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CHEMICAL ATTRIBUTES OF SOIL AND DRY MASS ACCUMULATION OF MAIZE FERTILIZED WITH CASSAVA WASTEWATER

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ADRIANA G. MAGALHÃES[1], MARIO M. ROLIM[2], ANAMARIA S. DUARTE[3], ELVIRA M. R. PEDROSA[4], ENIO F. DE F. e SILVA[5]

ABSTRACT: The aim of this study was to evaluate chemical attributes alterations of a clay-loam textured soil and dry mass accumulation of maize submitted to application of cassava wastewater doses in three assessment periods. The experiment was conducted under greenhouse using a completely randomized experimental design in a factorial 5 × 3, with four replicates. The analyzed factors of research were doses of cassava wastewater (0; 12.6; 25.2; 50.4; 75.6 m^3 ha^{-1}) and assessment periods (20, 40 and 52 days after germination). The following parameters were determined: electric conductivity of soil saturation extract, pH in water, content of available P, content of exchangeable K^+, Ca^{2+}, Mg^{2+} and Na^+ of soil, dry mass of leaves and stem. The application of cassava wastewater on soil enables increase of pH, electric conductivity of saturation extract, contents of available P, contents of exchangeable K^+ and Na^+ and dry mass of leaves and stem. However, only pH and content of exchangeable K^+ of soil, the electric conductivity of saturation extract and dry mass of leaves and stem are influenced by assessment period.

KEYWORDS: residue, starch, nutrients, organic fertilization, *Zea mays*.

ATRIBUTOS QUÍMICOS DO SOLO E ACÚMULO DE MATÉRIA SECA DO MILHO BIOFERTILIZADO COM MANIPUEIRA

RESUMO: O objetivo deste trabalho foi avaliar as alterações dos atributos químicos de um solo de textura franco-argilosa e o acúmulo de matéria seca do milho submetido à aplicação de doses de manipueira em três épocas de avaliação. O experimento foi conduzido em casa de vegetação utilizando delineamento experimental inteiramente casualizado, em esquema fatorial 5 × 3, com quatro repetições. Os fatores de estudo da pesquisa foram: doses de manipueira (0; 12,6; 25,2; 50,4 e 75,6 m^3 ha^{-1}) e épocas de avaliação (20; 40 e 52 dias após a germinação). Foram determinados os seguintes parâmetros: condutividade elétrica do extrato de saturação do solo, pH em água, teor de P disponível, teores de K^+, Ca^{2+}, Mg^{2+} e Na^+ trocáveis do solo e massa seca de folhas e de colmo. A aplicação de manipueira no solo propicia aumento do pH, da condutividade elétrica do extrato de saturação, do teor de P disponível, dos teores de K^+ e Na^+ trocáveis, e da massa seca das folhas e colmo; no entanto, apenas o pH e o teor de K^+ trocável do solo, a condutividade elétrica do extrato de saturação e a massa seca das folhas e do colmo são influenciados pela época de avaliação.

PALAVRAS-CHAVE: resíduo, fecularia, nutrientes, adubação orgânica, *Zea mays*.

INTRODUCTION

Following maize and rice, cassava is the third biggest source of nutrition used in tropical and subtropical regions, consumed by approximately 600 million people, specially, those who live in

[1] Engª Agrônoma, Doutora, Departamento de Engenharia Agrícola, UFRPE/Recife – PE, Fone: (81) 3320-6279, agmguedes@gmail.com
[2] Engº Civil, Prof. Doutor, Departamento de Engenharia Agrícola, UFRPE/Recife – PE, Fone: (81) 3320-6276, rolim@deagri.ufrpe.br
[3] Engª Civil, Profa. Doutora, IFPE/Recife – PE, Fone: (81) 2125-1600, asousaduarte@gmail.com
[4] Engª Agrônoma, Profa. PhD, Departamento de Engenharia Agrícola, UFRPE/Recife – PE, Fone: (81) 3320-6212, elvira.pedrosa@deagri.ufrpe.br
[5] Engº Agrícola, Prof. Doutor, Departamento de Engenharia Agrícola, UFRPE/Recife – PE, Fone: (81) 3320-6279, enio.silva@deagri.ufrpe.br
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developing countries (SILVA JÚNIOR et al., 2012; NHASSICO et al., 2008). According to FAO (2011), Nigeria is the world's largest cassava producer, with 52,403 millions of Mg, followed by Brazil and Indonesia with productions of 25,441 and 24,010 millions of Mg, respectively.

The cassava processing for production of flower and starch, according to CARDOSO et al. (2009), generates solid (soil, peel and fibrous matter) and liquid (washing water and water resulting from root pressing) residues, that are rich in nutrients and, therefore, of great importance from the agricultural viewpoint, once they can be alternatives for mineral fertilizers use, reducing input costs. Washing water is produced in greater quantity, obtaining, in average, 2 m^3 per Mg of processed cassava while pressing water, also called cassava wastewater, is produced in lower volume, in average 250 L are generated per Mg of pressed cassava (NASU et al., 2010).

The cassava wastewater is a milky liquid of light-yellow coloration. It contains sugar, starch, proteins, linamarin, salts and other substances (INOUE et al., 2010; SANTOS et al., 2010). It is considered a potentially pollutant residue and toxic to the environment due to its organic load and linamarin, which is a glycoside cyanogenic, from which comes the hydrocyanic acid (HCN), that can bring serious environmental problems, such as: reduction of dissolved oxygen, eutrophication of water bodies and death of aquatic fauna (DUARTE et al., 2013).

