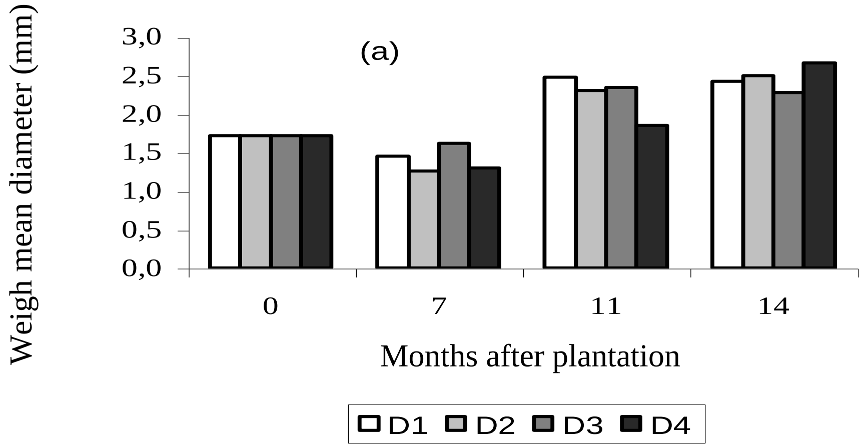
TABLE 3. Mean values of the variables AW, WMD e %AGREG 14 months after the beginning of the experiment.

Manipueira Dosage (L plant^{-1} month^{-1})	AW (mm)	WMD (mm)	Aggregation (%)
D1	0.61	2.52	61.07
D2	1.31	2.84	64.07
D3	0.32	2.43	57.45
D4	0.86	2.76	62.51

Thus, doses of *manipueira* had no effect on these dependent variables, indicating that there was no significant variation in soil moisture tensions related to upper and lower limits of available water and the factors that affect soil aggregation, in this specific case, organic matter.

The literature does not provide information of similar works with *manipueira*, however, PASSARIN et al. (2007) evaluated the stability of aggregates in a loam typical Rhodic Hapludox, treated with different doses of vinasse 0; 150; 300; 450 and 600 m^3 ha^{-1} and found that the same doses did not promote significant changes in weighted mean diameter (WMD) and soil %AGREG. CAMARGO et al. (1983) observed that in a medium-texture Dark Red Latosol which had received vinasse, there was no change in available water content in soils treated with vinasse. Additionally, there was no depth effect in the particles variable density.

Considering the evolution of WMD and % AGREG over the 14 months, there was an increase in the values of these variables during the experiment (Figure 1), which can be attributed to the increase in organic matter deriving from straw generated by from pseudostem defoliation. The starch that is completely embedded in the soil profile despite the hydrophilic nature, did not affect the stability of aggregates, which in part contrasts with the results of BASTOS et al. (2005), who assessed the stabilization of aggregates with addition of soluble starch of hydrophilic nature and did not verify influence of them in stabilizing the aggregates. Figure 1 shows the variations of the attributes relating to individual doses over time, but with a tendency of increasing the WMD and %AGREG.



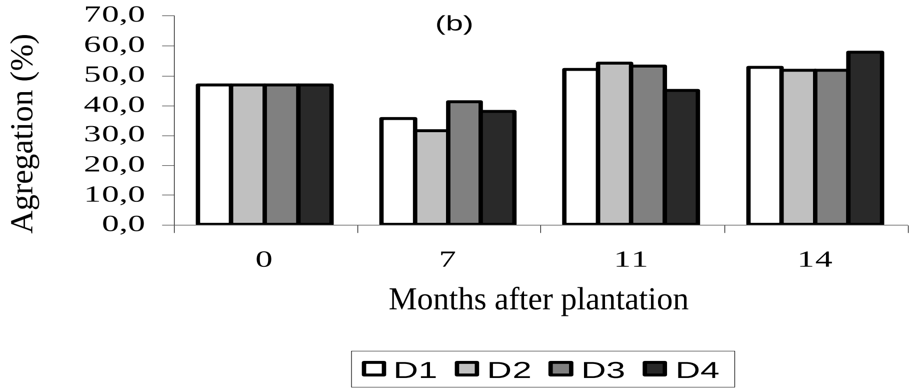


FIGURE 1.Weighted mean diameter (WMD) (a) and percentage of aggregate (%AGREG) (b) for the soil under different levels of *manipueira*.

