QUANTITATIVE RESPONSES OF FORAGE GRASSES TO MANIPUEIRA APPLICATION AS NATURAL FERTILIZER

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ABSTRACT: Manipueira has been efficient in plant fertilization, which makes it a potential candidate for fertilizing forage grasses in family farming. The objective of this study was to evaluate the development and production of three *Panicum maximum* cultivars in response to manipueira application in the semiarid region of Piauí. The experiment was carried out in a protected environment, located at the State University of Piauí, municipality of Picos. The experimental design was completely randomized with four replicates in a 3 x 5 factorial scheme, composed of the combination of three forage grass cultivars of the genus *Panicum maximum* and five manipueira doses. The soil used came from an area of native vegetation at the State University of Piauí. Manipueira was collected in flour houses in the microregion of Picos – PI. The variables evaluated were: plant height, leaf blade length, number of leaves per tiller, number of tillers per plant, total forage fresh weight and total forage dry weight. After the last cut, root length, root dry matter and shoot: root ratio were determined. In the first cut, there was an isolated effect of manipueira doses for plant height, leaf blade length and shoot fresh mass and interaction effect for number of leaves per tiller and number of tiller per plant. In the second cut, there was an isolated effect of manipueira doses for shoot dry mass and root dry mass, and interaction significance for plant height, leaf blade length, number of leaves per tiller, number of tillers per plant and root length. The dose of 44 m^3ha^{-1} was more efficient in the development of Mombaça and Tanzânia grasses, which were sensitive to values above this dose, showing significant reduction. The dose of 176 m^3ha^{-1} provided the best development of Massai grass, which shows that the species must be taken into account when establishing the biofertilizer dose to be applied. Manipueira has shown to be promising as an alternative source in the fertilization of forage grasses due to the benefit in the availability of nutrients and the high availability of this residue in the macroregion of Picos, semiarid region of Piauí, in addition to reducing environmental impacts through indiscriminate disposal.

KEYWORDS: *Panicum maximum*, pasture, biofertilizer, cassava wastewater, family farming.

RESPOSTAS QUANTITATIVAS DE GRAMÍNEAS FORRAGEIRAS A APLICAÇÃO DE MANIPUEIRA COMO FERTILIZANTE NATURAL

RESUMO: A manipueira tem sido eficiente na fertilização de plantas, o que torna uma ferramenta em potencial para a adubação de gramíneas forrageiras na agricultura familiar. Objetivou-se com esse estudo avaliar o desenvolvimento e produção de três cultivares de *Panicum maximum* em resposta a aplicação de manipueira no semiárido piauiense. O experimento foi realizado em ambiente protegido, localizado na Universidade Estadual do Piauí, no município de Picos. O delineamento experimental foi o inteiramente casualizado com quatro repetições, em esquema fatorial 3 x 5, formados pela combinação de três cultivares de gramíneas forrageiras do gênero *Panicum maximum* e cinco doses de manipueira. O solo utilizado foi proveniente de uma área de vegetação nativa da Universidade Estadual do Piauí. A manipueira foi coletada em casas de farinha da microrregião de Picos–PI. As variáveis avaliadas foram: altura de planta, comprimento da lâmina foliar, número de folhas por perfilho, número de perfillhos por planta, massa fresca de forragem total, e massa seca de forragem total. Após o último corte foram determinados o comprimento de raiz, massa seca de raiz e a relação parte aérea: raiz. Houve efeito isolado das doses de manipueira para a altura de planta, comprimento da lâmina foliar e massa fresca da parte aérea. No segundo corte, houve efeito isolado das doses de manipueira para a massa seca da parte aérea e massa seca da raiz, e significância da interação para altura de planta, comprimento da lâmina foliar, número de folhas por perfilho, número de perfillhos por planta e comprimento radicular. A dose de 44 m^3ha^{-1} foi mais eficiente no desenvolvimento dos capins Mombaça e Tanzânia, que se mostraram sensíveis a valores acima dessa dose, o que proporcionou redução significativa. A dose de 176 m^3ha^{-1} proporcionou o melhor desenvolvimento do capim Massai. Isso mostra que se deve levar em consideração a espécie, no estabelecimento da dose do biofertilizante a ser aplicada. A manipueira se mostrou promissora como fonte alternativa na adubação de gramíneas forrageiras, devido o benefício na disponibilização de nutrientes e pela elevada disponibilidade desse resíduo na Macrorregião de Picos, no semiárido piauiense, além de reduzir os impactos ambientais pelo descarte indiscriminado na natureza.