Although cassava wastewater is a residue that presents risks when discarded "in natura" in the environment, the presence of nutrients, especially potassium, magnesium, nitrogen and phosphorus, sustains the possibility of its use as fertilizer in agricultural operations (DUARTE et al., 2012). SILVA JÚNIOR et al. (2012), using industrial residue from a flour mill house located in the city of Tancredo-BA, observed a composition of 3,456 mg L^{-1} K^+; 1,627 mg L^{-1} N; 617 mg L^{-1} Mg^{2+}; 328 mg L^{-1} P; 278 mg L^{-1} Ca^{2+} and 22 mg L^{-1} of N^+, showing that this residue can be sustainably used as fertilizer.

Evaluating the application effect of cassava wastewater doses in physical and chemical attributes of a Dystrophic Entisol from Pernambuco state, DUARTE et al. (2013) reported an increase of flocculation levels, ECse, pH and contents of available P, exchangeable K^+, Ca^{2+}, Mg^{2+} and Na^+ of soil. Studying the possible use of cassava wastewater as agricultural input, MÉLO et al. (2005), under laboratory conditions, concluded that the concentration of exchangeable calcium, potassium, sodium and magnesium linearly increased in three typical soil of Minas Gerais state, Spodic Orthic Quartzarenic Neosol (Entisol), Loamy-sand Typic Dystrophic Yellow Latosol (Oxisol) and Alic Mesoferric Clayey Typic Dystrophic Yellowish Red Latosol (Oxisol), treated with cassava wastewater.

On the other hand, CABRAL et al. (2010), when employed 0, 150, 300, 450 and 600 m^3 ha^{-1} of treated cassava wastewater in black-oat cultivation in dystrophic Red Latosol (Oxisol), in Maringá-PR, concluded that only potassium content increases in soil layers and the remaining analyzed elements presented reduced contents.

Thus, since cassava wastewater is generated in great amounts that, most of the times, are indiscriminately discarded into the environment; as well as the great nutritional contribution that this residue presents, the aim of this study was to evaluate changes on chemical attributes of a clay-loam textured soil and dry mass accumulation of maize submitted to application of cassava wastewater doses in three assessment periods.

MATERIAL AND METHODS

The experiment was carried out from November 9th of 2011 to January 28th of 2012, under greenhouse in the Rural Technology Department from the Federal Rural University of Pernambuco, Recife-PE, Brazil, with geographic coordinates: 08º 01' 01" of South latitude and 34º 56' 47" of West longitude.

Soil material was collected from the Experimental Station of the Agronomic Institute of Pernambuco, in the city of Itambé-PE, in layers from 0 to 20 cm of depth. Concerning physical and chemical soil characterization, three samples were collected, air-dried, prepared and passed through sieves of 2 mm mesh, for further determination of physical and chemical attributes before incorporation of cassava wastewater (Table 1), as methodology proposed by EMBRAPA (1997).

TABLE 1. Physical and Chemical soil attributes before the incorporation of cassava wastewater.

Parameters	Values
Sand (g kg^{-1})	660
Silt (g kg^{-1})	36.8
Clay (g kg^{-1})	303.2
ECse (dS m^{-1})	0.30
pH in water	5.50
Phosphorus (mg dm^{3})	1.26
Potassium (cmol$_c$ dm^{3})	0.27
Calcium (cmol$_c$ dm^{3})	1.65
Magnesium (cmol$_c$ dm^{3})	1.25
Sodium (cmol$_c$ dm^{3})	0.08

Irrigation was managed considering the container capacity, as described by MILNER (2002) and, for this purpose, weighting tests were conducted in three pots before cultivation, which were filled up as follows: 500 g of gravel number 0, to facilitate the drainage; bidim envelope®, which served to avoid soil material loss and 20 kg of soil material used for cultivation. After the installation, the pots were saturated through capillarity and weighted on a daily basis until constant weight was obtained, which means, when the soil presented maximum capacity of water retention (container capacity). The water volume applied in each plant was obtained through weight difference from pot with soil in container capacity and the weight of each of these pots containing one plant, which were measured daily. Each pot used for cultivation of experimental parcel was filled up in a similar way to pots used for container capacity test.

The implemented crop was hybrid maize AG 1051 from Agroceres, developed for sweet corn and silage production. Maize seeding was conducted on the 20th day after application of cassava wastewater in soil, time required for nutrient stabilization and evaporation of hydrocyanic acid present in residue. In each pot, three seeds were disposed at around 1 centimeter of depth after germination, thinning was carried out by keeping only one plant per pot, with the aim of homogenizing parcels. The cultivation lasted for 52 days; a period when the plant presented eight pairs of completely unfolded leaves, preceding the emission of floral tassel.

The experimental design was completely randomized in a factorial 5 × 3; with four replicates, totaling 60 experimental parcels. The studied factors were the following doses of cassava wastewater: 0; 12.6; 25.2; 50.4; 75.6 m^3 ha^{-1} and assessment periods, at 20, 40 and 52 days after seeding (DAS). Wastewater dose (25.2 m^3 ha^{-1}) was fixed taking into account potassium concentration within this residue and in soil, as well as maize requirements on this nutrient, which is of 20 kg ha^{-1}, according to recommendation proposed by IPA (2008); and the remaining doses were defined multiplying by 0.5; 2 and 3 times. It is remarked that liming was not necessary and mineral fertilization was not carried out during the experiment, aiming to evaluate only cassava wastewater effects on soil and crop.