Doses of *manipueira* had no effect on soil bulk density, according to analysis of variance at 10% probability (P> 0.10), whereas no difference was observed between the mean ρb by the Tukey's test (P> 0.10) (Table 4). While the literature does not provide similar work, i.e., regarding *manipueira*, similar behavior was observed by GONÇALVES et al. (2010) that evaluated the effect of secondary-treated domestic wastewater (STW) regarding porosity of an Rhodic Hapludox in the city of Lins, state of São Paulo, Brazil, and found that the variation of soil density was insignificant throughout the soil profile and between the plots. MAGESAN et al. (1999) also observed no change in soil density at 0-10 and 10-20 cm, after 7 years of irrigation with effluent, applying 3.120 mm year^{-1}. In the case of ρ_p, the equivalent average of D3 did not differ from D1 and D4, having only statistically differed from dose D2 and D0 (Table 4).

TABLE 4. Physical properties of soil under different doses of *manipueira* in the three studied depths.

Treatment	Soil Dens. ρ_b (Mg m^{-3})	Part. Dens. ρ_p (Mg m^{-3})	Total Porosity η (m^3 m^{-3})	Sat. H. Cond. Ko (mm h^{-1})
D0	1.56 a	2.57 c	0.391b	1.03 a
D1	1.59 a	2.44 ab	0.35 a	2.10 a
D2	1.55 a	2.53 b	0.38 b	1.65 a
D3	1.62 a	2.40 a	0.32 a	2.13 a
D4	1.58 a	2.47 ab	0.36 ab	1.35 a
Average	1.58	2.48	0.36	1.65

The treatment averages followed by different letters in the columns differ from one another by the Tukey's test at a level of 5% of significance.

Total porosity was affected by the applied treatments, whereas D1 and D3 had lower averages compared to D2, which did not differ from the dose of D0 and D4. These results show no coherence between each other and do not indicate any trend, despite the effects detected in the analysis of variance and differences between property averages, which shows that other variables may have had influence on the results. The literature shows a reduction of the total porosity of the soil with the application of wastewater, as observed by GONÇALVES et al. (2010) that applying treated domestic wastewater in a Rhodic Hapludox, noted a decrease in porosity in almost any soil profile. JNAD et al. (2001) explained the changes in porosity by applying wastewater by several factors: (a) the accumulation of Na^+ in suspension (b) deposition of organic material on the surface of the pores, and (c) increase of Na^+ in soil and dispersion/expansion of clays.

The results of the saturated hydraulic conductivity showed considerable variation (c.v.=45%), with no significant difference between treatments. These results may have been influenced by the use of *manipueira*, considering that SOUZA & SOUZA (2001) found no average values below 6.0 mm h^{-1} for the saturated hydraulic conductivity of the soil in question.

In Table 5, analysis of variance showed a significant effect of doses of *manipueira* levels of P, K, Ca, Mg, Al, H+Al and Na in the soil, however there was no significant difference between doses for phosphorus, which average was 3.95 mg dm^{-3}. In the case of potassium there was a significant difference between the levels observed in levels of *manipueira* ($P<0.05$). The dose D4 resulted in higher content, of 0.29cmolc dm^{-3}, followed by D1 and D3 doses, with an average of 0.23 and 0.19 mg dm^{-3}, respectively (Table 5). These results are coherent, since potassium is the most abundant element in *manipueira* and agree with those obtained by PINHO (2007) and MARQUES (2009) that evaluated different doses of *manipueira* on different soil types. RIBEIRO et al. (2009) showed an increase of exchangeable K^+ in the soil, highlighting the potential use of wastewater as nutrients suppliers to the soil.

