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Sward structure, morphological components and forage yield of massai grass in response to residual effect of swine biofertilizer

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ABSTRACT. The present study aimed to evaluate the residual effects of the application of biofertilizer and mineral fertilizer on sward structure and morphological components of *Panicum maximum* cv. Massai. The experimental design comprised randomized blocks with six treatments consisting of increasing doses of swine biofertilizer (0, 10, 20, 30 and 40 Mg ha^{-1}) and mineral fertilization (150 kg N ha^{-1}, 33 kg P ha^{-1}), with four replicates. The variables analyzed were pasture height, light interception, leaf area index, forage mass and morphological components. Plant height responded linearly and positively to biofertilizer levels in the three evaluations. The highest averages for light interception (51.63%) and leaf area index (1.64) were observed for the 240 days (40 Mg ha^{-1}). Dry leaf mass was influenced by the increase in biofertilizer dose, with increments of 39.68%, 25.07% and 44.66% for the 240, 300 and 360 days, respectively, when compared to the control treatment. Mineral fertilization promoted lower mass of dead material and lower leaf area index but did not differ from biofertilizer for the other variables. The residual effect of swine biofertilizer was greater than that of mineral fertilization, with a minimum use of 20 Mg ha^{-1} a practical agronomic recommendation.

Keywords: dry matter; forage; grass fertilization; organic fertilizer; *Panicum maximum*; tropical grass.

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Introduction

The establishment of pastures with plants that are productive under the edaphoclimatic conditions of the brazilian semiarid region can reduce pressure on areas of native vegetation and strengthen the raising of livestock in the region (Luna et al., 2014; Pereira, Emerenciano Neto, Difante, Assis, & Lima, 2019).

Massai grass (*Panicum maximum*), is a drought-tolerant tropical grass with desirable characteristics for animal production (Lopes et al., 2013). Studies that determine the best management strategies for this forage in the driest region of Brazil are, therefore, important. This is particularly true because of the diversity of production environments in the region with soils naturally acidic and with low levels of organic matter.

Structural characteristics of pastures are parameters that contribute to understanding the consumption of animal forage (Difante, Nascimento Júnior, Silva, Euclides, & Montagner, 2011). In addition, the contribution of biomass that supports more or less expressive responses of plants to nutrient availability is linked to factors such as the frequency and interval of forage cuts (Medica, Reis, & Santos, 2017) and the adoption of other techniques such as control of its structure (Carvalho et al., 2017).

Another relevant aspect within livestock management is the management of organic waste. The use of animal waste as a sustainable proposal can mitigate environmental damage, reduce production costs, increase availability of organic matter and improve soil quality (Lourenzi et al., 2013; Gomes, Peruzatto, Santos, & Sellitto, 2014).

In this regard, swine farming, which is economically important for Brazil (Associação Brasileira de Proteína Animal [ABPA], 2018), is one of the livestock sectors most commonly related to environmental damage due to the production of waste. A viable and practical solution is the use of these residues through anaerobic biodigestion in biodigesters, which transform waste into two sustainable bases: biogas and biofertilizer (Silva, Novaes, Kuroki, Martelli, & Magnoni Júnior, 2012; Rodrigues et al., 2014; Bócoli, Mantovani, Miranda, Marques, & Silva, 2016).

Biofertilizer increases the levels of organic matter and nutrients in the soil, which can reduce the demand for imported mineral fertilizers (Scherer, Nesi, & Massotti, 2010; Castoldi, Costa, Costa, Pivetta, & Steine, 2011; Moreira, Fernandes, Colen, & Cruz, 2015). However, application levels must be moderate to obtain maximum crop yields (Lim, Wu, Lim, & Shak, 2015). Zootechnical results require financial planning and the economic viability of the production process is important. In this sense, the adoption of the use of swine biofertilizer can be more than a technical solution for the environmental management of organic waste, bringing economic gains due to the reduction of mineral fertilizer costs (Souza, Marinho, Albuquerque, Viana, & Azevedo, 2012).

In agronomic practice it is important to understand how plants respond to the dynamics of nutrients, such as nitrogen (Haynes, 2012). Furthermore, the residual effect of inputs added to the soil are dependent on the process of decomposition, which, in addition to being complex, is regulated by soil chemical properties and physics (Sánchez, Willson, Kizilkaya, Parker, & Harwood, 2001; Dunjana, Nyamugafata, Shumba, Nyamangara, & Zingore, 2012; Zhou, Peng, Perfect, Xiao, & Peng, 2013; Maluf, Soares, Silva, Neves, & Silva, 2015; Zwetsloot, Lehmann, & Solomon, 2015; Thomas, Luo, Li, & Hao, 2017).