Cassava wastewater came from a flourmill house located in the city of Pombos-PE, Brazil. The determination of physical and chemical compositions of cassava wastewater (Table 2) was conducted in Laboratory of Environmental Engineering and Quality (LEAQ) and in Laboratory of Soil Mechanics and Effluent Management of UFPE and UFRPE, respectively, following the methodology proposed by APHA (1995).

TABLE 2. Physical and chemical characteristics of the cassava wastewater.

Parameters	Values
Chemical Oxygen Demand- COD (mg L^{-1})	119,220.4
Electric conductivity(dS m^{-1})	9.61
pH	6.83
Potassium (mg L^{-1})	4,793.9
Phosphorus (mg L^{-1})	286.4
Magnesium (mg L^{-1})	1,588.2
Sodium (mg L^{-1})	742.0
Calcium (mg L^{-1})	241.9

Soil chemical attributes were characterized following methodology described by EMBRAPA (1997). Through that, it was determined the contents of available P, exchangeable K^+ and Na^+ from Mehlich-1 extracting solution (HCl 0.05 mol L^{-1} + H_2SO_4 0.0125 mol L^{-1}), with measurement carried out by colorimetry and flame photometry, respectively; and contents of exchangeable Ca^{2+} and Mg^{2+} obtained using the extracting solution of KCl 1 mol L^{-1} with reading accomplished with atomic absorption spectrometry.

The electric conductivity of saturation extract (ECse) was measured by preparing a saturated paste according to methodology proposed by Richards (1954). Measurements of ECse and of pH in water were carried out following methodology proposed by EMBRAPA (1997).

At 20, 40 and 52 days after germination (DAG), the plants were collected, weighted and subsequently, the samples were put in paper bags, identified and taken to greenhouse with forced ventilation of air at 65°C until reaching constant weight. After the period of 72 hours, dry mass of leaves (DML) and dry mass of stem (DMS) were determined according to methodology proposed by BENINCASA (2003).

Data was submitted to analysis of variance and regression, considering level of probability of up to 5% by F test, with the aid of program SAS – Statistical Analysis System (SAS, 2001).

RESULTS AND DISCUSSION

The results obtained by variance analysis of data related to chemical attributes of soil showed that studied variables were significantly influenced by application of increasing doses of cassava wastewater in soil, except the exchangeable calcium content (Table 3). Regarding assessment periods, only exchangeable potassium content, ECse and pH were significantly affected.

TABLE 3. Summary of variance analysis of soil chemical attributes and dry mass of maize stem and leaves depending on doses of cassava wastewater and assessment periods.

Source of variation	GL	pH	CE	K	P	Na	Ca	Mg	DML	DMS
Dose (D)	4	12.90**	1.35 ns	74.80**	35.04**	5.97 ns	0.08 ns	3.77 ns	133.76**	37.46**
Time (T)	2	7.60ns	40.69**	56.86**	12.64**	2.49 ns	3.16 ns	0.27 ns	374.66**	103.89**
D × T	8	3.01ns	3.17 ns	11.31**	1.75 ns	1.70 ns	0.79 ns	0.59 ns	31.52**	10.35**
CV (%)		2.47	25.17	21.67	21.72	9.49	10.13	42.43	18.09	23.04

CV (%) = coefficient of variation; ** = respectively significant at probability level of error of 1%; ns = not significant

Regarding exchangeable potassium of soil (Figure 1), it is verified that application of increasing doses of cassava wastewater caused significant increase (P<0.01) of this nutrient in soil; therefore, the content of this nutrient decreased with the extentension of cultivation time. At 20 DAG, the contents of exchangeable potassium in soil were 0.08 and 0.54 $cmol_c$ dm^{-3} when doses of 0 and 75.6 m^3 ha^{-1} were applied respectively; then, at 52 DAG, it was of 0.19 $cmol_c$ dm^{-3}, achieved with incorporation of the highest dose of cassava wastewater in soil (75.6 m^3 ha^{-1}), evidencing a decrease of 65% of this nutrient.