PALAVRAS CHAVE: *Panicum maximum*, pastagem, biofertilizante, água residuária de mandioca, agricultura familiar.

INTRODUCTION

Livestock is one of the main economic pillars of Brazil, where the production of forage obtained from cultivated pastures is the basis of Brazilian livestock activity (Fleitas et al., 2018; IBGE, 2018).

However, the main harmful consequence of this situation has been the large number of degraded pastures in the country. This is due to soil depletion in terms of organic matter content and the ability to make nutrients available to forages, limiting productivity and production sustainability (Lima et al., 2018). This fact makes proper fertilization management necessary. According to Teixeira et al. (2018), balanced fertilization and adequate pasture management are essential for obtaining more productive forages with good nutritional quality.

Recently, there has been a discussion about improving the quality of agricultural products produced in organic production systems, a fact that is no different for forage grasses that form the food base of the livestock activity. In this context, the search for ecological alternatives in agriculture to allow reducing the use of mineral fertilizers has increased (Sousa et al., 2017).

A natural fertilizer, common in family farming regions is manipueira, a residue generated from the processing of cassava to obtain flour or starch. It is a light-yellow milky liquid containing sugars, gums, proteins, linamarin, cyanogenic derivatives, salts and other substances (Cardoso et al., 2009; Duarte et al., 2012; Dantas et al., 2015). It is a nutrient-rich residue, with the presence of easy decomposition organic matter, which allows for the expressive and rapid release of nutrients (Barreto et al., 2014; Basheer et al., 2019). This makes manipueira a potential low-cost organic fertilizer.

However, this residue has been improperly disposed of in the environment, which can cause, in aquatic bodies, reduction in the availability of dissolved oxygen in the medium, causing the death of aerobic organisms, and its disposal in the soil impairs the balance between nutrients, increases salinity and decreases pH (Wosiacki & Cereda 2002; Dantas et al., 2015; Dantas et al., 2017; Costa et al., 2020) making its use as agricultural input even more relevant, thus reducing environmental problems.

Some authors have shown the efficiency of manipueira as fertilizer (Araújo et al., 2012; Duarte et al., 2012; Barreto et al., 2014; Dantas, et al., 2015; Dantas et al., 2016; Dantas, et al., 2016; Dantas, et al. al., 2017; Araújo et al., 2019a; Araújo et al., 2019b; Costa et al., 2020). However, there are no studies on the effectiveness of this product on forage grasses in the microregion of Picos, especially focused on family farming, which makes this approach promising.

The microregion of Picos is characterized by family-based agriculture, with cassava being one of the main crops produced in the region, where large part is transformed into flour by artisanal process in the famous flour houses of the region, constantly generating this residue, which has no further use.

Therefore, the aim of this study was to evaluate the development and production of three *Panicum maximum* cultivars in response to the application of manipueira in the semiarid region of Piauí.

MATERIAL AND METHODS

The experiment was carried out in the experimental area of the State University of Piauí – UESPI (latitude 07° 04` 37” S and longitude 41° 28’ 01” W, altitude of 206 m a.s.l.) in the municipality of Picos, 300 km from the state capital, Teresina. The experiment was conducted in a protected environment with dimensions of 4 x 9 x 2 m (l x c x h), covered with shade at 50% shading. The climate, according to the Köppen climate classification, is semiarid, very hot, characterized by scarce and irregular rainfall distribution, with high average temperatures around 27 °C and average annual rainfall of 778 mm (Exposti, 2013).

The experimental design used was completely randomized, with four replicates, and treatments were arranged in a 3 x 5 factorial scheme, composed of the combination of three forage grass cultivars of the genus *Panicum maximum* (Masai, Mombasa and Tanzânia grasses) and five manipueira doses (0; 22; 44; 88 and 176 m^3 ha^{-1}), totaling 60 experimental plots.

The soil was collected in an area of native vegetation of UESPI, in the layer of 0.0 - 0.2 m, which was dried in the shade and sent to the laboratory for chemical and grain size analysis (Teixeira et al., 2017). The results are shown in table 1.