Thus, the use of the residual effect of swine biofertilizer can represents a sustainable strategy for production systems. The objective of the present study, therefore, was to evaluate the residual effects of swine biofertilizer and to compare with the mineral fertilization in pastures of massai grass.

Material and methods

The study was performed from July 2015 to August 2016 in the area of Grupo de Estudos em Forragicultura (GEFOR; Forage Study Group) of Escola Agrícola de Jundiaí (EAJ; Jundiaí Agriculture School) (5° 53' 35.12" S, 35° 21' 47.03" W, 50 m altitude), Universidade Federal do Rio Grande do Norte (UFRN; Federal University Rio Grande do Norte), in the municipality of Macaíba, state of Rio Grande do Norte, Brazil.

According to the Köppen classification, the climate of the region is composed of two types, As' and Bsh', which are characterized by dry winters and rainy and hot summers (Alvares, Stape, Sentelhas, Gonçalves, & Sparovek, 2013). The average temperature during the experiment was 27.1°C (maximum of 32 and a minimum of 21°C), while cumulative rainfall was 1161 mm (Figure 1).

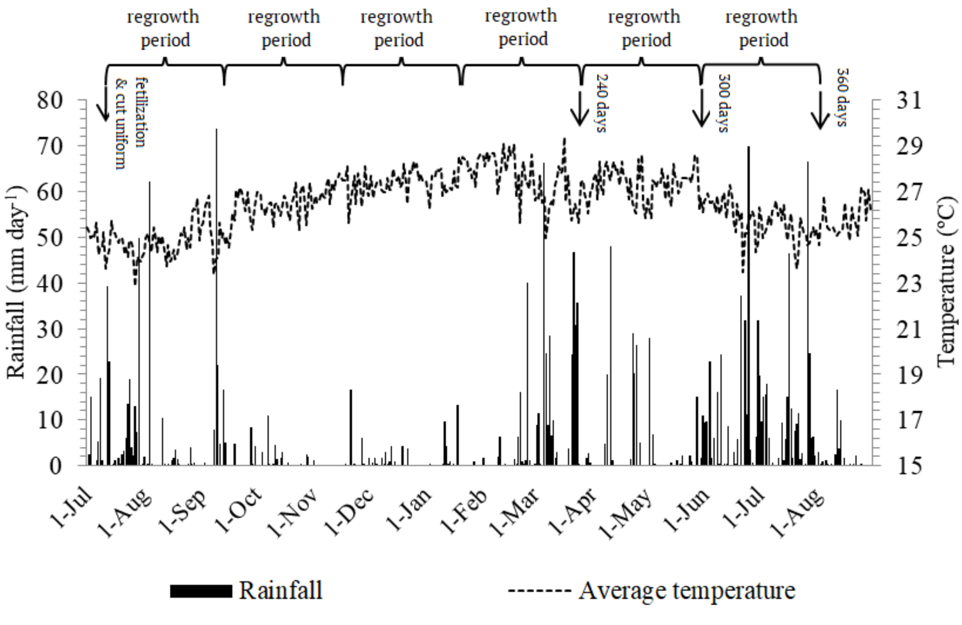

Figure 1. Daily rainfall and average temperature at the study site during the experiment.

The soil in the area is classified as Arenosol (Food and Agriculture Organization [FAO], 2015), with the following chemical characteristics at a depth of 0-20 cm: pH (in water): 5.88; 10.60 g dm^{-3} of OM; 4.00 mg dm^{-3} of P; 96.0 mg

dm^{-3} of K; 0.74 $cmol_c$ dm^{-3} of Ca^{2+}; 0.25 $cmol_c$ dm^{-3} of Mg^{2+}; 0.0 $cmol_c$ dm^{-3} of Al^{+3}; 1.21 $cmol_c$ dm^{-3} of H+Al; 35.0 mg dm^{-3} of Na^+; 10.86 mg dm^{-3} of Fe^{2+}; 0.95 mg dm^{-3} of Zn^{2+}; 0.13 mg dm^{-3} of Cu^{2+} and 3.86 mg dm^{-3} of Mn.