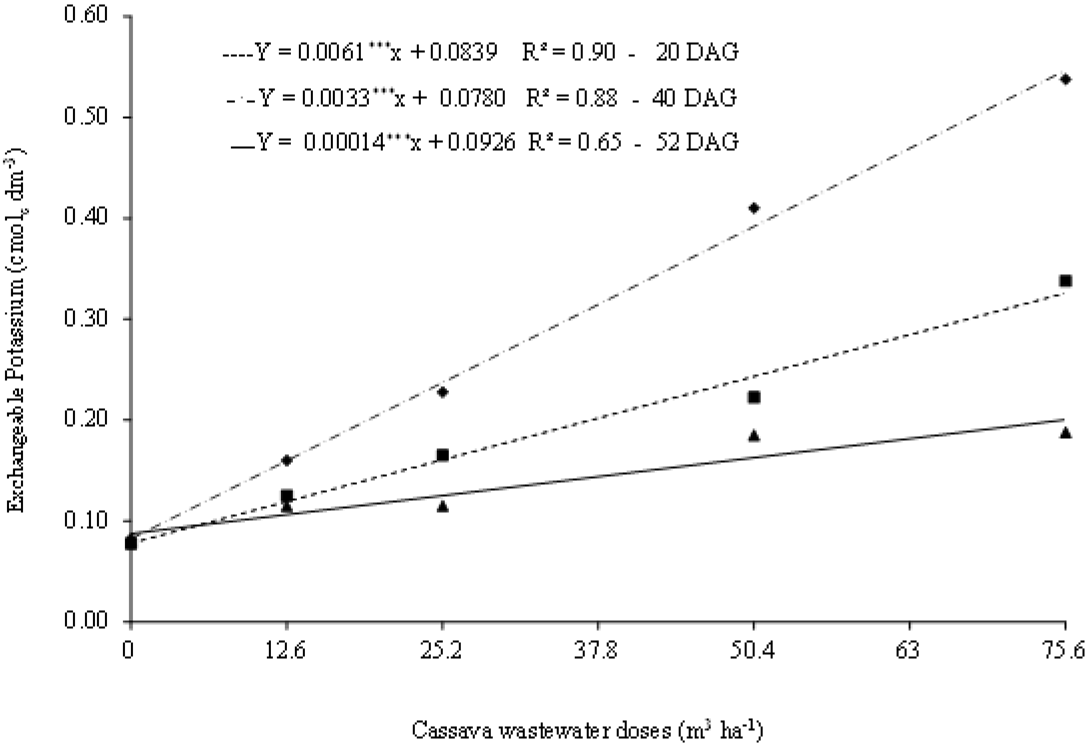


FIGURE 1. Exchangeable potassium content depending on doses of cassava wastewater and assessment periods (20, 40 and 52 DAG).

According to IPA (2008), contents above 0.2 $cmol_c$ dm^{-3} of exchangeable potassium in soil are considered high or adequate, evidencing that cassava wastewater garanteed an adequate contribuition of potassium only at 20 and at 40 DAG for doses above 20 and 40 m^3 ha^{-1}, demonstrating that in this period, cassava wastewater ensured an adequate potassium supply. At 52 DAG, the potassium contained in residue was not sufficient to mantain the exchangeable potassium of soil in adequate levels, even when higher doses of cassava wastewater were used, showing that, possibly, the absorption of this nutrient by maize plants was higher, once the maximum absorption of K by maize plants occurs in the period from 30 to 40 days after germination, overcoming the absorpion of N and P in this period, as reported by UENO et al. (2011).

CARDOSO et al. (2009) obtained similar results to the ones in this study, when using cassava wastewater in maize crop, statiing that there was a potassium increment in a dystrophic Quartzarenic Neosol (Entisol) comparable to an area where mineral fertilization was conducted.

Regression analysis was significant for available phosphorus content depending on application of cassava wastewater doses in soil, however, the interaction between isolated factors Doses and Assessment periods was not significant (Figure 2).

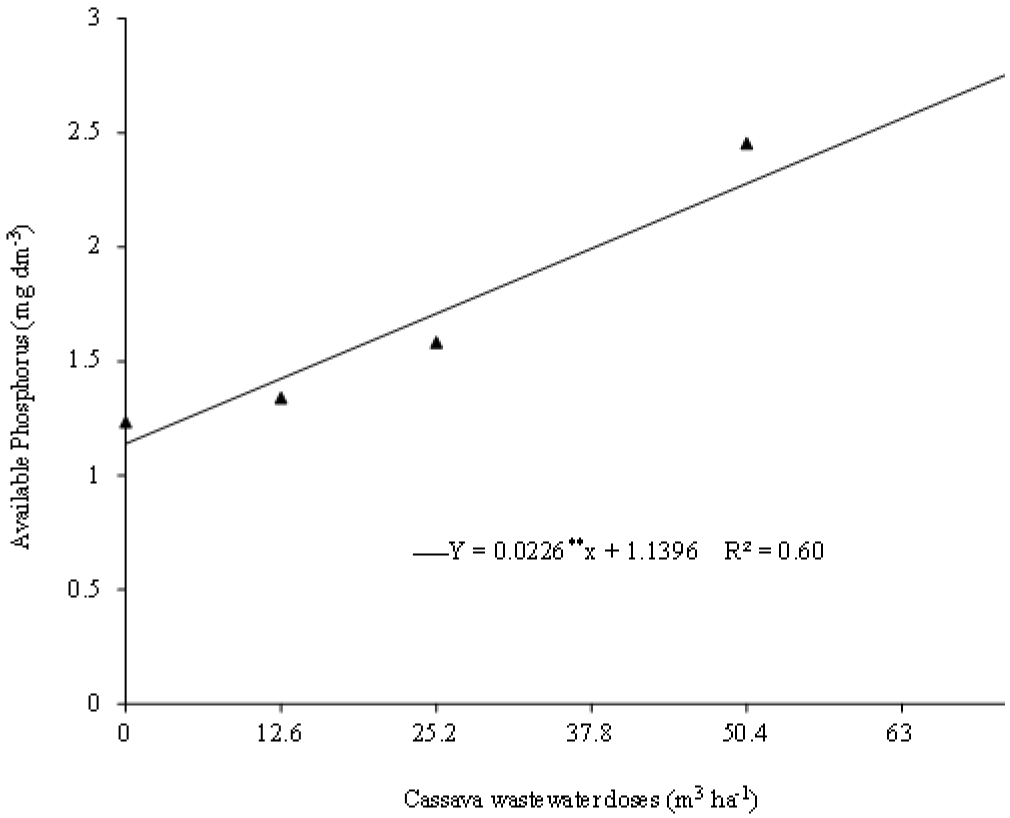


FIGURE 2. Available phosphorus content depending on doses of cassava wastewater applied in soil.