To the variable Ca, the average dose was 2.05cmmolc dm^{-3}, with no significant difference between the doses of *manipueira* ($P>0.05$). These values were higher than those found by CARDOSO et al. (2009), wherein the Ca levels ranged from 0.5 to 0.7 cmolc dm^{-3} in soil samples at depths of 0.20 and 0.40 m, respectively, for soils fertilized with *manipueira*. To the variable Mg, the average dose was 1.22 cmolc dm^{-3}, and no significant difference between the averages ($P>0.05$). The values were lower than those recorded by SARAIVA et al. (2007), who found values of Mg between 2.8 and 4.8 cmolc dm^{-3} in an experiment with maize fertirrigated with *manipueira* in a Rhodic Hapludox.

There was no significant difference between the averages of concentration of aluminum to different levels of *manipueira*, the average found being of 0.09. These values are coherent with the values found by INOUE et al. (2010). The Na average dose obtained was 0.36cmolc dm^{-3}, with no significant difference between the concentrations observed in them.

There were significant differences between the average concentrations of H+Al regarding different levels of *manipueira*, and the D3 dose got the highest value, i.e., 2.37cmolc dm^{-3}, followed by D2 and D4, with 2.00 and 1.72 cmolc dm^{-3}, respectively. These results showed no coherence, but the higher dose corresponded to lower concentration of H+Al, which is in accordance with PINHO (2007), who verified reduction of the concentration of H+Al with increasing of the dose of *manipueira*.

Table 6 shows that there was no significant difference between the values of pH that showed overall average of 5.70. The pH values were slightly higher than those observed by MARQUES (2009) who found values between 5.2 and 4.9 at depths of 0.20 and 0.40 m, respectively, in similar soil under application of 9.6 m^3 ha^{-1} of *manipueira*. SILVA et al. (2011) evaluated the effect of wastewater from coffee culture with four doses in two incubation periods, and also found no significant effect on pH.

The average CEC of doses was 5.78 cmolc dm $^{-3}$; this value is consistent with those found by PINHO (2007) in soils of sandy, sandy-loamy and loamy textural classes, under application of *manipueira* ranging from 5 to 7 cmolc dm. For the percentage of base saturation the *manipueira* dose average was 66.4% with no significant difference between each other. There was also no significant difference between doses for organic matter, while the average for all doses was 11.30 g dm^{-3}. The results are consistent with PINHO (2007), who found that in sandy-loamy and loamy soil textural classes at 15 and 90 days after application of *manipueira* there was no effect on the organic matter.

There was no significant effect of applying *manipueira* on microbial biomass or in acid phosphatase (Table 6). According to FERNANDEZ et al. (2000), the acid phosphatase enzyme activity has increased as the availability of P for plants and microorganism population of the soil is reduced, a sensitive indicator of the bioavailability of P. Carbon biomass values may be explained by the level of organic load existing in *manipueira* and its transformation by decomposing microorganisms that feed on carbon of the soil. Soil microbiota is the main responsible for the decomposition of organic wastes, by nutrient cycling and energy flow within the soil, influencing both the transformation of organic matter and storage of carbon and mineral nutrients (JENKINSON & LADD, 1981).

TABLE 5. Levels of P, K, Ca, Mg, Al, H+Al, Na in Dystrophic Yellow Latosol after application of *manipueira* and banana cultivation. Cruz das Almas, 2010.

