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Cassava wastewater as organic fertilizer in 'Marandu' grass pasture

Márcio G. S. Bezerra[1], Gualter G. C. da Silva[2], Gelson dos S. Difante[2], João V. Emerenciano Neto[3], Ermelinda M. M. Oliveira[2] & Luiz E. C. de Oliveira[1]

[1] Universidade Federal Rural do Semi-Árido/Programa de Pós-Graduação em Manejo de Solo e Água. Mossoró, RN. E-mail: marcio_gleybson@hotmail.com; luizcordeiro91@gmail.com
[2] Universidade Federal do Rio Grande do Norte/Unidade Acadêmica Especializada em Ciências Agrárias. Macaíba, RN. E-mail: gualtermve@gmail.com; gdifante@hotmail.com; ermelindasolos@gmail.com
[3] Universidade Federal do Vale do São Francisco/Colegiado Acadêmico de Zootecnia. Petrolina, PE. E-mail: joao_neto@zootecnista.com.br (Corresponding author)

Key words:
Brachiaria brizantha
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manipueira
environmental impacts

A B S T R A C T

This study aimed to evaluate the use of wastewater from the cassava processing as organic fertilizer on pastures of *Brachiaria brizantha* cv. 'Marandu'. The treatments were wastewater doses (0, 15, 30, 60 and 120 m^3 ha^{-1}), in a randomized block design with four replicates. The structural characteristics and morphological composition of the pastures were evaluated, from July 2013 to January 2014. The addition of wastewater promoted a positive linear increase in the three cuts for the canopy height, light interception and leaf area index. The maximum dry matter (DM) production was obtained with 120 m^3 ha^{-1} of wastewater (2796 kg ha^{-1} of DM in the second cut). The mass of senescent material in the second and third cuts fitted to positive linear equation. The increase in wastewater doses promoted the reduction of undesirable plants. The recommended dose of residual water in pastures of 'Marandu' grass is 120 m^3 ha^{-1}, which promotes a higher mass of forage and lower of undesirable plants.

Palavras-chave:
Brachiaria brizantha
Manihot esculenta
manipueira
impactos ambientais

Água residuária da mandioca como fertilizante orgânico em pasto de capim-marandu

R E S U M O

Objetivou-se avaliar o uso de água residuária do processamento da mandioca como fertilizante orgânico em pastos de *Brachiaria brizantha* cv. Marandu. Os tratamentos utilizados foram doses de água residuária (0, 15, 30, 60 e 120 m^3 ha^{-1}), em blocos ao acaso com quatro repetições. Foram avaliadas as características estruturais e a composição morfológica dos pastos, de julho de 2013 a janeiro de 2014. A adição de água residuária promoveu aumento linear positivo nos três cortes, para altura do dossel, interceptação de luz e índice de área foliar. A máxima produção de matéria seca (MS) foi obtida com 120 m^3 ha^{-1} de água residuária (2796 kg ha^{-1} de MS no segundo corte). A massa de material senescente nos segundo e terceiro cortes se ajustaram à equação linear positiva. O aumento das lâminas da água residuária promoveu a diminuição de plantas indesejáveis. A dose de água residuária recomendada em pastos de capim-marandu é de 120 m^3 ha^{-1}, a qual promove maior massa de forragem e menor de plantas indesejáveis.

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Introduction

Brazil stands out as the second largest cassava producer in the world; most of this production is used in the cassava processing to obtain starch and flour (FAO, 2010), which generates large production of waste of the starch factories (cassava wastewater). The disposal of this waste directly in the soil and water courses causes serious environmental impacts on the water and soil resources. Sustainable practices can contribute to the utilization of these wastes as inputs in production processes, which allows higher efficiency in the integration of various agricultural activities. The utilization of wastes in agriculture can be considered an alternative for their rational use, because it can increase agricultural yield and decrease possible environmental impacts on soil and water resources.

Compared with other organic wastes, cassava wastewater has higher contents of the main essential elements (N, P and K) required by plants (Magalhães et al., 2016). This characteristic allows the utilization of this waste as organic fertilizer considering the soil chemical composition and the doses tolerated by crops (Duarte et al., 2012). In both studies, the authors observed that cassava wastewater allowed increase in the biomass of the agricultural crops.

