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Structural and production characteristics and nutritive value of two tropical grasses submitted to different levels of nitrogen

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Abstrat

The objective of this study was to evaluate increasing levels of nitrogen on and production and nutritive value of Andropogon and Massai grasses under the edaphoclimatic conditions of the Brazil denominated Middle Nort Region. The design used was completely randomized, with sixteen replicatios. The treatments consisted of nitrogen rates: 0, 150, 300, 450 and 600 kg N ha^{-1} and two forages, which were evaluated independently. The grasses used were *Panicum maximum* cv. Massai and *Andropogon gayanus* cv. Kunth. For Andropogon grass, there was an effect of nitrogen fertilization on thecharacteristics: leaf elongation rate, stem elongation rate, leaf senescence rate and leaf blade final length and, in all cases, the behavior was quadratic. Nitrogen also influenced the morphogenic characteristics: leaf appearance rate, leaf elongation rate, leaf senescence rate, phyllochron, leaf blade final length, number of live leaves per tiller and It was not significant for tiller population density of Massai grass, but the behavior varied according to the characteristic, in which leaf appearance rate and number of live leaves per tiller had decreasing linear behavior, while in phyllochron it increased linearly as nitrogen doses increased. Most of the productive characteristics of the grasses had increasing linear behavior (total biomass production of forage, leaf biomass and stem biomass in Andropogon grass, while in Massai grass, only the total forage production and dead material accumulation had an increasing linear behavior with increase of N doses. Quadratic effect only for masai leaf biomass behavior and there was practically no production of stems, affecting the leaf-stem ratio) while the highest efficiency of nitrogen utilization was achieved with the application of 150 kg N ha^{-1} for the two grasses. Nitrogen fertilization also favored the nutritive value of the two grasses positively, with linear increase for crude protein and mineral matter contents, only in Massai, and reduction in the contents of neutral detergent fiber, acid detergent fiber and hemicellulose of grasses. Increasing doses of nitrogen fertilization favors the production, structure and chemical composition of the two grasses. However, the highest efficiency of use is obtained with the application of 150 kg N ha^{-1}.

Keywords: *Andropogon gayanus*; forage production; leaf elongation; *Magatyrsus* (*Panicum*) *maximum*; nitrogen use efficiency.
Abbreviations: Al_aluminum, Ca_calcium, $Cacl_2$_Calcium chloride, CCAA_center for agricultural and environmental sciences Cm_centimeter, Cm^3_cubic centimeter, Dm^3_cubic decimeter, g_gram, ha_hectare, K_potassium, Kg_kilogram, mg_milligram, Mg_ magnesium, mm_millimeter, N_nitrogen, NH3_ammonia, OM_Organic matter, P_phosphor, Ph_hydrogen potential, RF/C_leaf blade/stem ratio, UFMA_Federal University of Maranhão, ºC_degrees Celsius, %_Percentage.

Introduction

Ruminant production in Brazil is largely sustained in tropical weed pastures. There is a wide range of forage species for the choice in the implementation of pastures for the most varied edaphoclimatic conditions of the country. In this sense, Andropogon grass (*Andropogon gayanus*) is a grass with high productive potential, sometimes forgotten in the management question, in view of presenting high stem lengthening. However, Rodrigues et al. (2014) verified high forage production with values around 20 tons of forage mass during the year. Another alternative is the Massai grass (*Megatyrsus* (*Panicum*) *maximum* cv. Massai), which is more demanding in soil fertility, but it is the cultivar of this species that most tolerates soils with low fertility and low levels of P and has an advantage over the Andropogon grass of not lengthening the stem so much, which allows it to be a good alternative for deferral of pastures. To maintain the sustainability of pastoral ecosystems, it is necessary to correct and fertilize them according to the desired level of production and the requirement of forage species. Nitrogen is one of the nutrients that directly influence the production and nutritional value of pasture (Campos et al., 2016). This nutrient, even present in the soil as a constituent of organic material or in mineral form, has its limited supply (Costa et al., 2006). Due to the complexity of n dynamics in the soil, climatic conditions, productive factors, there is a difficulty to define the best dose to be applied to the different forage species. The recommendation of fertilization is usually performed according to the requirements of the species, with variation even within the genus and species, which reflects in the efficiency of nitrogen utilization by them. Knowing this efficiency becomes imperative both economically and environmentally, since the loss of nitrogen contributes to environmental pollution, waste of non-renewable natural resources and increases in the cost of production (Lana, 2005).

Therefore, our hypothesis is that there is a minimum dose that guarantees maximum production with high nitrogen utilization efficiency. The objective of this study was to evaluate the effect of increasing levels of nitrogen on the structural characteristics and nutritive value of Andropogon and Massai grasses under the edaphoclimatic conditions of the Brazil called Middle Nort Region.

Results

Morphogenic and structural characteristics of forages

There was effect (P<0.05) of nitrogen fertilization in Andropogon grass for the leaf elongation rate, stem elongation rate, total senescence rate and final leaf blade length and, in all cases, the behavior was quadratic. The maximum values were found with the applications of 456, 567, 410 and 396 kg N ha^{-1}, respectively (Figures 1a, 1b, 1c and 1d).

In the case of Massai grass, nitrogen fertilization influenced (P<0.05) leaf appearance rate, leaf elongation rate, total senescence rate, phyllochron, leaf blade final length, number of live leaves per tiller and No significant, but the behavior varied according to the characteristic. The leaf appearance rate and number of leaves decreased (Figures 2a and 2f) and phyllochron, which is the interval for the consecutive appearance of two leaves, increased (Figure 2d) with the increase in N doses. The leaf elongation rate, total senescence rate and leaf blade final length presented quadratic responses with maximum values found with the applications of 471, 545 and 557 kg N ha^{-1}, respectively (Figures 2b, 2c and 2e).