Treatment	P	K	Ca	Mg	Na	Al	H+Al	OM
	mg dm^{-3}	----------------------------cmolc dm^{-3}----------------------------						g kg^{-1}
D1	5.03a	0.19ab	2.22a	1.28 a	0.36a	0.11a	1.59a	11.13a
D2	3.71a	0.17a	2.06a	1.20 a	0.38a	0.11a	2.00ab	10.89a
D3	3.55a	0.23ab	1.76a	1.10 a	0.42a	0.12a	2.37b	11.37a
D4	3.50a	0.29b	2.14a	1.29 a	0.32a	0.05a	1.72ab	11.84a
Average	3.95	0.22	2.05	1.22	0.36	0.09	1.91	11.30

The treatment averages followed by different letters in the columns differ from one another by the Tukey's test at a level of 5% of significance

TABLE 6. Average values of pH, CEC (cmolc dm^{-3}), V%, OM (g kg^{-1}), acid phosphatase (Ug PNP g^{-1} h^{-1}), Biomass Carbon (Ug C.g^{-1} dry soil), Cruz das Almas, 2010.

Treatment	pH	CEC	V%	OM	Acid phosphatase	Biomass Carbon
D1	5.81 a	5.66 a	70.9	11.13 a	42.43 a	166.81 a
D2	5.74 a	5.79 a	65.0	10.89 a	46.85 a	156.78 a
D3	5.43 a	5.93 a	59.2	11.37 a	46.97 a	144.37 a
D4	5.82 a	5.78 a	69.9	11.84 a	51.62 a	178.51 a
Average	**5.70**	**5.78**	**66.4**	**11.30**	**46.97**	**162.11**

The treatment averages followed by different letters in the columns differ from one another by the Tukey's test at a level of 5% of significance.

CONCLUSIONS

The use of *manipueira* influenced the particle density and porosity of the soil and did not promote change in saturated hydraulic conductivity and soil density.

The variables available water (AW), weighted mean diameter (WMD), and percentage of aggregate (% AGREG), did not suffer influence of the increasing of doses of *manipueira* used.

Increased doses of *manipueira* studied did not affect the biological indicators assessed in the soil and did not affect soil pH. The use of *manipueira* as a fertilizer in the doses used in this study showed a low increase of K, P, H+Al and Al in the soil and a slight increase in Mg, Ca, Na, CEC and V%.

REFERENCES

ALMEIDA, M. da C. de.; TRINDADE, A.V.; MAIA, I.C.S.; MARQUES, M.C. Influências dos diferentes sistema de manejo no comportamento da microbiota do solo em áreas sob cultivo de mamão na região de Cruz das Almas, BA. *Revista de Biologia e Ciências da Terra*, v.8, n.1, p.67-75, 2008.

ALVES, J.M.A.; COSTA, F.A da C.; UCHÔA, S.C.P.; SANTOS, C.S.V. dos.; ALBUQUERQUE, J. de A.A. de.; RODRIGUES, G.S. Avaliação de dois clones de mandioca em duas épocas de colheita. *Revista Agro@mbiente On-line*, Boa Vista, v.2, n.2, p.15-24, 2008.

ALVES, W.W.A.; AZEVEDO, C.A.V.; NETO, J.D.; LIMA, V.L.A. Área foliar do algodoeiro irrigado com água residuária adubado com nitrogênio e fósforo. *Revista Verde de Agroecologia e Desenvolvimento Sustentável*, Mossoró, v.4, n.1, p.41-46, 2009.

BASTOS, R.S.; SÁ MENDONÇA, E. de; ALVAREZ, V.H.; CORRÊA, M.M. Formação e estabilização de agregados do solo decorrentes da adição de compostos orgânicos com diferentes características hidrofóbicas. *Revista Brasileira Ciência do Solo*, Viçosa, v.29, p.11-20, 2005.

BEZERRA, B.G.; FIDELIS FILHO, J. Análise de crescimento da cultura do algodoeiro irrigada com águas residuárias. *Revista Ciência Agronômica*, Fortaleza, v.40, n.3, p. 339-345, 2009.