Table 1. Chemical and grain size characterization of soil in the 0.0-0.2m layer. Picos, PI.

pH	P	K^+	Na^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H+Al	Sb	T	m	V	MO
	-----------$mgdm^{-3}$-------------			--------------------------------$cmol_c dm^{-3}$-------------------------------------						-----------------%-----------------		
5.0	4.3	17.6	16.3	1.1	0.3	0.5	2.6	1.4	4.0	25.6	36.1	1.1

pH in water, phosphorus (P), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), aluminum (Al^{3+}), hydrogen+aluminium (H+Al), sum of bases (Sb), CEC potential (T), aluminum saturation (m), base saturation (V) and organic matter content (OM). Sand: 71.8%; silt: 9.1%; clay: 19.1%.

Manipueira was collected in flour houses of the microregion of Picos, and a sample was separated and sent for laboratory chemical analysis (Table 2).

Table 2. Chemical characterization of manipueira. Picos, PI

N	P	K^+	Ca^{2+}	Mg^{2+}	Na^+	Zn^{2+}	Cu^{2+}	Fe^{2+}	Mn^{2+}
--$mg\ kg^{-1}$--									
450	90	550	10	180	100	0.70	0.10	1.40	0.10

Nitrogen (N), phosphorus (P), potassium (K+), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), zinc (Zn^{2+}), copper (Cu^{2+}), iron (Fe^{2+}) and manganese (Mn^{2+}) contents.

Soil acidity correction was carried out with application of limestone calculated based on the base saturation criterion, with dose sufficient to raise the base saturation to 60%, leaving the soil incubated in pots with capacity of 6 dm^3 for a period of 60 days before implantation of cultures.

Subsequently, manipueira doses were applied, leaving the soil incubated for 20 days, wrapped in aluminum foil to avoid problems of toxic effects of the residue on soil microorganisms and loss of water by evaporation. Residue doses were established taking into account the potassium (K) contents of soil and residue and based on the K requirement of cultures.

After the period of incubation of soil with manipueira, forages were sown at density of five seeds pot^{-1}. Seven days after germination, thinning was performed, leaving three plants pot^{-1}. Seventy days after sowing, uniformity cut was carried out at 0.2 m above the ground. Subsequently, the second cut was performed after 35 days. Irrigation was carried out in order to meet the crop requirements.

In each cut, the following variables were evaluated: plant height (PH, cm), leaf blade length (LBL, cm) number of leaves per tiller (NLT), number of tillers per plant (NTP), shoot fresh mass (SFM, g pot^{-1}) and shoot dry mass (SDM, g pot^{-1}). After the last cut, root length (RL, cm), root dry mass (RDM, g pot^{-1}) and shoot: root ratio (S/R) were determined.

To evaluate PH and LBL, a ruler graduated in millimeters was used, and for PH, the length measured from the soil up to the insertion of the last expanded leaf was taken as a basis, and for LBL, the length measured from the base of the blade up to its apex was considered. NLT and NTP were assessed by simple counting. To determine SFM, plants were cut to height of 0.2 m, and after cut, they were packed in paper bags and weighted. Subsequently, they were dried in an oven with air circulation at 65°C for 72 hours and after drying, plants were weighed on analytical scale to determine SDM. To determine RL and RDM, roots were all removed from pots, and then RL was evaluated with the aid of a millimeter ruler and dried in an oven with forced air circulation at 65ºC until constant weight and weighed for RDM determination. PH and RL variables were used to determine the shoot: root ratio.

Data obtained were submitted to analysis of variance using the F test (P≤0.05). Variety factor means, when significant, were compared by the Tukey's test at 5% probability. Manipueira doses, when significant, were submitted to polynomial regression analysis.

RESULTS AND DISCUSSION

According to the analysis of variance (Table 3), there was an isolated effect of manipueira doses on plant height (PH), leaf blade length (LBL) and shoot fresh mass (SFM) and interaction effect for number of leaves per tiller (NLT) and number of tillers per plant (NTP).