Productive characteristics of forages

There was effect (P<0.05) of nitrogen fertilization for production of total forage biomass, leaf biomass, stem biomass, dead material biomass, leaf/stem ratio and nitrogen utilization efficciency in Andropogon grass. The effect was increasing linear for total biomass production of forage, leaf biomass and stem biomass and decreasing linear for leaf/stem ratio (Figures 3a, 3b, 3c and 3e, respectively). The dead material biomass adjusted to the quadratic regression model as a function of the nitrogen doses applied (Figure 3d), with a maximum point obtained at 406 kg N ha^{-1}. The nitrogen utilization efficciency was influenced (P<0.05) by nitrogen fertilization, with maximum productive response in the dose of 150 kg N ha^{-1} (Figure 3f). For Massai grass, only There was a lack of production of biomass from dead material were influenced (P<0.05) by N doses (Figure 4). The effect was increasing linear for productions of total forage biomass and It was not significant for tiller population density (Figures 4a and 4c, respectively). The behavior for leaf biomass was quadratic (Figure 4b) with maximum point by applying 407 kg N ha^{-1}. The increase in leaf production (Figure 4b) follows the same trend of leaf elongation rate and final leaf blade length (Figures 2b and 2e). Regarding the efficiency of nitrogen utilization, as well as in Andropogon grass, the maximum productive response was observed for the dose of 150 kg N ha^{-1} (Figure 4d).

Chemical and bromatological composition of grasses

The drymatter increased linearly according to nitrogen rates applied to the two grasses, with increase of 95mg/kg in Andropogon grass and 123 mg/kg in Massai grass of dry matter, respectively, for each 1 kg of nitrogen applied (Figures 5a and 5b). Similarly, the crude protein contents in both grasses increased linearly according with nitrogen doses applied, increasimg of 120 mg/kg of crude protein (Figures 5c and 5d) for each 1 kg of nitrogen applied in Andropogon grass and Massai grass. The neutral detergent fiber contents presented linear reductions in the order of 49,5 in Massai grass and 79,4 mg/kg in Andropogon grass, to each 1 kg of nitrogen applied (Figures 6a and 6b). The acid detergent fiber and hemicellulose contents did not change in Massai grass (Figures 7b and 8b). However, in Andropogon grass there was a linear reduction to 28 in acid detergent fiber and 52 mg/kg in hemicellulose for each 1 kg of nitrogen applied (Figures 7b and 8b, respectively). The mineral matter increased linearly in the order of 26 mg/kg in Massai grass: Figure 9b and presented a quadratic response in Andropogon grass: Figure 9a. In this case, the maximum point was obtained by applying 518 kg N ha^{-1}.

Discussion

For Andropogon grass, the morphogenic (leaf elongation rate, stem elongation rate and total senescence rate) and structural (final leaf blade length) characteristics presented quadratic behavior as a function of increasing nitrogen doses, with doses for maximum expression ranging from 396 to 567 kg N ha^{-1}. Magalhães et al. (2013) when evaluating irrigation depths and increasing doses of N on Andropogon grass, also observed quadratic behavior for leaf elongation rate associated with the irrigation depth of 80%, in which the highest value was obtained by applying 615 kg N ha^{-1}, with 3.24 cm/tiller/day, a value higher than what we observed, which ranged from 1.19 to 2.45 cm/tiller/day, more specifically in the region of cell division (Gastal and Nelson, 1994). Stem elongation rate, although influenced by nitrogen doses, presented small observed variation with values ranging from 0.01 to 0.07 cm/tiller/day. These values are much lower than those found by Sousa et al. (2010), who evaluated the Andropogon grass as a function of three intensities of leaves (20, 27 and 34 cm), with values 0.150, 0.278 and 0.250 cm/tiller/day, respectively. It is noteworthy that the cutting height was 15 cm for the Andropogon and Massai grasses. According to Pena et al. (2009), cutting height can influence the accumulation and morphological composition of the fodder produced and can be used to control stem elongation. The final leaf blade length of the work of Magalhães et al. (2013) also suffered the effect of nitrogen fertilization associated with higher irrigation depth, 30.4 cm/leaf, with 583.2 kg N ha^{-1}. The final leaf blade and sheath lengths increase in successive leaves of a tiller until it remains constant, pattern reversed when the internosis lengthens, so that the leaf is smaller in relation to the sheath and, therefore, the flag leaf is shorter than the basal leaves of the tiller. Total senescence rate reduces the amount of quality forage, since senescence leaves redistribute nutrients to younger leaves, and higher rates will reflect on the accumulation of dead material from the pasture.

Massai grass in turn had more characteristics influenced by nitrogen fertilization (leaf appearance rate, leaf elongation rate, total senescence rate, phyllochron, leaf blade final length and number of leaves. Philochron had increasing linear effect or else, by increasing nitrogen application there is a reduction in leaf appearance rate and then increase in phyllochron, which is the time for the appearance of two leaves in the plant. This will result in the reduction of number of leaves of the Massai grass, a way of the plant to keep the number of leaves constant, since it is a genetic characteristic of the plant. These results are different to those observed by Martuscello et al. (2006), when working with doses of nitrogen and defoliation in Massai grass.

The leaf elongation rate, total senescence rate and leaf blade final length had quadratic behavior with maximum points obtained in 471, 545 and 557 kg N ha^{-1}, respectively (Figures 2b, 2c and 2e), doses higher than the maximum level for Andropogon grass. In fact, this is what was already expected due to panicum grasses presenting greater responsiveness. For the Massai grass amplitude observed for tiller population density ranged from 5.45 to 16.85 tillers per pot, for the lowest and highest dose of nitrogen, respectively (Figure 2e). Nitrogen increases the tillering in grasses by its ability to form axillary buds, which can potentially lead to new tillers and, consequently, increases forage production, as part of proteins and nucleic acids (Silva et al., 2014).