CAMARGO, O.A.; VALADARES, J.N.S.; GERALDO, R.N. *Características químicas e físicas de solo que recebeu vinhaça por longo tempo*. Campinas: Instituto Agronômico, 1983. 30 p. (Boletim Técnico, 76).

CAOVILLA, F.A.; SAMPAIO, S.C.; SMANHOTTO, A.; NÓBREGA L.H.P.; QUEIROZ, M.M.F.; GOMES, B.M. Características químicas de solo cultivado com soja e irrigado com água residuária da suinocultura. *Revista Brasileira de Engenharia Agrícola e Ambiental*, Campina Grande, v.14, n.7, p.692-697, 2010.

CARDOSO, E. ; CARDOSO, D.; CRISTIANO, M.; SILVA, L. da; BACK, A.J. ; BERNARDIN, A.M.; PAULA, M.M.S. Use of manihot esculenta, crantz processing residue as biofertilizer in corn crops. *Research Journal of Agronomy*, v.3, p.1-8, 2009.

DAMASCENO, S.; CEREDA, M.P.; PASTORE, G.M. Desenvolvimento de *Geotrichum fragrans* em manipueira. *Energia na Agricultura*, v.14, n.2, p.7-14, 1999.

DICK, R.P.; BREAKWELL, D.P.; TURCO, R.F. Soil enzyme activities and biodiversity measurements as integrative microbiological indicators. In: DORAN, J. W.; JONES, A. J. *Methods for assessing soil quality*. Madison: Soil Science Society of America, 1996. p.247-272.

ERTHAL, V.J.T; FERREIRA, P.A.; MATOS, A.T.; PEREIRA, O.G. Alterações físicas e químicas de um argissolo pela aplicação de água residuária de bovinocultura. *Revista Brasileira de Engenharia Agrícola e Ambiental*, Campina Grande, v.14, n.5, p.467-477, 2010.

FERNANDEZ, L.A.; FAQUIN, V.; FURTINI NETO, A.E.; CURI, N. Frações de fósforo e atividade da fosfatase ácida em plantas de feijoeiro cultivadas em solos de várzea. *Revista Brasileira de Ciência Solo*, Viçosa-MG, v.24, p.561-571, 2000.

GONÇALVES, R.A.B.; GLOAGUEN, T.V.; FOLEGATTI, M.V.; LIBARDI, P.L.; LUCAS, Y.; MONTES, C.R. Distribuição de tamanho de poros nos solos irrigados com água sódica e de águas residuais. *Revista Brasileira de Ciência Solo*, Viçosa, v.34, n.3, p.701-707, 2010.

INOUE, K.R.A.; SOUZA, C.F.; MATOS, A.T.; SANTOS, N.S.; ALVES, E.E.N. Características do solo submetido a tratamentos com biofertilizantes obtidos na digestão da manipueira. *Tecnologia & Ciência Agropecuária*, João Pessoa, v.4, n.2, p.47-52, 2010.

JENKINSON, D.S.; LADD, J.N. Microbial biomass in soil: measurement and turnover. In: PAUL, E.A.; LADD, J.N. (Ed.), *Soil Biological. Biochemistry*. Washington, v.5, p.415-471,1981.

JNAD, I.; LESIKAR, B.; KENIMER, A.; SABBAGH, G. Subsurface drip dispersal of residential effluent: II. Soil hydraulic characteristics. *Transactions of the ASAE,* St. Joseph, v.44, p. 1159-1165, 2001.

KIEHL, E.J. *Fertilizantes orgânicos*. São Paulo: CERES, 1985. 492 p.

MAGESAN, G.N.; WILLIAMSON, J.C.; SPARLING, G.P.; SCHIPPER, L.A.; LLOYD-JONES,A.R. Hydraulic conductivity in soils irrigated with wastewaters of differing strengths: Field and laboratory studies. *Australian Journal of Soil Research*, Sidney, v.37, p.391-402, 1999.