The requirement of *Brachiaria brizantha* cv. 'Marandu' for soils with intermediate to high fertility causes this pasture to tend to degrade over time, if not adequately managed. This grass crop, according to Euclides et al. (2009), represents 45% of the 100 million hectares of pastures cultivated in Brazil, evidencing the importance of studying alternatives of organic fertilizers to replace nutrients to plants, in order to contribute to the increase of yield and maintenance of the pasture and, consequently, avoid its degradation.

In this context, this study aimed to evaluate the use of cassava wastewater as organic fertilizer in pastures of *Brachiaria brizantha* cv. 'Marandu'.

Material and Methods

The experiment was carried out in the municipality of Macaíba, Rio Grande do Norte, Brazil. The experimental area is at the geographic coordinates of 5° 53' 35.12" S and 35° 21' 47.03" W. The experimental period was from July 2013 to January 2014. The climate of the region, according to the climate classification of Thornthwaite (1948), is dry sub-humid, with water surplus from May to August. The mean annual value of historic rainfall is 1048 mm and cumulative potential evapotranspiration is 1472 mm, while a total of 1011 mm was recorded during the experimental period.

The soil of the experimental area is Quartzarenic Neosol with sandy texture and regular topography. Soil chemical analysis (Table 1) were performed according to the methodology described in EMBRAPA (1997). Immediately after the results, the area received a broadcast application of 2 t ha^{-1} of dolomitic limestone (RNV 45%), one week before applying the treatments, and soil pH was increased to 6.4.

The cassava wastewater, obtained from a flour factory, was collected after the processing of pressing the cassava mass and stored in water tanks for the period of 15 days to eliminate the hydrocyanic acid and stabilize the fermentations. The chemical composition of the wastewater (macro and micronutrients) was determined according to the methodology described by APHA (2003), obtained after the period of stabilization indicating 1540, 350, 2940, 200, 380, 440, 5.0, 0.5, 22.0 and 4.5 mg L^{-1} of N, P, K, Ca, Mg, Na, Zn, Cu, Fe and Mn, respectively.

The pasture used in the experiment was *Brachiaria brizantha* cv. 'Marandu', established in 2010 and grazed by sheep thenceforth. During the experimental period, conventional sprinkler irrigation was used to apply a daily total depth of 9.6 mm, from 11 to 13 h, three times a week. The experimental area of 728 m² (14 x 52 m) was divided into four blocks with six plots, each one with total area of 12 m² (4 x 3 m), border of 30 cm and evaluation area of 8.16 m². The spacing between plots was 1 m and between blocks, 2 m. In the beginning of the experiment, a standardizing cut was performed in the pasture at 15 cm from the soil level.

The treatments consisted of doses of cassava wastewater: 0, 15, 30, 60 and 120 m³ ha^{-1} (Table 2). The experimental design was randomized blocks with five treatments and four replicates. The cassava wastewater doses were applied using a watering can, twice, 50% after the standardizing cut and 50% immediately after the first cut, to avoid possible harmful effects on the pasture at the higher doses.

The canopy height was measured before each cut using a 1-m-long ruler graduated in centimeters. Ten random points were measured to better represent the plot. The height of each point corresponded to the mean height of the curvature of the leaves around the ruler.

The forage contained in the evaluation area of each plot was harvested every 60 days and the cutting height was 15 cm above the soil level. The harvested samples were identified and weighed to obtain the fresh mass. To evaluate forage dry mass, approximately 250 g of fresh matter harvested from each sample were placed in paper bags and dried in a forced-air oven at 55 °C for 72 h, and weighed again.

Table 2. Quantity of nutrients added to the soil (kg ha^{-1}) by the application of cassava wastewater

Dose (m³ ha^{-1})	N	P	K	Ca	Mg
	(kg ha^{-1})				
0	-	-	-	-	-
15	23.1	5.25	44.1	3.0	5.7
30	46.2	10.50	88.2	6.0	11.4
60	92.4	21.00	176.4	12.0	22.8
120	184.8	42.00	352.8	24.0	45.6

Table 1. Chemical and physical characteristics of the soil samples of the experiment

P	K	Na	pH	Ca	Mg	Al	H + Al	CEC*	V	Granulometry (g kg^{-1})		
mg dm^{-3}				cmol$_c$ dm^{-3}					(%)	Sand	Clay	Silt
2.0	51.0	10.0	5.2	0.7	0.2	0.0	1.4	2.4	44.0	939	40	21

*Potential cation exchange capacity

For the evaluation of the morphological components, the rest of the harvested samples (after removing the subsamples to determine the dry weight) were manually separated into leaf blade, stem (stem + sheath), senescent material and undesirable species, to determine the weights and percentages of participation of each component and the leaf/stem ratio in the structure of the pasture.

