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Biomass components and structure of massai grass fertilized with nitrogen and grazed by sheep

[*Componentes da biomassa e estrutura do capim-massai adubado com nitrogênio e pastejado por ovinos*]

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ABSTRACT

To evaluate the biomass components of massai grass subjected to nitrogen (N) fertilization levels (control - 0; 400; 800 and 1200 kg ha^{-1} year^{-1} of N) and under rotational stocking with sheep, this study was undertaken using a completely randomized design with measurements repeated in time. A quadratic response was observed reaching maximum values as the levels of nitrogen fertilization increased for green forage biomass, green leaf biomass, green stem biomass (5,172.9; 4,146.3; 1,033.9 kg ha^{-1} cycle^{-1}, respectively), forage total density (179.1 kg ha^{-1} cm^{-1}), canopy height (36.8 cm) and live material/dead material ratio (4.0) at levels 896; 934; 797; 879.2; 751.4 and 1,161 kg ha^{-1} year^{-1} of N, respectively. For all variables, oscillation was observed between the grazing cycles studied. Nitrogen fertilization has a positive response on the biomass components and canopy structure of massai grass.

Keywords: forage production, green leaf biomass, nitrogen fertilization, *Panicum maximum*

RESUMO

Objetivou-se avaliar os componentes da biomassa do capim-massai sob lotação rotativa com ovinos e adubado com doses de nitrogênio (controle - 0; 400; 800 e 1200 kg de N ha^{-1} ano^{-1}), em delineamento inteiramente ao acaso, com medidas repetidas no tempo. Constatou-se resposta quadrática, alcançando valores máximos com o incremento das doses de nitrogênio para as produções de biomassa de forragem verde, de lâmina foliar verde, de colmo verde (5172,9; 4146,3; 1033,9 kg ha^{-1} ciclo^{-1}, respectivamente) e para a densidade total de forragem (179,1 kg ha^{-1} cm^{-1}), altura do dossel (36,8 cm) e relação material vivo/material morto (4,0) nas doses 896; 934; 797; 879,2; 751,4 e 1161 kg ha^{-1} ano^{-1} de N, respectivamente. Para todas as variáveis, verificou-se oscilação entre os ciclos de pastejo estudados. A adubação nitrogenada exerce respostas positivas sobre os componentes da biomassa e a estrutura do dossel do capim-massai.

Palavras-chave: adubação nitrogenada, biomassa de folha verde, Panicum maximum, *produção de forragem*

INTRODUCTION

The maximization of biomass production up to the productive genetic potential of forages reflects from specific conditions such as light, humidity, nutrient availability, temperature and management. Soil fertility is one of the main factors influencing the quality and biomass production of forage plants. Among the nutrients, nitrogen plays an important role in increasing productivity (Alves *et al*., 2008; Pompeu *et al*.,

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2010; Magalhães *et al*., 2006) and in the quality of the forage produced (Chagas and Botelho, 2005), besides providing greater regrowth vigor by accelerating the recovery capacity of the defoliated plants, guaranteeing persistence and perenniality of the pastures throughout the successive cycles of grazing or cutting.

Forage biomass production is the main component that defines the carrying capacity of pastures, hence the relevance of knowledge of its components to understand how the management practices (fertilization, irrigation, adjustment of animal load and others) influence them.

The response potential of forages to fertilization, especially nitrogen, is an important aspect in the selection of cultivars for intensive livestock systems in pasture. Massai grass, a forage of the genus *Panicum maximum* introduced in 2001 by Embrapa has revealed important characteristics in studies conducted by Martuscello *et al.* (2006) and Lopes *et al.* (2011a), regarding the production of leaf biomass, leaf blade / stem ratio, high capacity to emit leaves and tillers, among other characteristics, in response to nitrogen fertilization under greenhouse conditions. However, studies with the purpose of evaluating the biomass components and canopy structure of the massai grass under intensive management conditions in rotational stocking with sheep and fertilized with nitrogen under irrigation are still incipient.

Due to the above, this research was carried out with the objective of studying the massai grass managed under rotational stocking with sheep and fertilized with nitrogen through the evaluation of the biomass components and canopy structure.

MATERIAL AND METHODS

The experiment was carried out on a pasture of *Panicum maximum* cv. Massai, at the Nucleus of Teaching and Studies in Forage Crop of the Animal Science Department of the Agricultural Sciences Center of the Federal University of Ceará - NEEF / DZ / CCA / UFC, in Fortaleza - CE.

Fortaleza is located at an average altitude of 21 meters, with the following geographic coordinates: latitude south of 03° 45' 47", longitude west of 38° 31' 23", with climate type Aw', tropical rainforest, according to the Köeppen classification. The monthly average temperature (maximum average, average and minimum average), precipitation and insolation of the experimental period are shown in Figure 1.