In the Andropogon grass there was no significance, because probably the cut at 15 cm may have been very drastic, promoting the decapitation of apical meristems, resulting in deaths and consequently reduction in the number of tillers.

Most of the yield characteristics of the grasses had increasing linear behavior (production of total forage biomass, leaf biomass and stem biomass), which indicates that higher production values could be obtained with the application of higher doses of N. Even if there was an indication of linear behavior, the observed increment was not enough to guarantee a higher efficiency of nitrogen use by the plant. Magalhães et al. (2013) also observed an increasing linear behavior as a function of increasing doses of nitrogen in the irrigation depth of 80%. Tropical grasses can respond up to 1800 kg N ha^{-1} (Vicente-Chandler et al., 1959). This is due to the ability of tropical grasses to produce dry matter, because their C4 metabolism favors the incorporation of carbon to compose their tissues, a potential that, in many cases, is limited by nitrogen supply (Howden et al., 1999). However, it is necessary to evaluate the cost benefit and the effects of the environmental impact that these high doses cause.

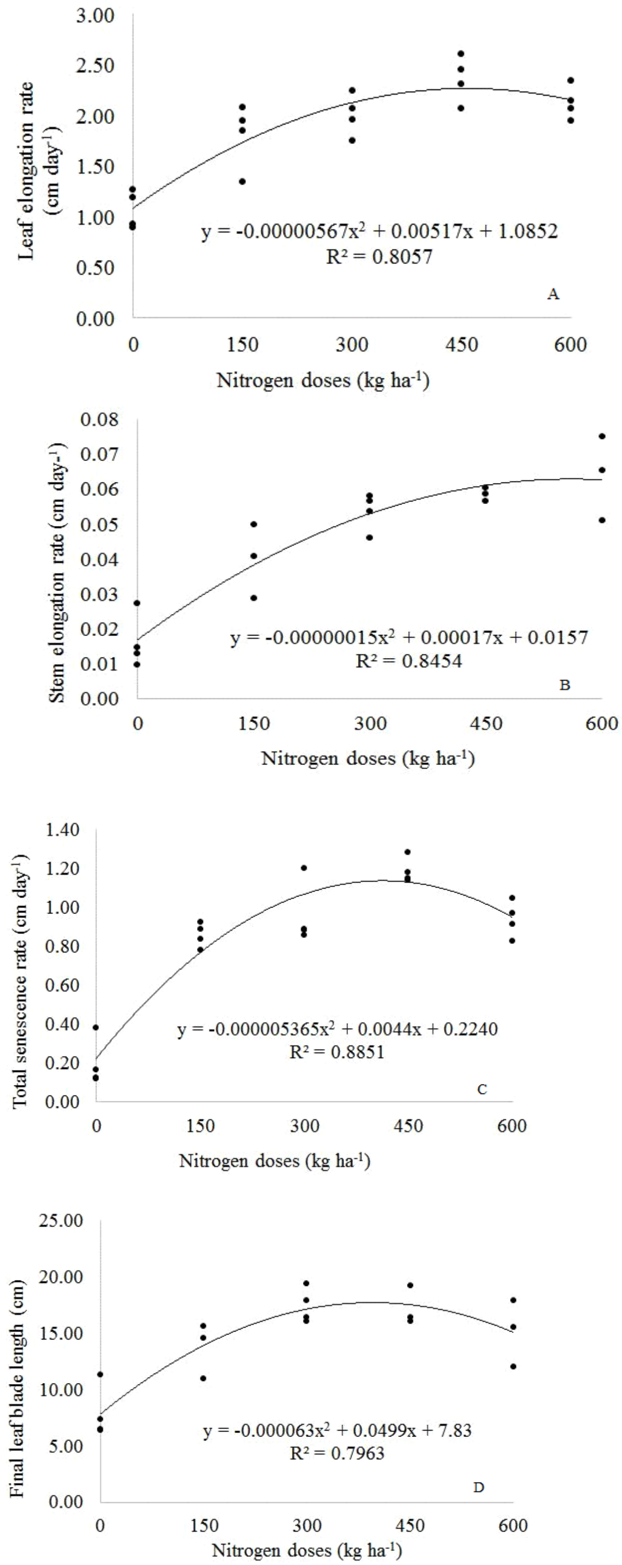

Figure 1. Morphogenic leaf elongation rate (a) stem elongation rate (b) and total senescence rate (c) final leaf blade length (d) characteristics of Andropogon grass as a function of increasing nitrogen doses.