The experiment was performed in a massai grass pasture established in January 2010 and grazed by sheep until June 2015. According to soil analysis, liming was carried out by distributing 2 Mg ha^{-1} of dolomitic limestone (effective calcium carbonate, ECC – 45%) following recommendations for the culture by Cavalcanti (2008).

The experimental design comprised a completely randomized blocks with six treatments and four replicates (plots with 8.16 m^2 of useful area). The treatments consisted of five increasing doses of biofertilizer (0; 10; 20; 30 and 40 Mg ha^{-1}) and an additional treatment with mineral fertilizer (150 kg N ha^{-1} and 33 kg ha^{-1} of P, via urea and simple superphosphate, respectively), according to culture recommendation (Ribeiro, Guimarães, & Alvarez, 1999), based on soil analysis.

Biofertilizer was obtained by anaerobic digestion of swine manure and had the following chemical composition: N: 7.28 g kg^{-1}; P: 5.90 g kg^{-1}; K: 1.36 g kg^{-1}; Ca^{2+}: 9.36 g kg^{-1}; Mg^{2+}: 2.18 g kg^{-1}; Na^+: 52.0 g kg^{-1}; Zn^{2+}: 117.0 mg kg^{-1}; Cu^{2+}: 75.0 mg kg^{-1}; Fe^{2+}: 363.0 mg kg^{-1}; and Mn: 62.0 mg kg^{-1}.

Treatments were applied to plots after cutting for pasture uniformity in July 2014. Mineral fertilizer was divided into two applications, with the first being applied at the same time as the application of the biofertilizer treatments and the second 60 days later. Six successive cuts, made at 60-day intervals, were made to the pasture leaving a residue height of 0.15 m. The responses of plants to the residual effects of fertilization were evaluated for the last three cuts at 240, 300 and 360 days of sward regrowth.

Pasture height was measured before each cut at ten random points per plot using a graduated ruler (centimeters). The height at each point corresponded to the average height of the curvature of the leaves around the ruler, with residual sward height of forage being 0.15 m.

The light interception (LI) and leaf area index (LAI) was measured immediately prior to each cut, five readings were made above the forage canopy and at soil level in each plot using a Model PAR – 80 AccuPAR Linear PAR/LAI Ceptometer (DECAGON Devices®) canopy analyzer apparatus. Measurements were always made between 9:00 and 12:00h, and the percentage of light intercepted by the canopy was obtained through Equation (1):

$$LI\% = 100\% - [(s / a) \times 100] \quad (1)$$

Where LI% is the percentage of light intercepted by the canopy, s is the reading at soil level and a is the reading above the canopy. The same device as used to obtain LI% was used to directly measure LAI at the same sampling points.

To determine the other variables, all the forage plants contained in the useful area of each plot were cut at 0.15 m above the soil, collected, placed in identified plastic bags and weighed individually to determine green weight. A representative sub-sample (minimum of 0.3 kg) was taken to estimate total dry mass production (TDMP). The remainder of the collected material was subjected to manual separation of morphological components into the following fractions: leaf (leaf blade), stem (green stem + sheath) dead material and unwanted plants. The fractions were placed in previously identified paper bags, weighed on a digital scale and placed in a forced ventilation oven at 55°C for 72h until constant mass. The fractions were then weighed to estimate dry weight of each fraction of the sample in order to estimate dry mass production of each botanical component (Bezerra et al., 2017).

Data were subjected to analysis of variance and averages of the three cuts were compared by Tukey's Test ($p < 0.05$). Regression analysis was performed for biofertilizer doses as a function of cuts. Statistical analyses were performed using software Sisvar, version 4.6 (Ferreira, 2014).

Results and discussion

The height of the massai grass pasture increased linearly as a function of the doses of biofertilizer (Figure 2A), with increments of 9.26, 7.33 and 17.46% for the 240, 300 and 360 days of regrowth, respectively, when comparing the lowest (0 Mg ha^{-1}) to the highest (40 Mg ha^{-1}) doses. As the number of cuts advanced, the height of the pasture decreased. This finding can be explained by reduced nutrients in the soil over time, with nutritional requirements of the plants not being met, even with the highest dose of biofertilizer. In addition, nutrients are released from organic fertilizer slowly, which promotes such results, unlike mineral fertilizers that are quickly released either to plants or to the soil (Novais et al., 2007).