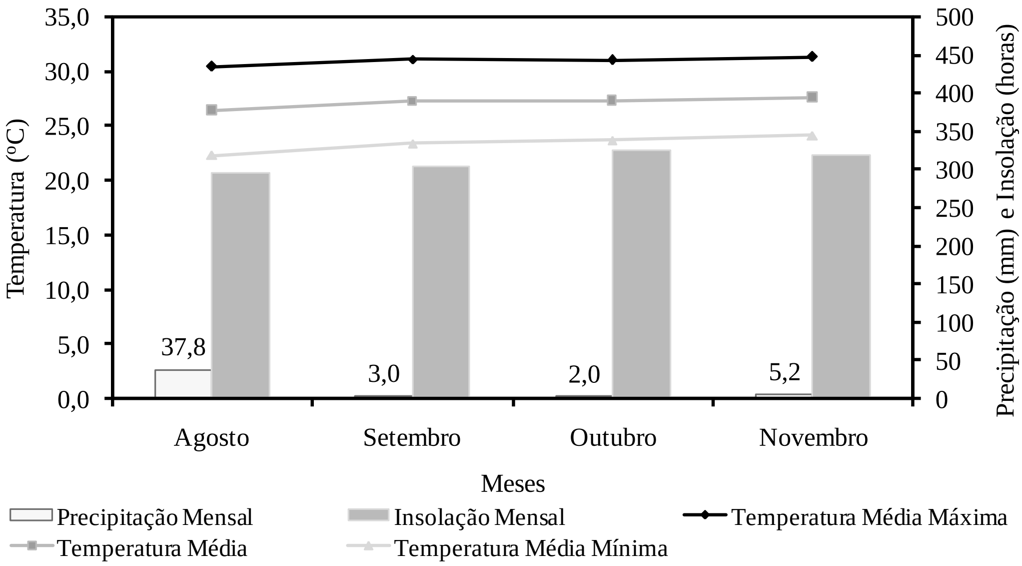


Figure 1. Climatic data of the experimental period in Fortaleza - CE, in 2009.

The soil of the experimental area is classified as yellow Argisol, having as its source material sandy-clay sediments of the barreira formation (Sistema…, 1999). The soil analysis (0-20 cm depth) carried out at the beginning of the experiment presented the following chemical characteristics: 9 mg dm^{-3} P; 15.64mg dm^{-3} K; 1.3$cmol_c$ dm^{-3} Ca^{2+}; 1.2 $cmol_c$ dm^{-3} Mg^{2+}; 0.35$cmol_c$ dm^{-3} of Al^{3+}; 0.10 $cmol_c$ dm^{-3} of Na^{+}; organic matter: 18.62 g kg^{-1}; base saturation: 2.64 $cmol_c$ dm^{-3}; cation exchange capacity: 2.99 $cmol_c$ dm^{-3}; pH in water: 5.7; 10.9 ppm Fe^{2+}; 0.4mg dm^{-3} Cu^{2+}; 8.3mg dm^{-3} Zn^{2+} and 11.9mg dm^{-3} Mn, and were corrected according to CFSEMG (Ribeiro *et al.,* 1999) recommendations for grasses with high productive potential.

The experimental design was completely randomized, arranged in split-plots, with repeated measurements in time (successive grazing cycles) with two replicates (42.3 m^2 paddocks). Nitrogen doses (control - without nitrogen fertilization, 400, 800 and 1,200 kg ha^{-1} $year^{-1}$) were studied in the plots, and the grazing cycles in the subplots. The grass was planted in September 2008 by sowing, after tillage (harrowing), with sowing rate equivalent to 2.0 kg ha^{-1} of viable pure seeds (VPS), being managed under rotational stocking with sheep until the experimental period.

The pasture of massai grass was managed under low-pressure fixed sprinkler irrigation (service pressure < 2.0 kgf cm^{-2}), with liquid supply of 7.0 mm day^{-1}, 3-day irrigation shift, and time of irrigation (Ti) of 8 hours, at night, seeking a better uniformization of the applied amount. In order to determine the parameters mentioned above, the irrigation system was previously evaluated, simulating how it would work during the experimental period.