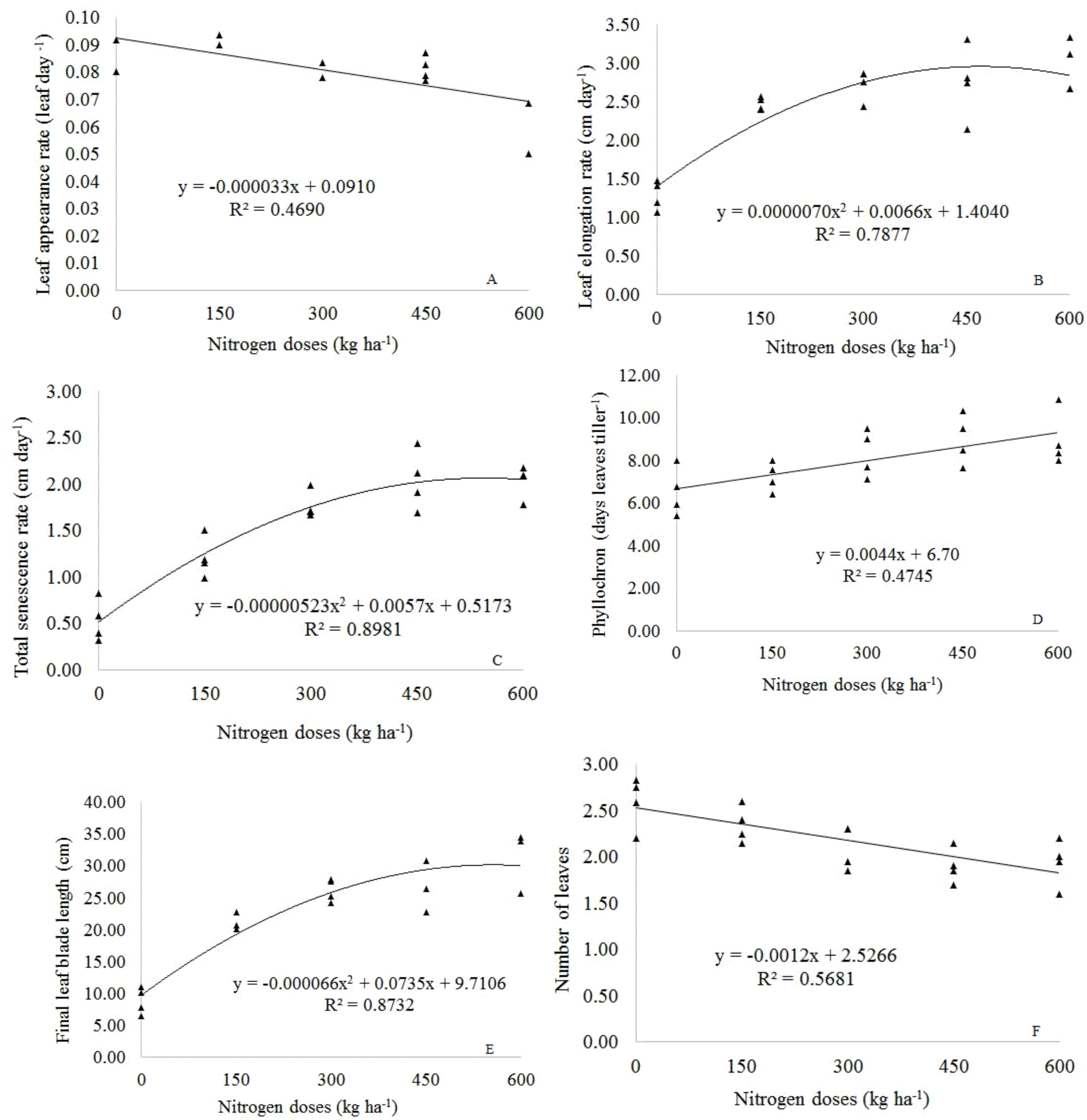

Figure 2. Morphogenic leaf onset rate (a), leaf elongation rate (b), total senescence rate (c) and phyllochron (d)) and structural leaf blade final length (e) and number of leaves (f) characteristics of Massai grass as a function of increasing nitrogen doses.

It is noteworthy that the cutting height was 15 cm for the Andropogon and Massai grasses. According to Pena et al. (2009), cutting height can influence the accumulation and morphological composition of the fodder produced and can be In this sense, Lana et al. (2005) evaluated the Lineweaver-Burk kinetic saturation model to obtain the kinetic constants Ks and Vmax of the Michaelis-Menten model, and stated that marginal increases in plant growth and animal growth reduce with the increase in nutrient supply. This can be proven when evaluating the nitrogen utilization efficiency (Figures 3f and 4d), in which the highest efficiency occurs in the dose of 150 kg N ha-1. In order to evaluate the efficiency of nitrogen utilization it is necessary to understand the return obtained with the increase in nitrogen doses. Based on this knowledge, it is possible to outline recommendations for fertilization of forage plants, avoiding waste and damage in nature, since the