A 60% increase on available phosphorus content of soil was observed (Figure 2) as the greatest dose of cassava wastewater was used (75.6 m^3 ha^{-1}), when compared to content of available phosphorus in soil that did not receive cassava wastewater (0 m^3 ha^{-1}). For doses of 0 and 75.6 m^3 ha^{-1}, the contents of available phosphorus of soil were equal to 1.14 and 2.85 mg dm^{-3}, respectively. Although the phosphorus increase in soil was significant, it was not sufficient to elevate contents of this nutrient to the level considered adequate by IPA (2008), which varies from 21 to 30 mg dm^{-3} for maize crop. Nevertheless, the plants did not demonstrate symptoms of phosphorus deficiency, like reduction of plant size, purplish coloration and necrosis of older leaves during experimental period.

Similarly as in this study, MÉLO et al. (2005), studying modifications by application of cassava wastewater in three typical soils of Minas Gerais state (Entisols and Oxisols), also observed a positive effect of available phosphorus due to increasing residue doses, with higher content of phosphorus in sandy soil than in clayey soil. Controversially, SILVA JÚNIOR et al. (2012), when administering cassava wastewater as fertilizer source in banana, did not observe significant increase of available phosphorus in soil contents (Typic Dystrophic Yellow Latosol - Oxisol) located in the state of São Paulo.

Exchangeable sodium, as well as phosphorus, was only influenced by the doses of cassava wastewater (Figure 3), demonstrating an increasing linear effect as the residue doses applied in soil increased, obtaining contents of exchangeable sodium equal to 0.09 and 0.11 $cmol_c$ dm^{-3} when 0 and 75.6 m^3 ha^{-1} of cassava wastewater were applied in soil, respectively.

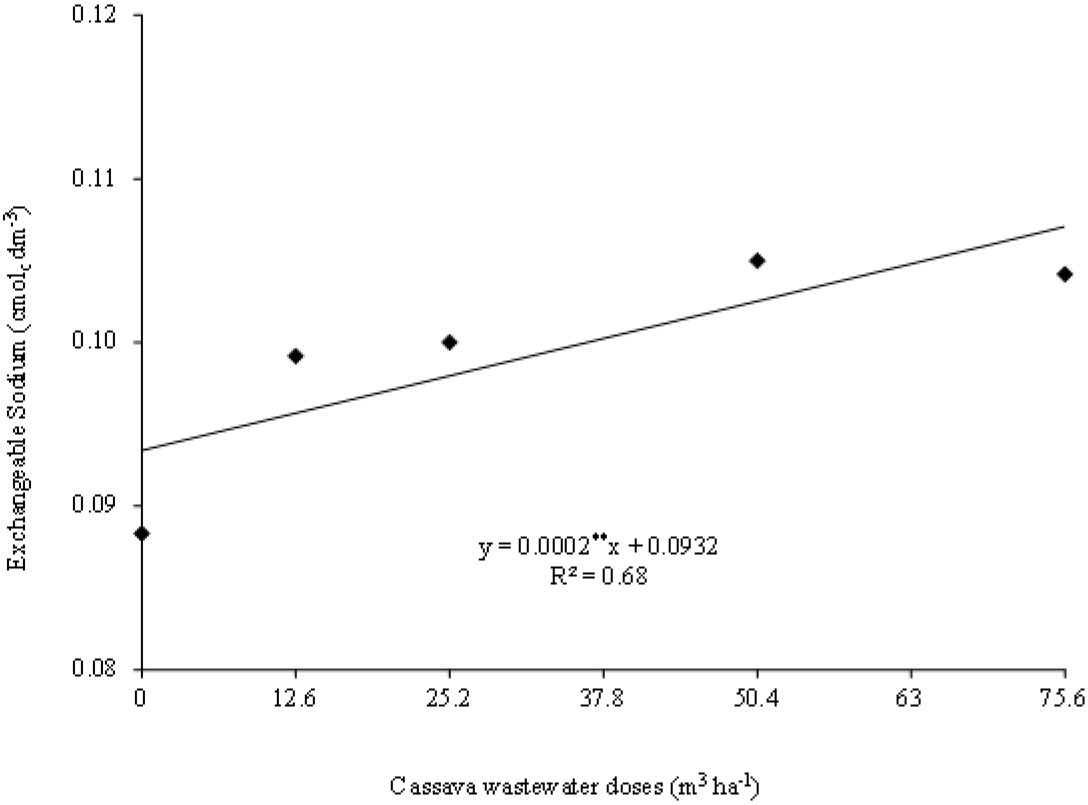


FIGURE 3. Exchangeable sodium content depending on doses of cassava wastewater applied in soil.

Regarding exchangeable magnesium, in spite of statistical analysis showing significant effect for the factor Doses, there was not an adjust of model that justified data performance; and for exchangeable calcium, the use of cassava wastewater did not promote significant effect on content of such element independently of applied dose and assessment period.

The results obtained in this study, concerning exchangeable sodium content, coincide with findings from MÉLO et al. (2005), who observed increment of such cation in analyzed soils (Spodic Orthic Quartzarenic Neosol, Loamy-sand Typic Dystrophic Yellow Latosol and Alic Mesoferric Clayey Typic Dystrophic Yellowish Red Latosol) as cassava wastewater replaced mineral fertilization.