Light interception by the canopy (LI) was measured immediately after the cut, using the canopy analyzer AccuPAR Linear PAR/LAI ceptometer, Model PAR-80 (Decagon Devices), through five readings above the forage canopy and five at the soil level in each plot, always between 9 and 14 h. The light interception percentage (LI%) was obtained using the following expression: LI% = 100% - (soil/above x 100). The leaf area index was obtained through direct reading in the same device used for LI.

The contents of total chlorophyll (A and B), expressed in Falker Chlorophyll Index (FCI), were estimated using a chlorophyll meter (ClorofiLOG, model CFL 1030), through five readings in different plants in the same plot. The readings were always performed in the middle third of the leaf blade of the first fully expanded leaf (from top to bottom) and exposed to solar radiation.

The design was randomized blocks, with treatments arranged in a split plot; the doses were allocated in the plots and the cuts in the subplots. The data were subjected to analysis of variance and the effect of cassava wastewater doses were evaluated through regression analysis, at 0.05 probability level.

The statistical analyses were performed using the statistical program Sisvar, version 4.6 (Ferreira, 2011). The following statistical model was used (Eq. 1):

$$Yijk = \mu + Bi + Mj + \alpha ij + Ck + (MC)jk + \beta ijk \qquad (1)$$

where:

Yijk - value observed in the block i, dose j and cut k;

μ - mean overall effect;

Bi - effect of the block i, i = 1-4;

Mj - effect of the dose j, j = 0, 15, 30, 60 and 120 m^3 ha^{-1} of wastewater;

αij - effect of the random error attributed to the plot;

Ck - effect of the cut k, k = 1-3;

(MC)jk - effect of the interaction between the dose j and the cut k; and,

βijk - effect of the random error attributed to the subplot.

Results and Discussion

The interaction between cassava wastewater doses and cuts was significant for all variables ($p < 0.05$), except for the mass of undesirable plants ($p < 0.05$). The cassava wastewater resulted in positive linear effect on pasture height in the first and second cuts (Figure 1A). The lower response of pasture height in the first cut can be justified by the lower availability of nutrients, because the wastewater application was split, with only 50% of the dose in the beginning of the evaluation period. In the third cut, there was no response of pasture height, probably because there were no new applications of wastewater and also because there was no residual effect of the applications prior to the second cut.

The wastewater application caused positive linear effect only in the second cut on light interception (LI) (Figure 1B) and on leaf area index (LAI) (Figure 1C). The similarity in the behavior observed in LI and LAI can be explained by the high correlation between these variables; the increase in leaf area causes greater shading of the plants, with consequent increase in light interception by the forage canopy. The ideal LAI can