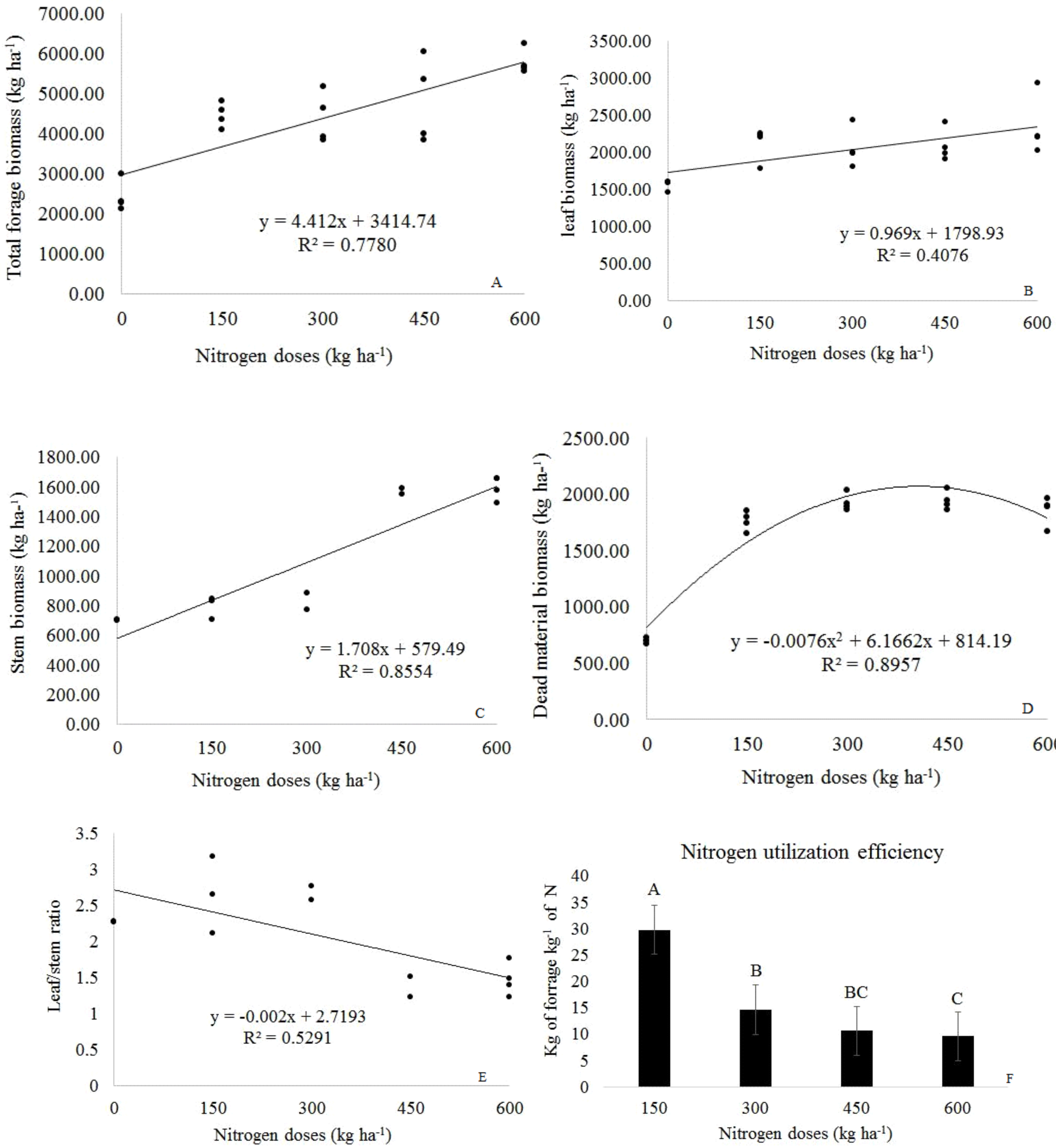

Figure 3. Production of total forage biomass (a), leaf biomass (b), stem biomass (c), dead material biomass (e), leaf/stem ratio (e) and nitrogen utilization efficiency (f) in Andropogon grass as a function of increasing nitrogen doses.

nitrogen that is not absorbed by the plant is leached and can reach the groundwater (Lana, 2005). O'Connor et al. (2019) verified a reduction in the concentration of NH_3 with the use of lower doses of nitrogen fertilizers in perennial Lolium pastures, which according to the authors may be a strategy to reduce the release of nitrogen into the atmosphere and groundwater. Dry matter and crude protein contents were favored by increasing the nitrogen dose of the two grasses. Bernardi et al. (2018) in a metanalytic study to summarize and analyze data on nitrogen fertilization in pastures formed by grasses of the genera Brachiaria, Cynodon and Panicum, also observed a linear increase in dry matter and crude protein production in relation to the control for Brachiaria and Panicum. According to these authors, the results show the effectiveness of nitrogen fertilization, because, even with the varied conditions in which summarized studies were performed, a consistent response to nitrogen is noted.