Table 3. Analysis of variance for plant height (PH), leaf blade length (LBL), number of leaves per tiller (NLT), number of tillers per plant (NTP), shoot fresh mass (SFM) and shoot dry mass (SDM) of *Panicum maximum*, in the first cut, under manipueira application. Picos, PI

Sources of variation	Mean Squares					
	PH	LBL	NLT	NTP	SFM	SDM
	--------------cm----------------				----------------g-----------------	
Cultivar (CUL)	5.92 ns	4.67ns	0.89*	4.15*	2.35 ns	0.60 ns
Manipueira doses (DM)	8.60*	14.77*	0.97*	0.15ns	3.94*	1.11 ns
CUL X DM	1.39 ns	3.26 ns	0.31 *	0.35 *	0.87 ns	2.71 ns
CV(%)	17.18	29.09	9.29	16.36	37.24	45.61

* Significant by the F test at 5% probability; ns not significant.

There was a quadratic behavior of manipueira doses for PH (Figure 1a), with dose 0 providing the highest average (28.5 cm). This possibly occurred due to the excess of nutrients in manipueira, which, when added to the soil, can cause growth restrictions and even alter its vegetative stages (Bovi et al., 2002). Barretto et al. (2014) also found reduction in corn HP with increasing manipueira doses.

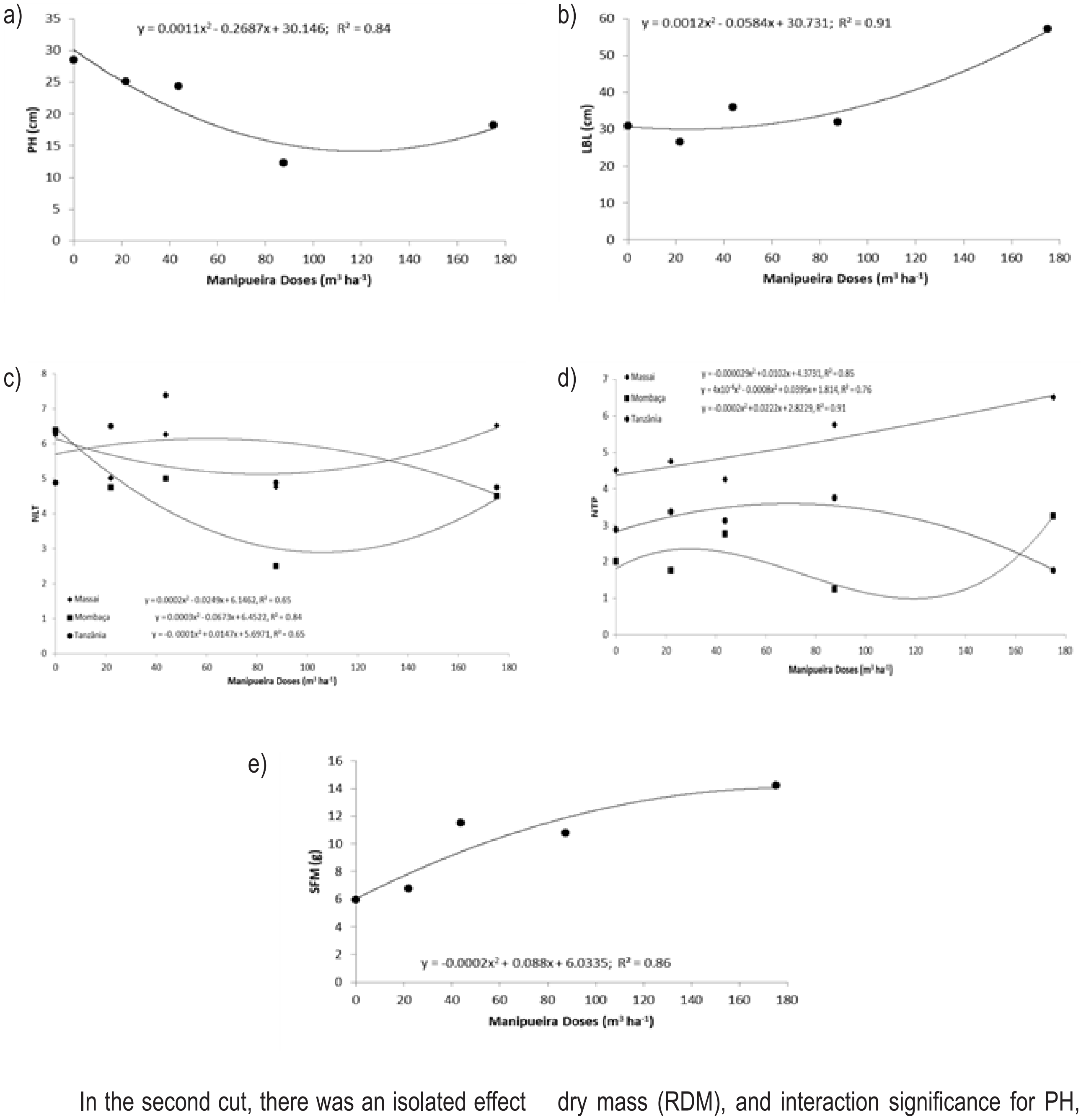
There was a quadratic behavior of manipueira doses for LBL (Figure 1b), with the application of 176 m^3 ha^{-1} providing the highest average (57.33 cm), representing an increase of 86% in relation to the non-application of manipueira. This gain is probably due to the contribution of potassium (K), as the deficiency of this element negatively affects the photosynthetic activity of the plant and consequently the LBL, which is associated with the photosynthetic capacity of forages (Taiz and Zeiger, 2017).