At 20 DAG insignificant effect was observed in soil pH when increasing cassava wastewater doses and for the remaining assessment periods, soil pH showed quadratic performance with the use of increasing residue doses in soil (Figure 4).

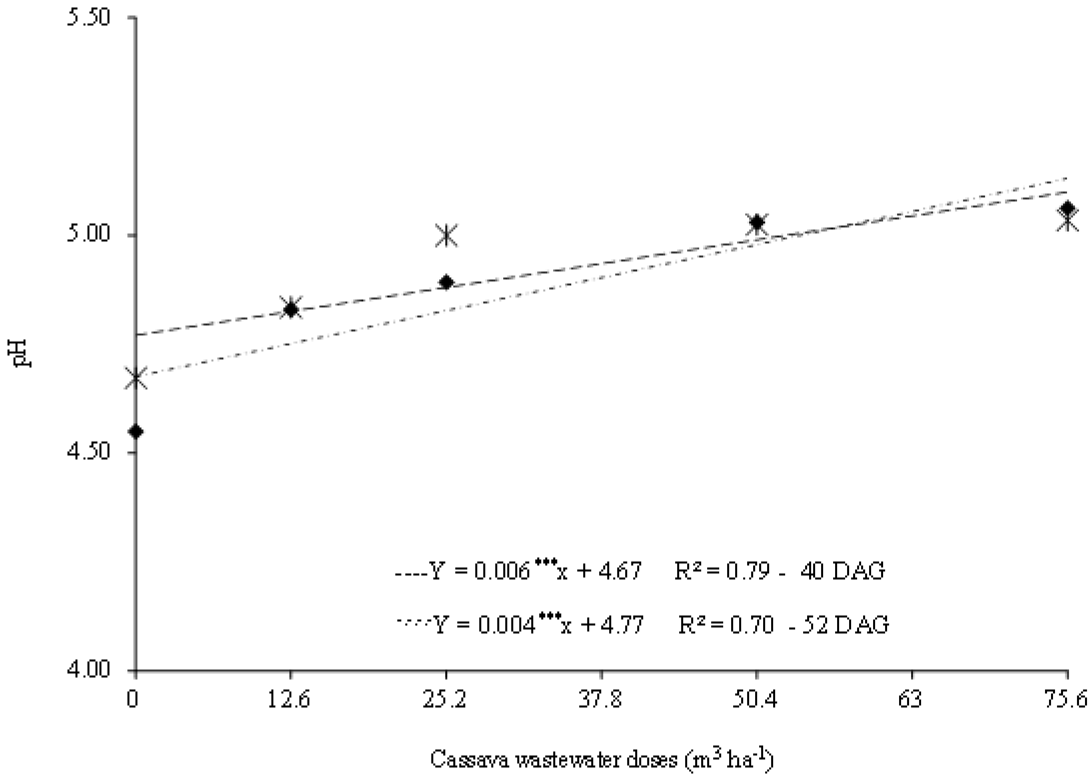


FIGURE 4. Variation of pH values with increasing doses of cassava wastewater for the assessment periods (40 and 52 DAG).

In absence of cassava wastewater (0 m^3 ha^{-1}), the soil pH was equal to 4.67 and 4.77, values obtained at 40 and 52 DAG, respectively; increasing to 5.07, maximum value estimated by regression equations for two assessment periods, when using dose of 55 m^3 ha^{-1}.

The incorporation of cassava wastewater to soil contributed to pH increase through exchangeable cation addition, mainly potassium, magnesium and calcium that were present in the residue (Table 2). The introduction of bases in soil favors ph rise, as these have the ability to be adsorbed in absorption complex, moving the elements (aluminum and hydrogen) responsible by potential acidity to soil solution, once dislocated to soil solution, the aluminum precipitates in form of Al_2SO_4, contributing to pH increase, according to BRIEDES et al. (2012).

The findings obtained in this research complied with observations from MÉLO et al. (2005), when verified that pH of three types of studied soils, Spodic Orthic Quartzarenic Neosol (Entisol), Loamy-sand Typic Dystrophic Yellow and Alic Mesoferric Clayey Typic Dystrophic Yellowish Red Latosol (Oxisol), increased with application of cassava wastewater confirming that the rise occurred due to mineralization of organic matter and cation liberation of alkaline metals or alkaline-earth metals associated to organic acids. On the other hand, SILVA JÚNIOR et al. (2012) and CABRAL et al. (2010) determined that application of cassava wastewater did not alter soil pH, when cultivating banana and oat, respectively.

Regarding electric conductivity (Figure 5), it is possible to observe that addition of cassava wastewater enabled linear significant effect only at 20 DAG; and in this period, ECse equal to 0.37 dS m^{-1} and 0.60 dS m^{-1} were found when doses of cassava wastewater equal to 0 and 75.6 $m^3 ha^{-1}$ were applied, respectively. For the other assessment periods (40 and 52 DAG), no significant influence of isolated factors Doses and Assessment periods was verified on ECse, once there was no interaction between these two factors.