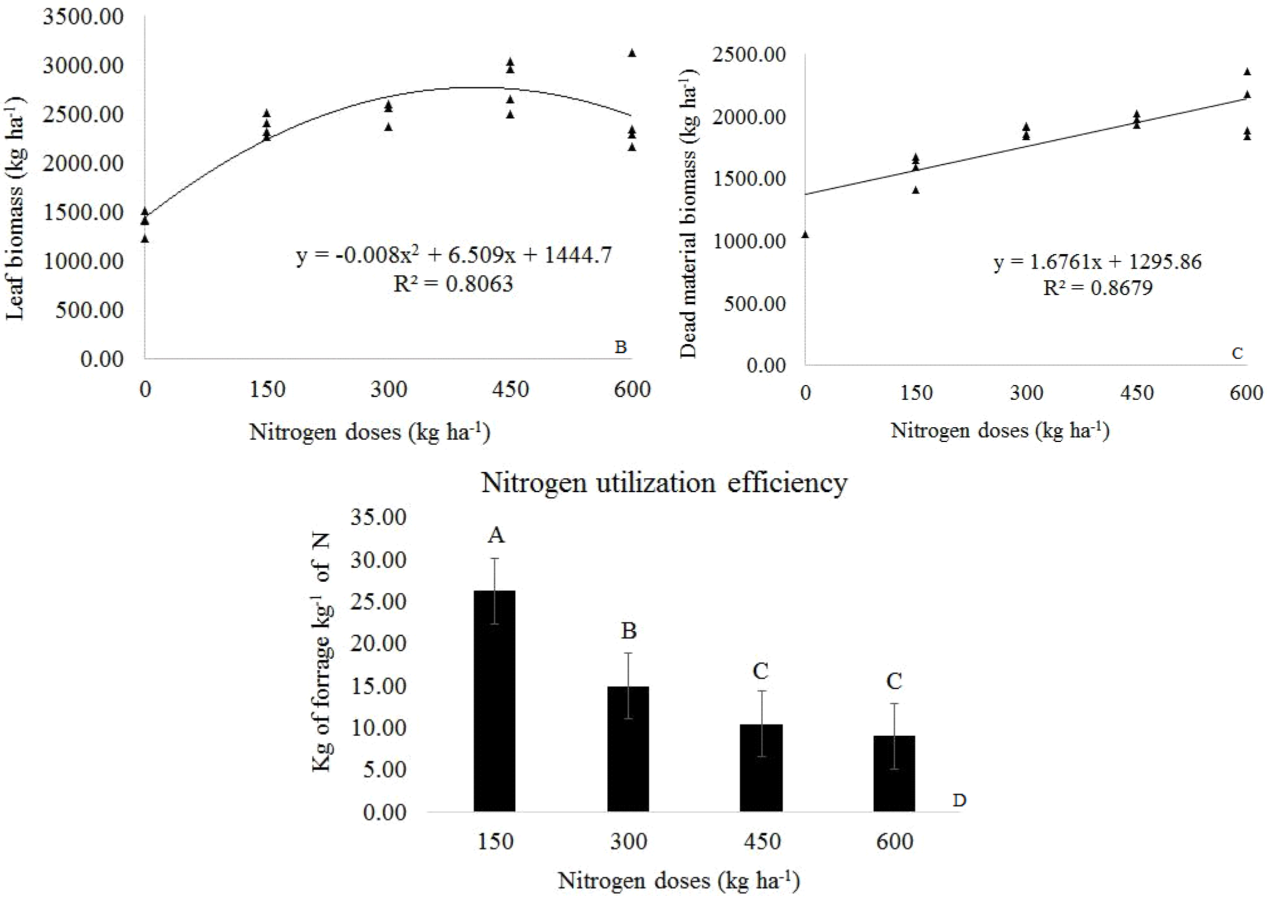

Figure 4. Masai forage total biomass production was lacking (Figure 4a), leaf biomass (b), dead material biomass (c) and nitrogen utilization efficiency (d) in Massai grass as a function of increasing nitrogen doses.

Considering that when crude protein contente is below 7% in dry matter, these are limiting to animal production, because it can compromise the degradability of the fiber and consequently the use of the material for animal performance (Van Soest, 1994; Lazzarini et al., 2009). It was observed that both Massai and Andropogon grasses would satisfactorily meet the minimum protein requirements.

The neutral detergent fiber contents had negative linear behavior for the two grasses (Figures 6a and 6b). This behavior is due to the fact that nitrogen stimulates the growth of new tissues, mainly leaves (Figures 5b and 6b), which have reduced concentration of cell wall constituents. Similar results were found by Campos et al. (2016), which also observed a negative linear correlation evaluating Xaraes palisadegrass under increasing doses of nitrogen. The neutral detergent fiber content is an important principle that defines the quality of forage, being considered a factor that limits the ingestive capacity by animals. Neutral detergent fiber is basically composed of lignin, hemicellulose and cellulose (Rocha et al., 2001), representing the chemical part of the forage that correlates more closely with the voluntary consumption of animals, and values above 55 to 60% correlate negatively with this variable (Van Soest, 1965). Only Andropogon grass showed negative linear effect for the acid detergent fiber (Figure 7b). The acid detergent fiber represents the percentage of lignin and cellulose present in the plant, i.e. the amount of fiber that is not digestible. By increasing nitrogen doses there was reduction of the contents of this fraction, which implies the possible improvement of forage digestibility, considering that this fraction represents the cellulose and lignin contents present in the forage. According to Van Soest (1994), nitrogen causes an increase in the concentration of amino acids and proteins that accumulate mainly in cell content, causing dilution of the cell wall and increasing digestibility. Probably, there was no effect of nitrogen doses on the acid detergent fiber contents in Massai grass, because it did not present the stem fraction, so the plant did not require a more rigid structure, which resulted in the reduction of cellulose and lignin contents.

The acid detergent fiber is indicative of the digestibility and energy value of forage due to the relationship with the lignin contents of food. Consequently, the lower the acid detergent fiber, the higher the energy value of the plant and the better the digestibility of the food (Magalhães et al., 2013). When there are high levels of acid detergent fiber, it can directly influence digestion, which will have a higher proportion of fibrous constituents, such as resistant pentosans, cellulose, lignina and cutin, which make up the cell wall and are responsible for the low digestibility of forage (Van Soest, 1994).

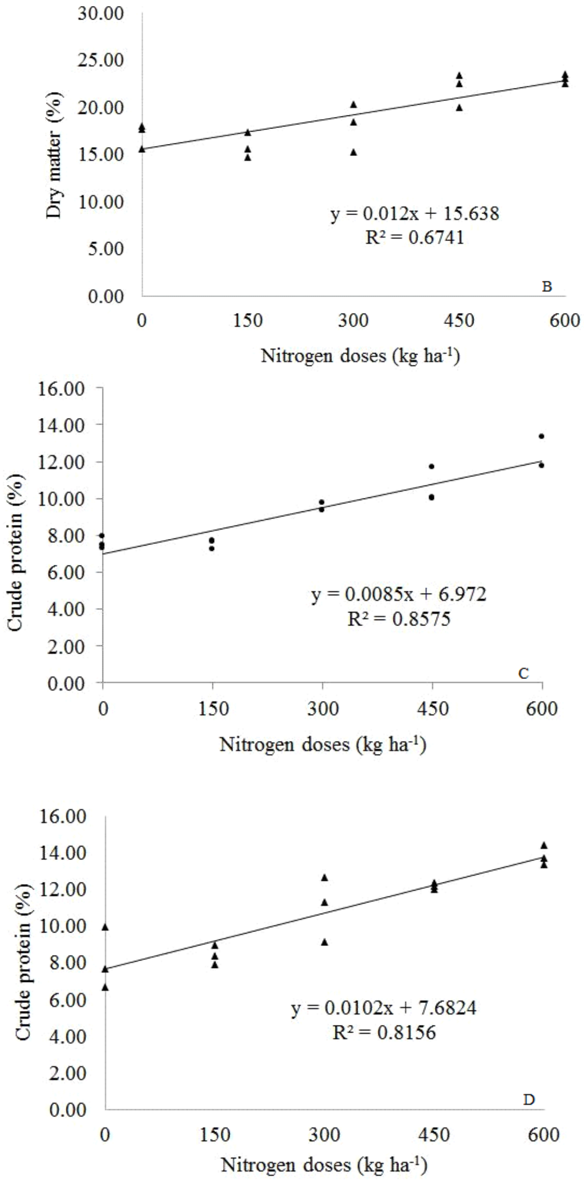

Figure 5. Andropogon dry matter is missing (Figure 5a) grass and crude protein content of Andropogon (c) and Massai (d) grasses as a function of increasing nitrogen doses.