In relation to NFP, Massai and Tanzania grasses reached the highest average at doses 176 and 73.5 m^3 ha^{-1}, respectively (Figure 1c). For Mombasa grass, increasing manipueira doses caused a decrease in this variable. This may be associated with the sensitivity of this culture to excess manipueira, where nutrients such as Manganese, Zinc, Iron and Calcium had their absorption impaired by excess K in the residue, thus reducing the synthesis of the chlorophyll molecule (Santos et al., 2010; Taiz and Zeiger, 2017). This behavior was also observed in Tanzania grass, where doses above 73.5 m^3 ha^{-1} showed reduction in NLT, with emphasis on the dose of 176 m^3 ha^{-1} in which the value was below control. Thus, there is a need to establish adequate doses of this biofertilizer not to harm the culture development. Magalhães et al. (2014) worked with manipueira application in the initial corn development and found that the dose of 75.6 m^3 ha^{-1}, close to the ideal dose for Tanzania grass, provided the highest value for variable number of leaves.

For NTP, increase was observed with manipueira application for all forages under study. Doses of 176, 176 and 55.5 m^3 ha^{-1} provided the highest means of this variable for Massai, Mombasa and Tanzania grasses, respectively (Figure 1d). The high capacity of nutrients such as Nitrogen (N) and Phosphorus (P), added by manipueira (Table 2) to stimulate the tillering of forage grasses is a plausible explanation (Benício et al., 2013; Pereira et al., 2015). Martuscello et al. (2015) argue that N favors the formation of axillary buds and tillering initiation, resulting in higher tillering rate. According to Benício et al. (2013), the absence of P substantially limits tillering. However, for Tanzania grass, doses above 55.5 m^3 ha^{-1} promoted reduction in NTP, which reinforces the need to calibrate the correct dose for each species in particular.

There was a quadratic behavior for SFM (Figure 1e), where dose of 220 m^3 ha^{-1} provided the best result (15.71 g). According to Cardoso et al. (2009), plants grown in area fertilized with manipueira have higher SFM due to nutrients present in the biofertilizer, mainly K and N. The positive effect of manipueira in increasing SFM values was also observed by Magalhaes et al. (2014) and Lucena et al. (2019), in corn crop, which was attributed to the nutrient richness of the residue.

Figure 1. Mean data on plant height (a), leaf blade length (b), number of leaves per tiller (c), number of tillers per plant (d) and shoot fresh mass (e) of *Panicum maximum*, in the first cut, in response to manipueira applications (P≤0.05).



In the second cut, there was an isolated effect of manipueira doses for shoot dry mass (SDM) and root dry mass (RDM), and interaction significance for PH, LBL, NLT, NTP and root length (RL) (Tables 4 and 5).

Table 4. Analysis of variance for plant height (PH), leaf blade length (LBL), number of leaves per tiller (NLT), number of tillers per plant (NTP), shoot fresh mass (SFM) and shoot dry mass (SDM) of *Panicum maximum*, in the second cut, under manipueira application. Picos, PI

Sources of variation	Mean Squares					
	PH	LBL	NLT	NTP	SFM	SDM
	--------------------cm-------------------				--------------------g-------------------	
Cultivar (CUL)	1670.33*	305.79*	5.21*	33.01*	47.87 ns	5.17ns
Manipueira doses (DM)	372.77*	147.04ns	5.64*	5.03*	40.94ns	3.21*
CUL X DM	392.97*	379.13*	3.52*	4.53*	37.15ns	2.01ns
CV(%)	13.59	24.98	13.25	8.16	32.07	28.76

* Significant by the F test at 5% probability; ns not significant.