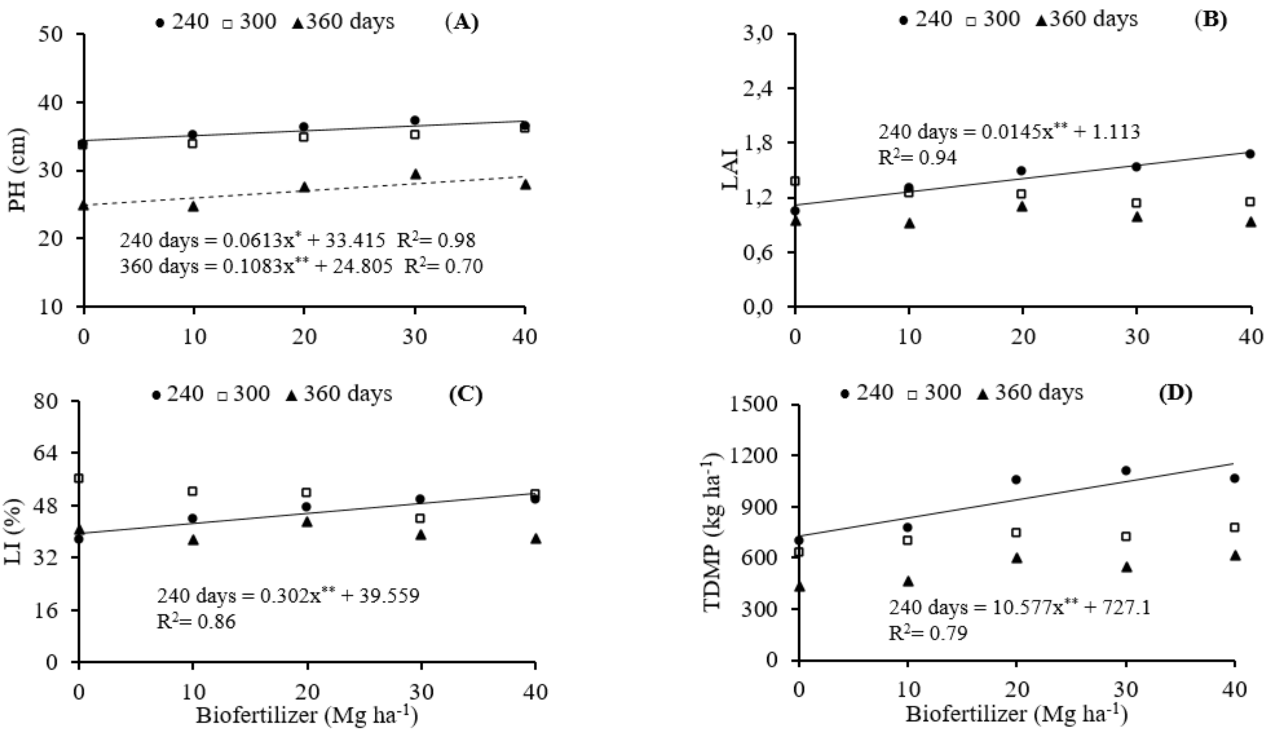

Figure 2. Pasture height (A), leaf area index (B), light interception (C) and total dry mass production (D) for massai grass as a function of biofertilizer dose applied to the soil, over three successive cuts. **, * Significant at 1% and 5% respectively.

It is possible that at the time of the 360 days regrowth, the nutrient reserves provided by biofertilizer were depleted and did not meet the maximum required by the crop, indicating the need for additional fertilization. The values found in the present work for plant height were similar to those observed by Emerenciano Neto et al. (2016), who used solid poultry and swine waste to fertilizer massai grass with a target of 150 kg N ha^{-1}. In this respect, we consider swine biofertilizer as a potential source of high nutrition for massai grass until the 240 days of regrowth.

The leaf area index (LAI) and light interception (LI) did not fit a mathematical model in the regression for the 300 and 360 days, however, for the 240 days regrowth, LAI and LI increased by 13.02% (Figure 2 B) and 7.63% (Figure 2C), respectively, with the increase in biofertilizer dose. These values, nonetheless, are considered very low and demonstrate an unfavorable condition of the pasture. Cutrim Junior, Cândido, Valente, Carneiro, and Carneiro (2011) pointed out that the 95% LI level must be the maximum limit of the regrowth period, and thus be interrupted by defoliation or cutting. One of the causes of these results could be a short regrowth period, however, the 60-day interval used in the present study was insufficient to re-establish the canopy. Thus, these results can be attributed to the low availability of nutrients in the soil.