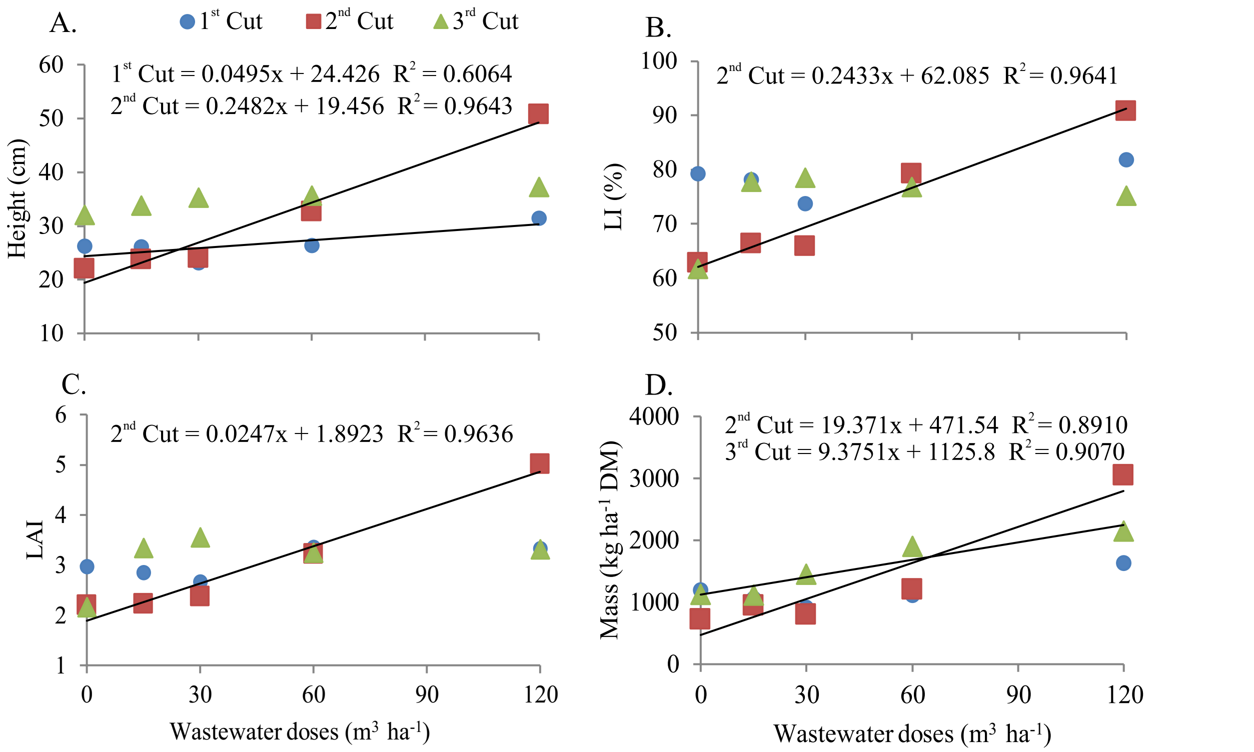

Figure 1. Canopy height (A), light interception (B), leaf area index (C) and dry matter production (D) in pastures of *Brachiaria brizantha* cv. 'Marandu' fertilized with cassava wastewater doses, in three cuts

promote greater soil cover, which decreases the effect of intense and direct solar radiation and promotes a microclimate that contributes to attenuating water losses through evaporation and maintaining the moisture in the soil for a longer period; consequently, it may favor the absorption of water and nutrients by the plant.

In the pastures that received the maximum doses of wastewater (120 m³ ha⁻¹), the observed values of LAI and LI (4.8 and 91.3%) were close to those reported by Reis et al. (2013) for the interruption of the regrowth period of the pastures, to achieve higher forage production with high proportion of leaves and low proportion of senescent material.

The use of cassava wastewater promoted positive linear effect in the dry matter production, in all cuts (Figure 1D). The maximum dose of wastewater (120 m³ ha⁻¹) led to increases of 324 and 92% in forage production, compared with the pasture without wastewater application, in the second and third cuts, respectively.

As for the previously described structural characteristics, the smaller effect in the first cut on forage production is a result of the split application. Bertonha et al. (2012), for *Brachiaria brizantha* cv. MG-5, Cabral et al. (2010), for black oat, and Barreto et al. (2014), for maize, also observed positive effects on the DM production with the utilization of wastewater.

The obtained forage production can be considered as satisfactory, since the 2280 kg ha⁻¹ of DM obtained at the maximum dose of wastewater (120 m³ ha⁻¹) were close to the 2320 kg ha⁻¹ of DM reported by Emerenciano Neto et al. (2013), in 'Marandu' grass pastures fertilized with 100 kg ha⁻¹ year⁻¹ of nitrogen, in the form of ammonium sulfate.

The mass of leaves showed positive linear response to the increase in the wastewater doses in the first, second and third cuts (Figure 2A). In the comparison between the maximum dose (120 m³ ha⁻¹) and the dose zero, there were increases in the mass of leaves of 59, 248 and 91% respectively in the first, second and third cuts.

With greater availability of nutrients in the soil, the plant prioritizes the increase in its leaf area (Figure 1B) to promote higher photosynthetic supply, with consequent increase in the mass of this component. With the application of the total dose (second cut), this effect became more evident, with higher LAI and mass of leaf blades.

Magalhães et al. (2015) observed reduction in the mass of leaf blades with high doses of wastewater in the maize crop, because this plant, with greater availability of nutrients, entered more rapidly in the reproductive stage, a behavior not observed in the 'Marandu' grass. According to Magalhães et al. (2016), cassava wastewater doses from 75.6 m³ ha⁻¹ on cause toxic effect on maize plants, with burning of leaf tips due to the high potassium content. The 'Marandu' grass proved to be tolerant to this condition, because this effect was not observed, event at higher doses than the mentioned study (120 m³ ha⁻¹).