Table 5. Analysis of variance for root length (RL), root dry mass (RDM) and SDM RDM -1 ratio of *Panicum maximum*, in the second cut, under manipueira application. Picos, PI

Sources of variation	Mean Squares		
	RL	RDM	SDM RDM^{-1}
	-----cm------	---g---	
Cultivar (CUL)	676.95*	8.60ns	31.56ns
Manipueira doses (DM)	457.66*	23.55*	107.20ns
CUL X DM	257.22*	4.98ns	134.90ns
CV(%)	7.28	63.30	87.41

* Significant by the F test at 5% probability; ns not significant.

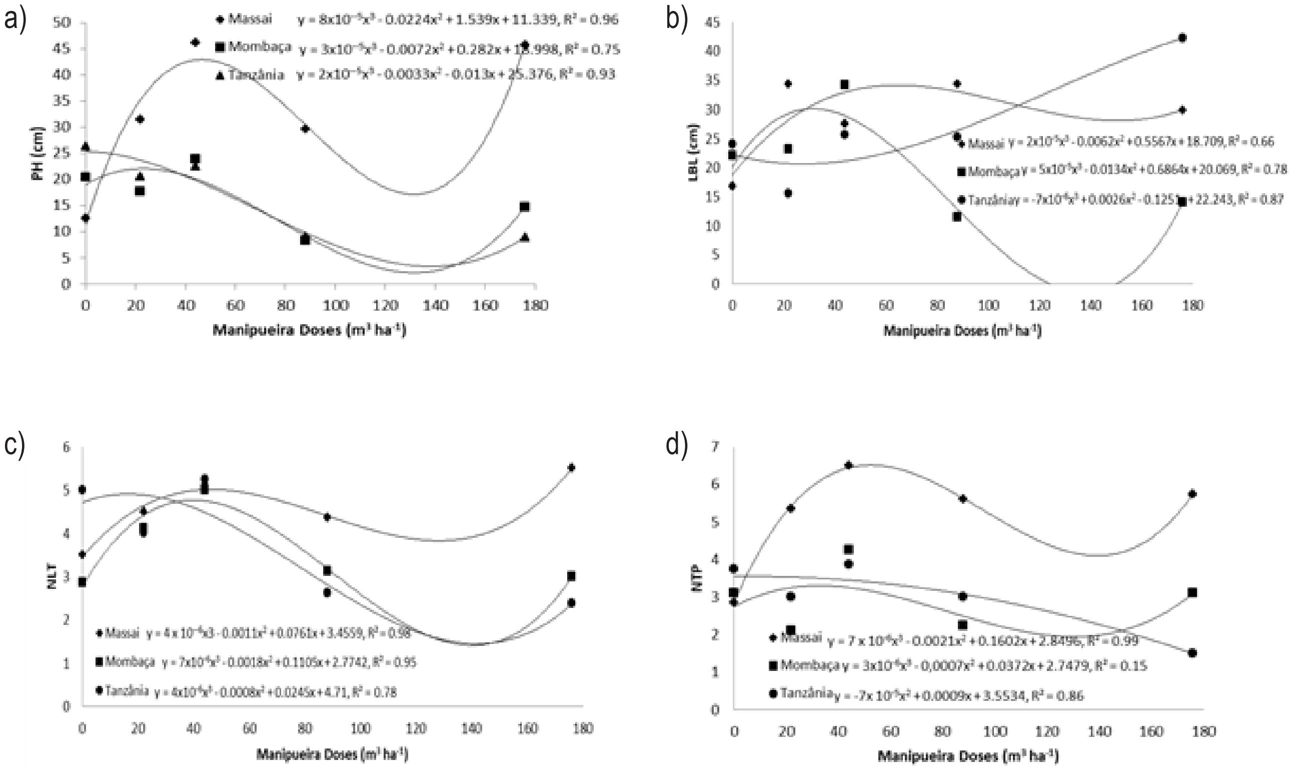
There was a cubic behavior of manipueira doses for PH (Figure 2a), with dose of 44 m^3 ha^{-1} providing the highest averages for Massai (43.13 cm) and Mombasa grasses (23.87). This probably occurred due to the reaction time of manipueira with the soil, making nutrients more available for the uptake of cultivars, a fact that, possibly, did not occur in the first cut. Similar results were found by Saraiva et al. (2007) and Lucena et al. (2019) in study analyzing fertigation with manipueira in corn in a protected environment, where they observed greater effect of plant height over time. The authors emphasize that the effect of manipueira on grass development is substantial in the medium and long term. For Tanzania grass, reduction in PH was observed with increasing doses, proving to be a cultivar sensitive to high doses. Mombasa grass was also sensitive to doses above 44 m^3 ha^{-1}.