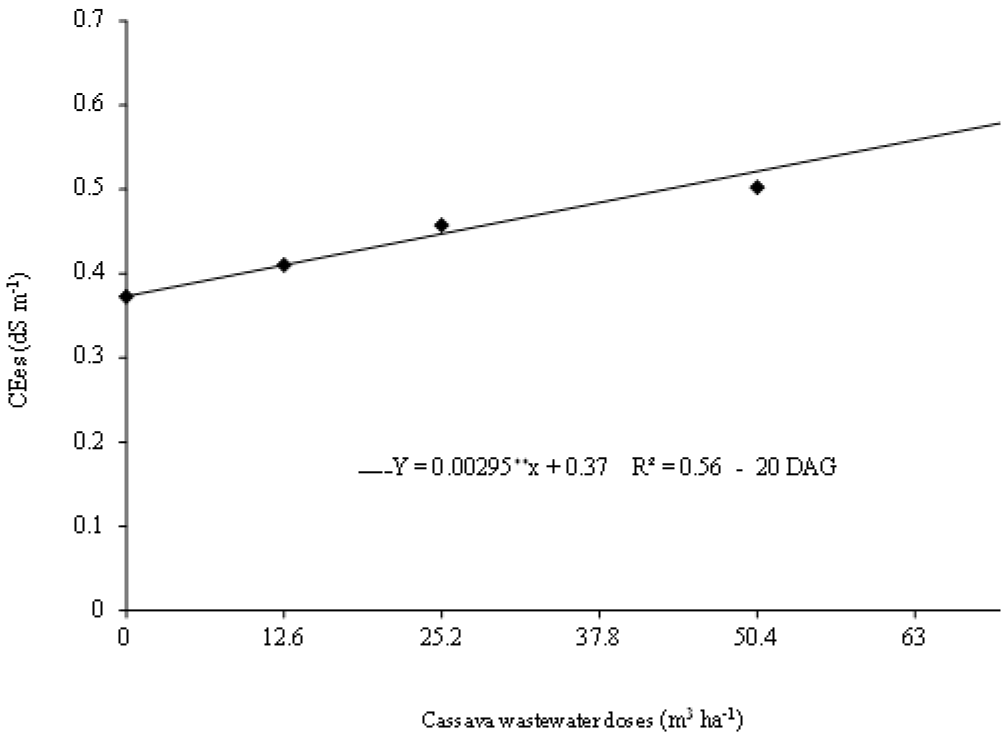


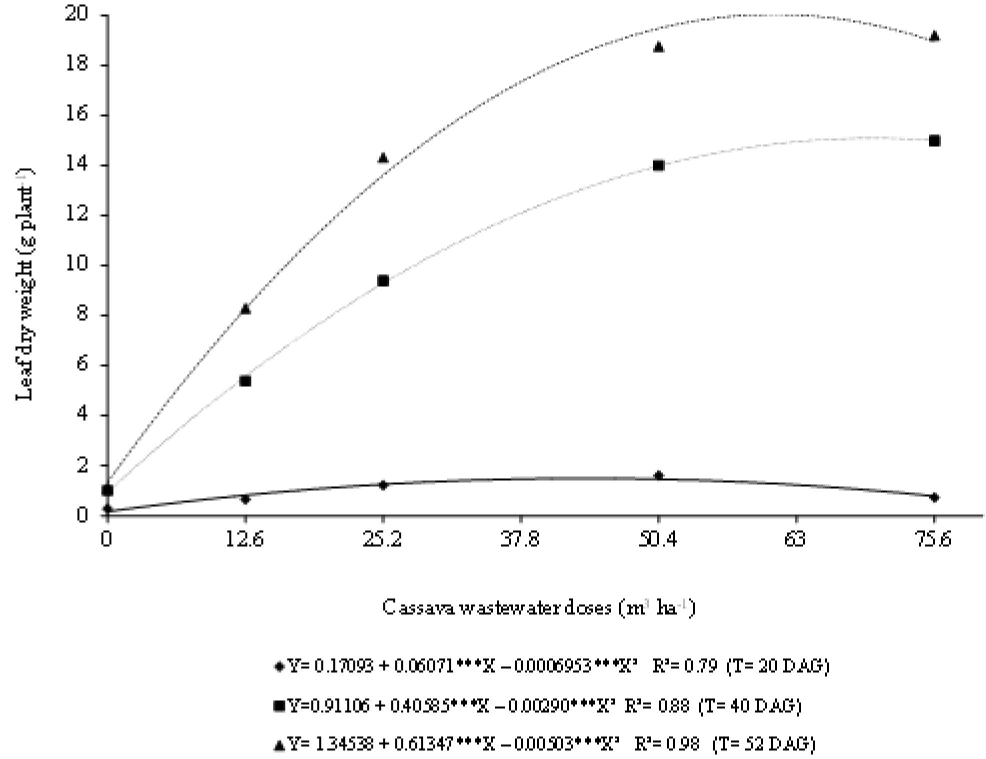
FIGURE 5. ECse values depending on doses of cassava wastewater and assessment periods (20 DAG).

The electric conductivity indirectly represents the total number of cations and anions found in soil solution (Lee, 2010) and as cassava wastewater is a residue rich in cations like K^+, Ca^{2+}, Mg^{2+} and Na^+, an increase of ECse is expected when this residue is incorporated to soil. In this study, this tendency was observed only at 20 DAG, and for the remaining assessment periods (40 and 52 DAG), the ECse was stabilized at 0.25 dSm^{-1}, evidencing a balance between ions found in soil solution and soil absorption complex. According to SÁ et al. (2010), the use of residues rich in organic matter, such as cassava wastewater (Table 2), increases buffering effect of soil and cation availability in its solution, once when adsorbed by plants, cations are released from soil solid form to the solution in a balanced way.