For Andropogon grass, it is observed that the acid detergent fiber levels decreased with the increase in nitrogen doses when applied to the soil, showing a negative linear behavior (Figure 4b), presenting mean values of 28.01%. These results were similar to those observed by Magalhães et al. (2011) working with increasing doses of nitrogen (0, 100, 200 and 300 kg/ha/year) and phosphorus (0, 50 and 100 kg/ha/year) for Brachiaria decumbens grass.

Materials and Methods

Description of the area

The experiment was carried out at the Forage Crops Section at CCAA/UFMA (03°44'33'' S, 43°21'21" W). According to the Köppen classification, the climate in the region is a hot wet tropical type (Aw).

Treatments and crop establishment

Two experiments were carried out, one with Andropogon grass and the other with Massai grass. The assays were conducted in a completely randomized design. There are five doses of nitrogen, so there are five treatments. For 80 pots, you need to have 16 repetitions.

After soil correction, based on soil analysis, No weeding, Andropogon grass and Massai grass, and after 25 days of germination, evaluations were started. About a year before the establishment of grass, there were taken 20 soil samples in the experimental area at a depth of 0-20 cm, and the analyses were pH in CaCl2 = 5.1; P=6 and S=6 mg/dm³, respectively; K=1.8, Ca=18, Mg=8 and Al=0.4, mmolc/dm³, respectively; OM=15 g/kg; and base saturation=50%.

Based on soil analysis, the base saturation was increased to 60% using limestone with total neutralization reactive power equal 90%. A dose equivalent to 100 kg ha-1 of P2O5 was used in the form of simple superphosphate. Pots with 19 cm height x 27 width were used, totaling a volume of 10,873 cm³. The amount of land used was 10 kg in each pot. The soil was collected at a depth of 0 to 20 cm.

The pot was watered every day for limestone to react with the soil. After 15 days of liming and phosphate, grass was sowed and after 25 days of planting, fertilization with nitrogen and

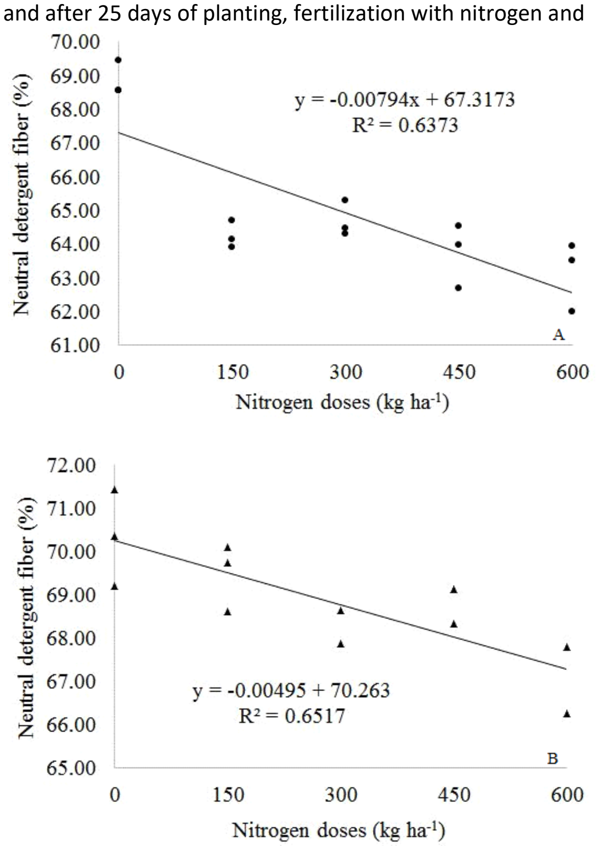

Figure 6. Neutral detergent fiber content of Andropogon (A) and Massai (B) grasses as a function of increasing nitrogen doses.

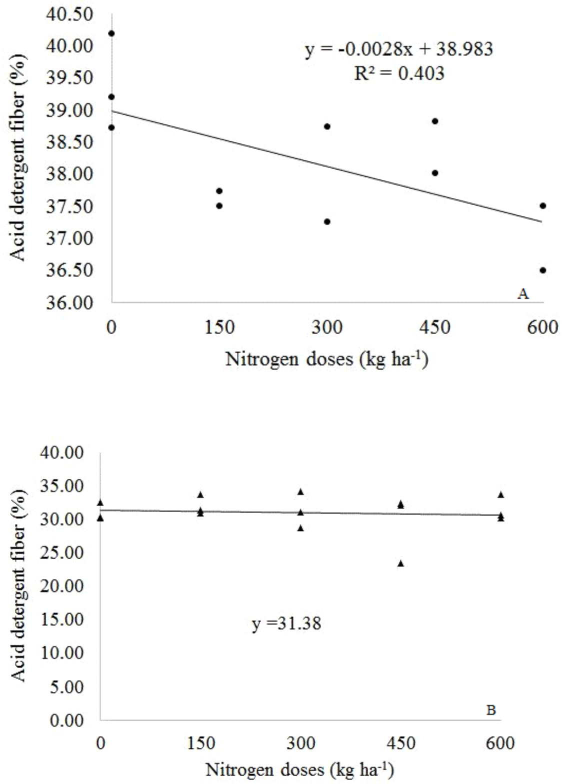

Figure 7. Acid detergent fiber content of Andropogon (A) and Massai (B) grasses as a function of increasing nitrogen doses.