There was a cubic behavior for LBL, where the three cultivars presented different values depending on manipueira doses (Figure 2b). Massai grass obtained the highest value (34.35 cm) at dose of 88 m^3 ha^{-1}. For Mombasa grass, the best dose was 44 m^3 ha^{-1}, providing value of 34.15 cm. Tanzania grass obtained the highest value (42.29 cm) at dose of 176 m^3 ha^{-1}. This gain was possibly due to the action of K, the nutrient most present in manipueira, which influences the photosynthetic activity (Taiz and Zeiger, 2017). Mombasa grass showed a sharp drop in this variable with doses above 44 m^3 ha^{-1}. This fact may have occurred due to some deleterious effect of nutrients, especially potassium, which, in excess, can compromise the absorption of other elements such as calcium, magnesium, zinc and manganese by more sensitive plants (Malavolta, 1997).

For NLT, the dose of 44 m^3 ha^{-1} provided the highest averages, with values of 5.12 and 5, for Massai and Mombasa grasses respectively (Figure 2c), with Mombasa grass being sensitive to doses greater than 44 m^3 ha^{-1}. In relation to Tanzania grass, increasing manipueira doses caused a decrease in this variable, but from the dose of 22 m^3 ha^{-1}, increase in this variable was observed, reaching the maximum value (5.25) at dose of 44 m^3 ha^{-1}. The higher NLT values at dose of 44 m^3 ha^{-1}can be explained by the presence of P in manipueira.

Regarding NTP, there was a cubic adjustment for Massai and Mombasa grasses with dose of 44 m^3 ha^{-1}, providing the highest values, 6.25 and 4.25, respectively (Figure 2d). This fact should possibly be attributed to the presence of P in the biofertilizer. Oliveira et al. (2012) obtained similar results on the number of tillers of Mombasa grass in sandy soil, where the presence of P provided significant gains, showing the importance of this residue in the addition of nutrients, mainly N and P, where their efficiency in stimulating the tillering of forage grasses is recognized (Benício et al., 2013; Pereira et al., 2015), especially in the soil under study, which is poor in nutrients, mainly P. For Tanzania grass, there was a quadratic behavior, with dose of 44 m^3 ha^{-1} having the greatest effect (3.87).

Figure 2. Mean plant height (a) leaf blade length (b), number of leaves per tiller (c) and number of tillers per plant (d) values of *Panicum maximum*, in the second cut, in response to manipueira applications (P≤0.05).