Concerning production components evaluated in this study, it is verified that dry mass of leaves (DML) and dry mass of stem (DMS) (Figures 6A and 6B) presented significant increase depending on cassava wastewater doses applied to soil and assessment periods. Greater accumulation of DML and DMS was verified at 40 and 52 DAG because maize plant development is higher in this period. At 52 DAG, the maximum values achieved with regression equations of DML and DMS were equal to, respectively, 20.04 and 4.79 g $plant^{-1}$, as the respective values were estimated for dose of cassava wastewater equal to 63 and 73 m^3 ha^{-1}, respectively.

In accordance with findings obtained in this study, DUARTE et al. (2012) reported that the increase of cassava wastewater doses enabled a significant increment of dry mass of lettuce aerial part. However, this variable was negatively affected when higher doses than 45 m^3 ha^{-1}were used, possibly due to antagonistic effect existing between cations K^+, Ca^{2+} and Mg^{2+} derived from cassava wastewater. SANTOS et al. (2010) also observed quadratic regression effect for dry matter of lettuce plants aerial part depending on cassava wastewater doses.

6A



6B

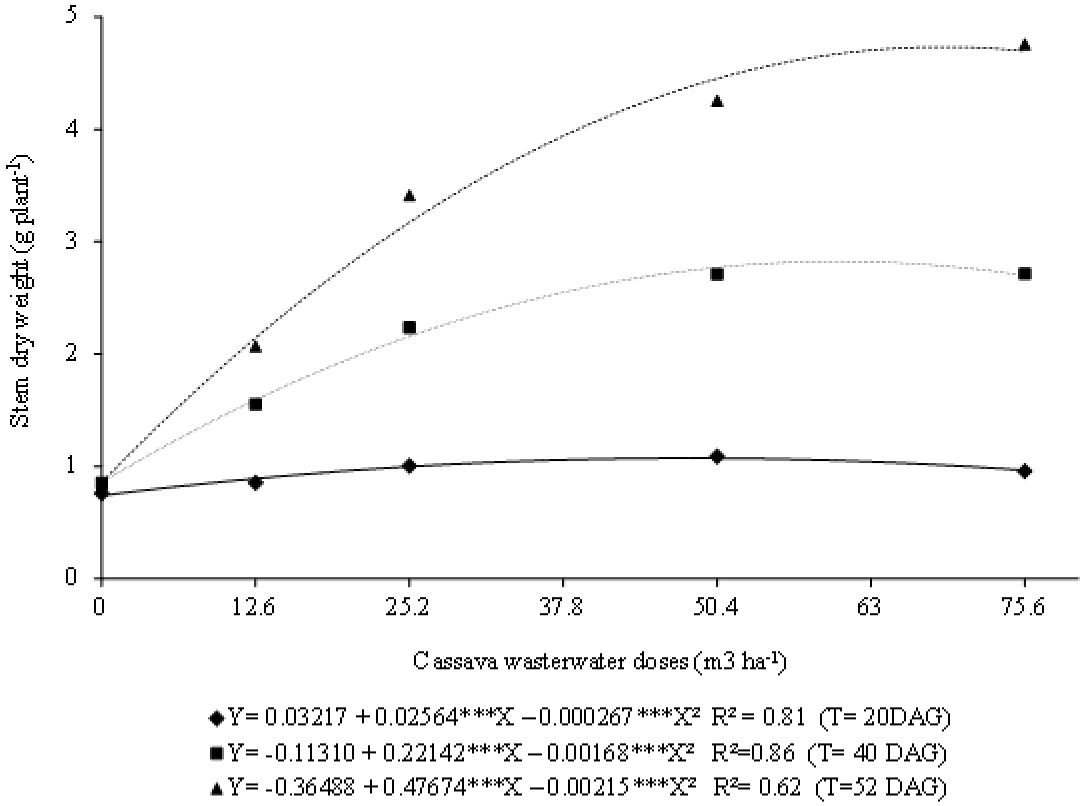


FIGURE 6. Leaf (6A) and stem (6B) dry weight of corn depending on doses of cassava wastewater and evaluation times (20, 40 e 52 DAG).

Comparing yields of two maize hybrids enriched with mineral fertilizers for a cultivation cycle of 52 days after germination, VON PINHO et al. (2009) concluded that maize dry mass was of 138.1 and 131.7 g ha^{-1} for hybrids GNZ2004 and P30F33, respectively, being much superior to this study. It supports the thesis that, organic fertilization hardly ever dispense chemical fertilization for reaching satisfactory productions (RESENDE et al., 2009). On the other hand, the use of organic fertilizers as complementary fertilization is a practice that can increase agricultural production and reduce the use of inputs, which, most of the times, are aggressive to the environment. (PEREIRA et al., 2013).

The achieved results in this study suggest that cassava wastewater could be used as a total or partial fertilization source due to its nutritional contribution, also minimizing expenditures with mineral fertilizers and avoiding environmental pollution generated by indiscriminate disposal of cassava wastewater.

CONCLUSIONS

1. The use of cassava wastewater as an alternative to mineral fertilization promotes increment in all evaluated variables of this study, except the dry mass of leaves (DML) and stems (DMS);

2. The pH, ECse, and content of exchangeable K^+ of soil, dry mass of leaves (DML) and of stem (DMS) of plants are influenced by assessment periods.

3. Doses of 63 and 73 m^3ha^{-1} promote higher values of dry mass of leaves (DML) and of stems (DMS), respectively.

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