The utilization of wastewater promoted linear effect on the mass of stem in the first and third cuts, and the highest values were observed in the pastures that received the wastewater dose of 120 m³ ha⁻¹ (Figure 2B) In the second cut, the mass of stems quadratically fitted to the wastewater doses, and the highest production was 838 kg ha⁻¹ of DM at the dose of 120 m³ ha⁻¹.

The application of cassava wastewater as organic fertilizer did not cause significant effect on the mass of senescent material in the first cut (Figure 2C). In the second and third cuts, there was a positive linear response, with masses of senescent material of 195 and 366 kg ha⁻¹ of DM.

The highest mass of stems observed with the use of wastewater resulted from the increase in the canopy height (Figure 1B). The plants, due to the greater growth, enter in the

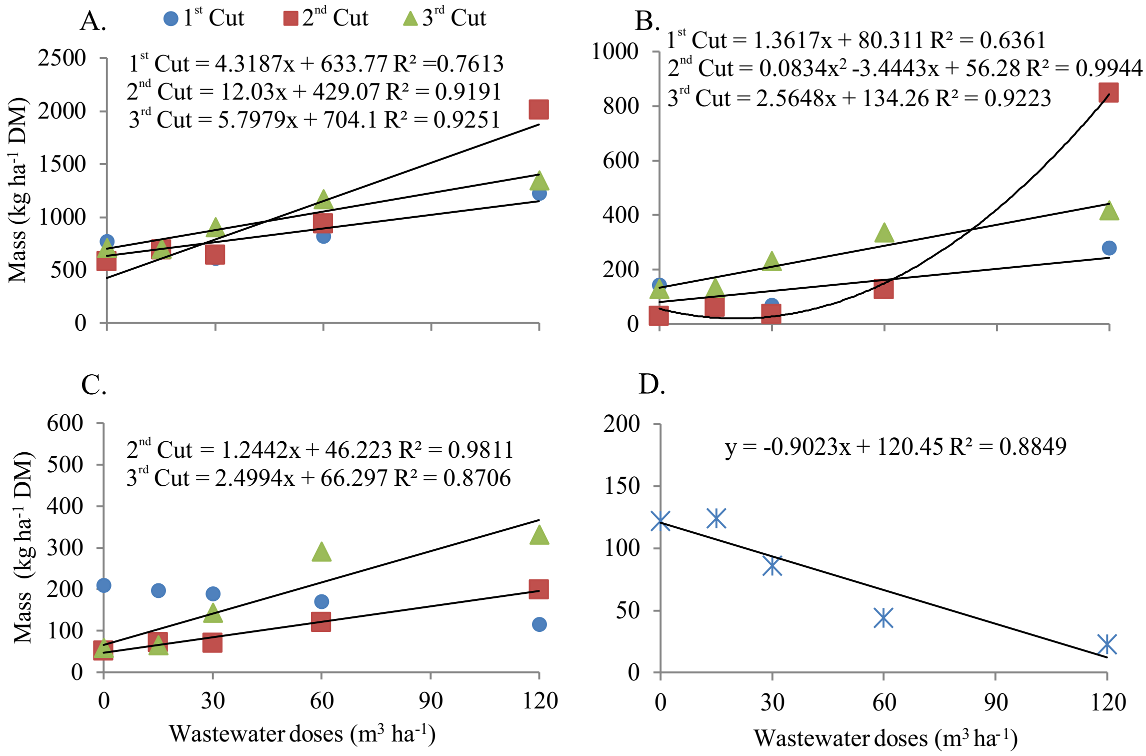

Figure 2. Masses of leaf blade (A), stem (B), senescent material (C) and undesirable plants (D) in pastures of *Brachiaria brizantha* cv. 'Marandu' fertilized with cassava wastewater doses, in three cuts