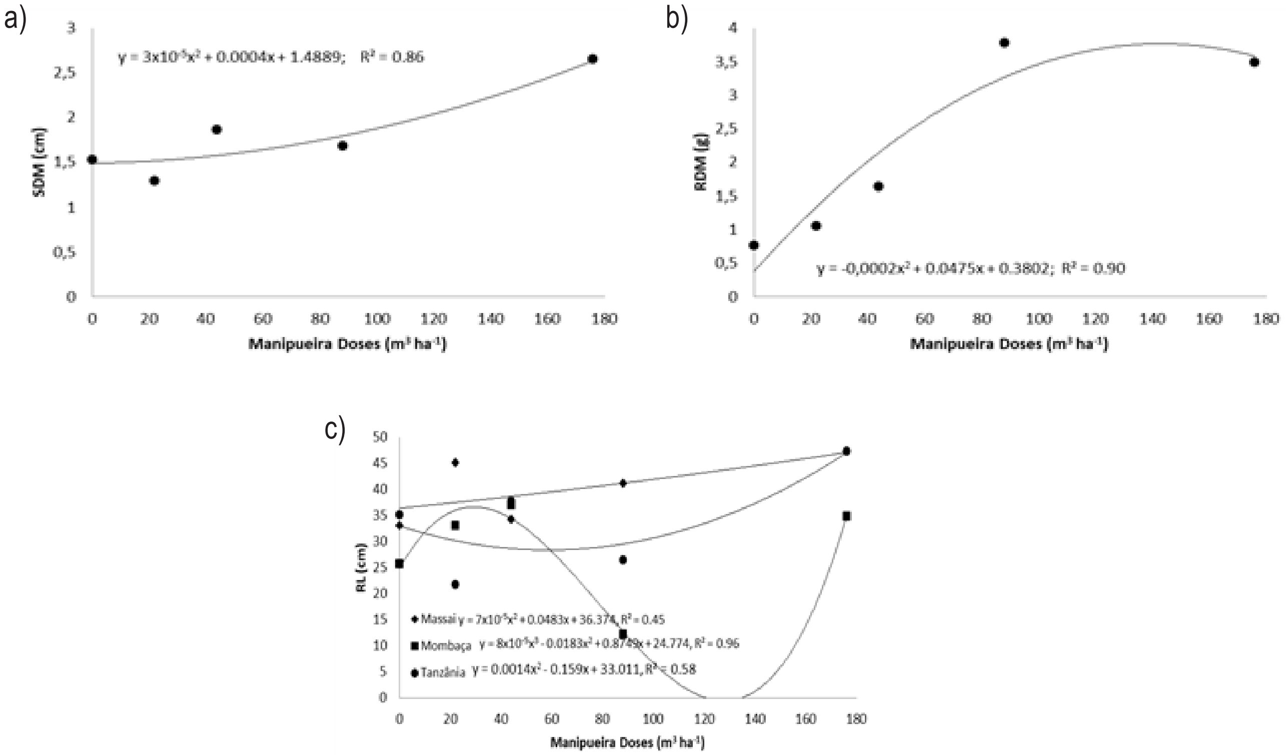
Mombasa and Tanzania grasses were sensitive to manipueira dose above 44 m^3 ha^{-1}, with a sudden drop in values. This may be associated with the acidity of manipueira, which interferes with the absorption of its nutrients by more sensitive plants (Araújo et al., 2019b), as observed for grasses evaluated in this study. This again reinforces the need to establish specific doses for each species in particular.

In relation to SDM, there was a quadratic behavior, where dose of 176 m^3 ha^{-1} provided the highest value (2.65 g), with increase of 73.2% in relation to control (figure 3a). Study carried out by Piedade et al. (2009) reveal that the amount of N present in wastewaters, in this case manipueira, can favor the good development of plants, providing increase in dry matter content.

There was a quadratic adjustment for RDM, where dose of 119 m^3 ha-1 provided the highest value (3.20 g) (Figure 3b), with increase of 321% in relation to dose 0.

For RL, there was a quadratic adjustment for Massai and Tanzania grasses with dose of 176 m^{3}ha^{-1}, providing the highest values, 47.25cm and 47.37cm, respectively (Figure 3c). Mombasa grass had a cubic adjustment with dose of 44 m^3 ha^{-1}, providing value of 37 cm. It is worth mentioning that Mombasa grass is extremely sensitive to doses above 44 m^3 ha^{-1}, with accentuated drop in values.

Figure 3. Mean shoot dry mass (a), root dry mass (b) and root length (c) values of *Panicum maximum*, in the second cut, in response to manipueira applications (P≤0.05).



Mombasa and Tanzania grasses were sensitive to doses above 44 m^3 ha^{-1}, mainly in the second cut, while Massai grass developed better at dose of 176 m^3 ha^{-1}. This shows that the species must be taken into account when establishing the biofertilizer dose to be applied.

Thus, it could be concluded that manipueira proved to be promising as an alternative source in the fertilization of forage grasses due to the benefit in the availability of nutrients and to the high availability of this residue in the microregion of Picos, semiarid region of Piauí, in addition to reducing environmental impacts by indiscriminate disposal, where the recommended dose for the development of Mombasa and Tanzania grass was 44 m^3 ha^{-1}, while the recommended dose for the development of Massai grass was 176 m^3 ha^{-1}.

However, further studies are needed to evaluate, under field conditions and for a longer period, the effect of this natural fertilizer on the growth and production of these forage grasses.

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