The production of forage dry matter with the 240 days varied from 727.41 (0 Mg ha^{-1} of biofertilizer) to 1150.49 kg ha^{-1} (40 Mg ha^{-1} of biofertilizer), which is an increase of 58.16% (Figure 2D). Average values for 300 and 360 days of regrowth were 711.57 and 532.83 kg ha^{-1}, respectively These results demonstrate a gradual decrease in forage mass with the advance of cuts. In other words, there is a reduction in productivity of massai grass beyond the 240 days of sward regrowth, for all treatments regardless of fertilizer used.

Leaf blade mass (Figure 3), behaved in an increasing linear manner with increasing biofertilizer dose, but reduced with the progression of cuts. The increase between the lowest and highest dose of biofertilizer corresponded to 51.14% (240 days), 31.55% (300 days) and 47.19% (360 days), indicating the beneficial effect of using biofertilizer as a source of nutrients for massai grass, especially nitrogen, which contributes to cell stretching and multiplication (Lopes et al., 2013).

The leaf fraction corresponded to 95%, 97% and 100% of the dry green mass (DGM) for the 240, 300 and 360 days of sward regrowth, respectively, which is similar to the result for pasture height. It should be noted that there was no significant quantification of stem in the last cut, with the whole aerial part above the residue being considered as leaf, which is good from the nutritional point of view because leaves contain the highest concentration of nutrients in forage. However, the elongation of the stem induces an increase in the forage canopy, facilitating the capture of photosynthetically active radiation by the leaves (Pereira et al., 2011).

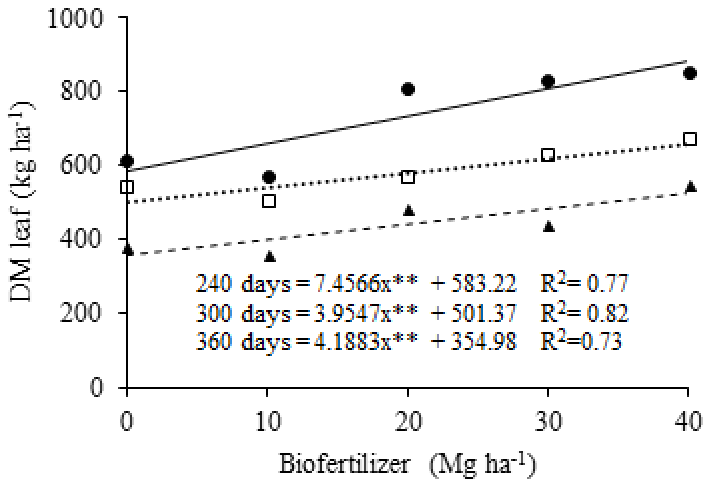

Figure 3. Production of leaf blade dry mass for massai grass as a function doses of biofertilizer added to the soil and successive cuts. ** Significant at 1%.

In the Table 1 is compared the averages obtained in the three cuts for the treatments of biofertilizer with the average for mineral fertilization. There is no significant effect ($p < 0.05$) on the results for total production of forage, leaves, stem, height and LI, while there was a significant effect on accumulation of dead material, undesirable plants and LAI. This finding demonstrates the potential of using biofertilizer in doses above 20 Mg ha^{-1} in partial or total substitution for mineral fertilizer.

Table 1. Production of total (T), leaf (L) and stem (S) dry mass (DM), dead tissue (DT) and undesirable plants (U); and pasture height (PH), light interception (LI) and leaf area index (LAI) in pastures of massai grass fertilized with doses of biofertilizer in comparison with mineral fertilization.