MARINI, F.S.; MARINHO, C.S. Adubação complementar para a mexeriqueira 'Rio' em sistema de cultivo orgânico. *Revista Brasileira Engenharia Agrícola e Ambiental*. Campina Grande, v.15, n.6, p.562-568, 2011.

MARQUES, M.C. *Atributos do solo, qualidade do lixiviado e crescimento de plantas de milho sob aplicação de água residuária da mandioca*. 2009. 92 f. Dissertação (Mestrado) - Universidade Federal Rural de Pernambuco, Recife, 2009.

MEDEIROS, S.S.de; SOARES, A.A.; FERREIRA, P.A.; NEVES, J.C.L.; SOUZA, J.A.de. Utilização de água residuária de origem doméstica na agricultura: Estudo do estado nutricional do cafeeiro. *Revista Brasileira de Engenharia Agrícola e Ambiental*, Campina Grande, v.12, n.2, p.109-115, 2008.

PASSARIN, A.L.; RODRIGUEIRO, E.L.; ROBAINA, C.R.P.; MEDINA, C.C. Caracterização de agregados em um Latossolo Vermelho distroférrico típico submetido a diferentes doses de vinhaça. *Revista Brasileira de Ciência Solo*, Viçosa-MG, v.31, n.6, 2007.

PINHO, M.M.C.A. *Características químicas de solos adubados com manipueira*. 2007. 56 f. Dissertação (Mestrado) - Universidade Federal Rural de Pernambuco, Recife, 2007.

RIBEIRO, M.S.; LIMA, L.A.; FARIA, F.H.S.; REZENDE, F.C.; FARIA, L.A. Efeitos de águas residuárias de café no crescimento vegetativo de cafeeiros em seu primeiro ano. *Engenharia Agrícola*, Jaboticabal, v.29, n.4, p.569-577, 2009.

SANTOS, J.S; LIMA, V.L.A; BORGES JÚNIOR, J.C.F; LEDA, V.B.D.; SILVA, L.V.B.D; AZEVEDO, C. A. V. Mobilidade de solutos em colunas de solo com água residuária doméstica e de suinocultura. *Revista Brasileira de Engenharia Agrícola e Ambiental*, Campina Grande, v.14, n.11, p.1226-1233, 2010.

SARAIVA, F.Z.; SAMPAIO, S.C.; SILVESTRE, M.G. Use of cassava industry wastewater in the vegetative development of corn in a protected environment. *Revista Brasileira de Engenharia Agrícola e Ambiental*, Campina Grande, v.11, n.1, 2007.

SOARES, L.H. de B.; ALVES, B.J.R.; CABALLERO, S.S.U.; BODDEY, R.M. *Balanço energético na produção de bioetanol de mandioca* (*Manihot esculenta* Crantz). Cruz das Almas: Embrapa Agrobiologia, 2008. 4 p. (Circular Técnica, 23).

SILVA, G.B.; ROLIM, M.M.; PEDROSA, E.M.R.; BEBÉ, F.V.; SILVA, E.F.F. Efeito da aplicação de água residuária da lavagem dos frutos de café sobre as propriedades químicas do solo. *Engenharia Agrícola*, Jaboticabal, v.31, n.1, p.158-166, 2011.

SOUZA, L.da S.; SOUZA, L.D. *Caracterização físico-hídrica de solos da área do Centro Nacional de Pesquisa de Mandioca e Fruticultura Tropical, Cruz das Almas, Bahia.* Cruz das Almas: EMBRAPA-CNPMF, 2001. 56 p. (Boletim de Pesquisa, 20).

VANCE, E.D.; BROOKCS, P.C.; JENKINSON, D.S. Microbial biomass measurements in forest soils: determination of kc values and tests of hypotheses to explain the failure of the chloroform fumigation-incubation method in acid soils. *Soil Biology & Biochemistry,* v.19, p.689-696, 1987.