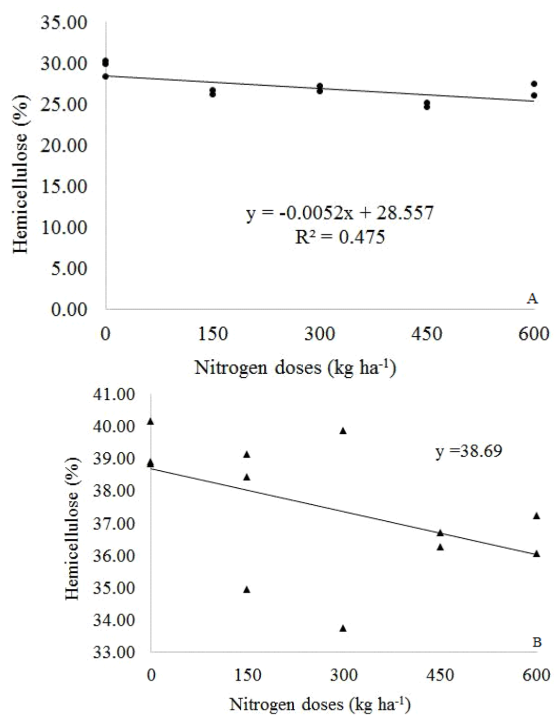

Figure 8. Hemicellulose content of Andropogon (A) and Massai (B) grasses as a function of increasing nitrogen doses.

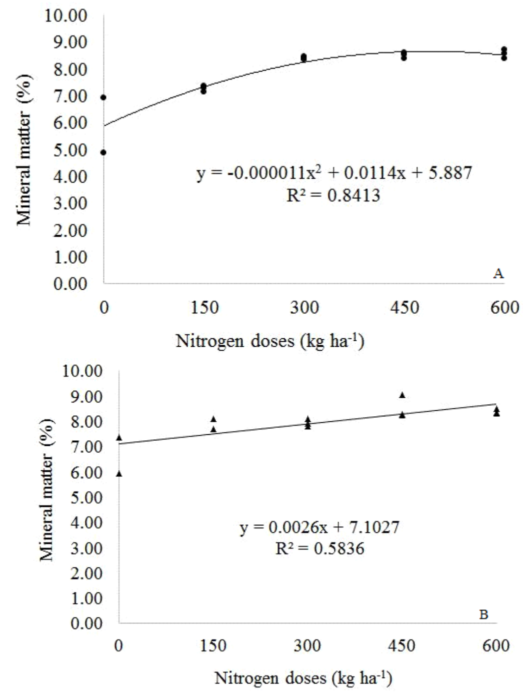

Figure 9. Mineral matter content of Andropogon (A) and Massai (B) grasses as a function of increasing nitrogen doses.

potassium in the form of urea and potassium chloride, respectively, was started. The potassium dose used was equivalent to 65 kg ha-1 of K2O, being divided into two times, and the doses of nitrogen applied were performed based on the treatments, being divided into three times. Nitrogen and potassium fertilizations were performed after production collection.

Morphogenic and productive traits

Two tillers were chosen inside each vessel and marked with colored yarn to evaluate the morphogenic characteristics. The evaluations were performed with the aid of millimeter rulers, every seven days during the experimental period. In each tiller, the number of leaves, leaf blade length, stem length and leaf classification were monitored for the stage (expanding, expanded, senescent and mortality). From the information, leaf appearance rate, leaf elongation rate, stem elongation rate, phyllochron, leaf senescence rate, final leaf blade length, there was no significance and number of live leaves per tiller were calculated.

At the end of the cycle, a pot sampling was performed, where all tillers were counted, then the forage mass was cut. Then, the samples were taken to the forage laboratory, the material was fractionated into leaf blade, stem (true stem + sheath) and dead material, the fractions were placed in paper bags identified and then weighed and dried in a forced air circulation oven at 55 °C until they reached constant weight and then were weighed again. Thus, the production of total forage, later divided into leaf blades, stems+sheaths and dead material for determination of leaf production, stem production and production of senescent material was estimated by drying in a forced air circulation oven at 55 °C for 72 hours.

Evaluation of chemical bromatological characteristics of forages

After drying, the samples were ground in a knife mill using a 1 mm porosity sieve. Dry matter values (AOAC, 2005, method number 930.15), mineral matter or ash (AOAC, 2005, method number 942.05), crude protein (AOAC, 2005, method number 984.13), without ethereal extract neutral detergent fiber (INCT-CA F-002/1 method) and acid detergent fiber (INCT-CA F-004/1 method) were quantified according to the standard analytical methods of the National Institute of Science and Technology in Animal Science - INCT-CA (Detmann et al., 2012).

Statistical analysis

The data were submitted to tests that ensured the basic prerogatives (homoscedasticity and normality tests) and then submitted to variance analysis. The 5% probability regression analysis was used to explore the effects of nitrogen fertilization under the parameters evaluated with the use of proc reg of the STATISTICAL ANALYSES SYSTEMS. SAS user's guide statistics, version 9.0. Cary, NC, USA: SAS Institute Inc., 2002.

Conclusion

The application of N showed an improvement in the morphogenic, nutritional and productive behavior of forages. However, the highest efficiency of nitrogen utilization for both grasses was obtained with application of 150 kg N ha^{-1}. The choice of grass will depend on the production system to which it is planned.

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