Variable	Biofertilizer (Mg ha^{-1})					Mineral Fertilizer	F	LSD	Coefficient of variation %
	0	10	20	30	40				
T $^{(DM)}$	609.24 a	685.37 a	721.72 a	865.40 a	680.17 a	836.02 a	ns	245.36	8.38
L $^{(DM)}$	480.63 a	507.39 a	548.23 a	769.02 a	608.10 a	697.51 a	ns	311.95	4.17
S $^{(DM)}$	19.86 a	15.13 a	13.32 a	26.08 a	17.20 a	23.63 a	ns	14.78	5.08
DT $^{(DM)}$	25.22 ab	18.80 ab	35.85 a	16.30 ab	15.73 ab	11.42 b	*	16.24	6.06
U $^{(DM)}$	144.05 a	124.32 a	83.53 ab	54.00 b	39.14 b	103.46 ab	**	65.84	12.35
PH $^{(cm)}$	31.90 a	31.62 a	32.05 a	33.99 a	33.09 a	33.76 a	ns	4.51	6.95
LI $^{(\%)}$	42.87 a	42.21 a	44.76 a	51.40 a	46.78 a	43.45 a	ns	10.42	9.45
LAI	1.08 b	1.23 ab	1.48 a	1.14 ab	1.29 ab	1.04 b	*	0.43	3.60

*: Means followed by the same letter in a row do not differ significantly (0.05 level) by Tukey's Test. $^{(DM)}$: kg DM ha^{-1}. LSD: Least significant difference. **, * Significant at 1% and 5%, respectively.

Stem mass (Table 1), did not vary among doses of biofertilizer. This finding can be attributed to the lower availability of nutrients in the soil resulting in no elongation of the stem above the cutting height (0.15 m). Emerenciano Neto et al. (2016) also observed the absence of the stem component when evaluating the use of poultry and sheep manure as fertilizer for massai grass. According to these authors, the low participation of the stem component in forage mass is characteristic of massai grass due its low rate of elongation and narrow thickness.

The production of dead material mass did differ among treatments (Table 1), with the highest average being observed with the biofertilizer dose of 20 Mg ha^{-1}. From an agronomic point of view, and under the imposed conditions, these data indicate a low pasture senescence rate, which is favorable since there is no interest in high production of dead material because it reduces the nutritional value of forage (Emerenciano Neto et al., 2013). In addition, the effect of biofertilizer on LAI at a dose of 20 Mg ha^{-1} was superior to that of other treatments, due to the better use of soil resources for the construction of the photosynthetic apparatus (Lemaire, Oosterom, Jeuffroy, Gastal, & Massignam, 2008; Rostamza, Chaichi, Jahansouz, & Alimadadi, 2011).

When related to the other variables studied in this work, the behavior of the accumulation of dead material can be seen to be associated with a low rate of leaf elongation, in addition to the ever less appearance of new leaves and tillers, reflecting a small production of green mass. On the other hand, the plants are recognized to have tolerance to low nutrient availability, and it is hoped that further studies may contribute to understanding the survival strategies of massai grass plants in nutrient deficit, especially nitrogen, that according to Braz et al. (2012) is an indispensable role for the recovery of pasture.

The mass of undesirable plants differed statistically among treatments (Table 1). The incidence of these plants was greater in treatments with lower doses of biofertilizer and in the mineral fertilization treatment. Therefore, the shorter forage canopy, and the growth habit of massai grass, contribute to the development of undesirable plants and thus to competition for, mainly, water and nutrients.

It should be noted that in addition to the continuous extraction of nutrients from the soil via plants, the rainfall period (Figure 1) may have intensified the leaching of nutrients present in the soil. Thus, maintenance fertilization is recommended to replace these nutrients so as to maintain or even increase forage production. Corroborating these results, Maggi, Freitas, Sampaio, & Dieter (2011) found increases in potassium levels in soil percolate with the application of increasing doses of swine wastewater, due to the mobility characteristic of this element that makes it easily leached. For Fortes Neto et al. (2013), the leaching of nutrients, as well as chemical changes in the soil and plant responses, depend on the chemical composition of the waste used, the type of soil and the plant species.

It is important to highlight the growth capacity of massai grass, even with nutrient restrictions, after several cuts and in soil with low moisture retention in a region with an unfavorable climate due to water stress (Figure 1). This shows that this cultivar is an alternative for supplying fodder in semiarid regions, mainly due to its productive potential, as found by other studies developed with forage in the same region (Emerenciano Neto et al., 2013, 2017; Luna et al., 2014; Bezerra et al., 2017; Fernandes et al., 2017).

Conclusion

Use residual effect of swine biofertilizer influences the structure and morphological composition of pastures of massai grass, making it a sustainable alternative for plant production in semiarid regions, with a minimum use of 20 Mg ha^{-1}, a practical agronomic recommendation.

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