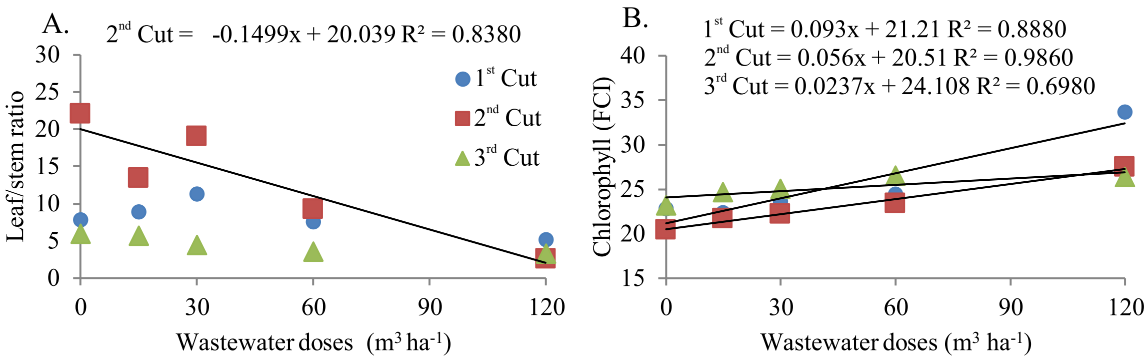

Figure 3. Leaf/stem ratio (A) and total chlorophyll (B) in pastures of *Brachiaria brizantha* cv. 'Marandu' fertilized with cassava wastewater, in three cuts

process of stem elongation in search for light to produce new leaves and increase in LAI (Pereira et al., 2011). This behavior was more evident in the second cut, in which, with greater supply of nutrients (total application), there was a higher pasture growth, which can be proved by the absence of this effect at the wastewater doses from 0 to 30 m^3 ha^{-1}. The increase in canopy height with consequent increase in light interception (Figures 1A and 1C) also caused self-shading of the plants, especially at the maximum dose of wastewater, which also promoted greater accumulation of senescent material in the canopy due to the lower penetration of light in this stratum, with consequent senescence of the leaves.

Even with greater increment of senescent material with the use of wastewater, this component did not harm the structure of the canopy. Likewise, Emerenciano Neto et al. (2013), using an annual nitrogen dose of 100 kg ha^{-1} in pastures of 'Marandu' grass, obtained 1203 kg ha^{-1} of senescent material with mean height of 52.44 cm, a result much higher than those observed at the maximum dose of wastewater (184 kg ha^{-1} of N).

For the mass of undesirable plants, the doses fitted to a linear equation, regardless of the cut, and the mass decreased with the increase in wastewater doses (Figure 2D). This result can be attributed to two factors: (a) to the herbicide action of the wastewater (Neves et al., 2014), which can be intensified depending on the plant species exposed to the contact with this waste, since there are more and less tolerant plants to such action. The drastic effect of the wastewater on the undesirable plants can be due to the greater susceptibility of the species found in the area of the present study; (b) the other cause can be attributed to the improvement in the nutritional status of the plants and their greater growth (Height, LI, LAI and forage mass), making them competitive with consequent shading and death of the undesirable species.

The leaf/stem ratio was not affected by the application of wastewater in the first and third cuts (Figure 3A). In the second cut, the response was decreasing linear, the leaf/stem ratio decreased with the increase in the applied doses and varied from 20 to 2.1 with the doses of 0 and 120 m^3 ha^{-1}, respectively, which can be attributed to the greater growth of the plants when the highest dose of wastewater was used, with consequent greater height of the canopy (Figure 1A).

The obtained values for leaf/stem ratio above one demonstrate higher amounts of leaves in the pasture, which gives better quality of the forage supplied to the grazing animals (Pinto et al., 1994). In an experiment conducted by Euclides et al. (2009), for animals in pastures of *Brachiaria brizantha* cv. 'Marandu', 'Piatã' and 'Xaraés', the nutritive value of the forages was less important than the leaf blade/stem ratios in the control of weight gain of the animals.

The total chlorophyll (TC) fitted to the linear equation in response to the wastewater doses in the three cuts. The increment of total chlorophyll with wastewater doses represents improvement in the quality of the pasture, because the total chlorophyll has high correlation with the nitrogen contents present in the leaf tissue of the plant. As a consequence, such correlation also applies to the contents of crude protein. The adequate nutritional status of the pasture, besides promoting improvements and nutritional value for the animal, also promotes the maintenance of the stand of plants, which means longevity of the pasture.

Barreto et al. (2014) evaluated wastewater doses in the maize crop, and the mean nitrogen content in the leaf tissue of the plants increased with the increment in the wastewater dose, a fact that proves the high capacity of mobilization of nitrogen from the soil to the plant when this organic fertilizer is used. However, in this same crop, Magalhães et al. (2016) did not observe increase in the leaf N contents. In this case, the nutrients were mobilized to the grains. From the environmental perspective, it is also important, because it shows that most nutrients will be absorbed by plants and will not act as pollutants.

Conclusion

The cassava wastewater, when used at the dose of 120 m^3 ha^{-1}, improves the characteristics of the pasture, such as higher forage mass and chlorophyll content, and lower presence of undesirable plants.

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