Phosphate (simple superphosphate), potassium (potassium chloride) and micronutrient (FTE BR-12) fertilizations were carried out according to the results of the soil analysis. The applications of nitrogen (urea) and potassium were partitioned. The nitrogen dose for each treatment was divided in two plots, the first half being applied immediately after the exit of the animals from the paddock and the second half applied in the rest period, according to each dose evaluated. In all nitrogen applications, the urea was diluted in water in order to improve the uniformity of application due to the small amount of fertilizer per plot, which makes it difficult to apply in the solid form, with subsequent irrigation to avoid possible "burning" of the leaves. In the application, a backpack sprayer was used, with standard volume according to the previously performed field test. Potassium was supplied in three applications, the first one (160 kg ha^{-1} K_2O) performed at the beginning of the experiment, along with the first nitrogen application. The second and third applications (160 and 160 kg ha^{-1} of K_2O, respectively) were carried out along with the first dose of nitrogen immediately after the animals left in each of the subsequent grazing cycles. The supply of phosphorus (250 kg ha^{-1} of P_2O_5) was done in one time, along with the first potassium and nitrogen applications, at the beginning of the experiment setup. At this time, the micronutrients (50 kg ha^{-1} of FTE BR-12) were applied.

The rest period was approximately 1.5 new leaves per tiller, as determined in the pre-trial at the beginning of the experiment setup, providing an interval of 22; 18; 16 and 13 days for doses 0.0 - control; 400; 800 and 1,200 kg ha^{-1} $year^{-1}$ of nitrogen, respectively. The animals used to lower the pasture to the recommended residual height were sheep (½ Morada Nova x ½ Non-defined Breed), allocated in paddocks of 42.3 m^2. The "mob-grazing" technique (Gildersleeve *et al.*, 1987) was used, with groups of animals for rapid defoliation (duration of 7 to 11 hours), simulating a rotational stocking. As the animals grazed, the height of the grass was monitored with a ruler until the canopy reached the recommended residual height of approximately 15 cm, corresponding to the residual LAI for exit of the animals from the paddock of approximately 1.5, as determined in the pre-trial for the setup of the experiment.

At each grazing cycle, the total pre-grazing biomass inside two 0.25 x 0.25m frames was harvested at the soil level in each experimental plot (42.3 m^2 paddock), and they were sent to the laboratory for separation of the components: expanded leaf, emergent leaf, pseudo stem (stem + sheath) and dead material.

After separation of the components mentioned before, the samples were placed in a forcedventilation oven (55°C until reaching constant weight), for further calculation of green forage biomass (GFB, kg ha^{-1} $cycle^{-1}$), green leaf blade biomass (GLB, kg ha^{-1} $cycle^{-1}$), dead forage biomass (DFB, kg ha^{-1} $cycle^{-1}$), green stem biomass (GSB, kg ha^{-1} $cycle^{-1}$), and total forage density (TFD, kg ha^{-1} $cycle^{-1}$). Leaf blade/stem ratio (LB/S), live material/dead material ratio (LM/DM), pseudo stem length (cm) and canopy height (cm) were also evaluated.

The data were submitted to analysis of variance, mean comparison test and regression analysis. The interaction between doses of N x grazing cycles was presented when significant (P< 0.05) by the F test. The grazing cycles were compared by the Tukey's test (P< 0.05). The effect of nitrogen fertilizer doses was evaluated by regression analysis. The choice of the models was based on the significance of the linear and quadratic coefficients, using Student's “t” test (P< 0.05) and the coefficient of determination. The MIXED and GLM procedures of the SAS statistical program (SAS…, 2003) were adopted.

RESULTS AND DISCUSSION

No interaction was observed (P> 0.05) between the factors N doses x grazing cycles for canopy height, with significance (P< 0.05) being limited to the isolated factors. The present variable was influenced (P< 0.05) by the N doses (Figure 2A) and presented itself as almost equal (P> 0.05) over the grazing cycles (Figure 2B), with a difference (P< 0.05) observed only between the first and second grazing cycles, with the second one presenting lower value then the first one, possibly reflecting an impact of the initial grazing on the plant, due to the fact that its structure was not yet adapted to intensive grazing, as a consequence of the morphological adaptations of the grass during the regrowth process. In cycles 2, 3 and 4, it was observed that the pre-grazing height was homogeneous, reflecting the uniform and vigorous growth of the plant in response to the consolidation of its structure.

Nitrogen fertilization provided a quadratic response (P< 0.05) on the canopy height, being maximized (36.8 cm) at the dose equivalent to 751.4 kg ha^{-1} $year^{-1}$ (Figure 2A). The initial increase in the height of the pasture reflected the greater availability of nitrogen in the soil and its consequent absorption by the plants, as this nutrient accelerated the growth of the tissues. The increase in the height of the canopy was consistent with the increase (P< 0.05) in the length of the pseudo stem with the nitrogen fertilization, being estimated at 10.5 and 12.5cm in doses 0,0 and 1,200 kg ha^{-1} $year^{-1}$, respectively (Figure 2A), presenting lower values (P< 0.05) in grazing cycles 3 and 4 (Figure 2B).

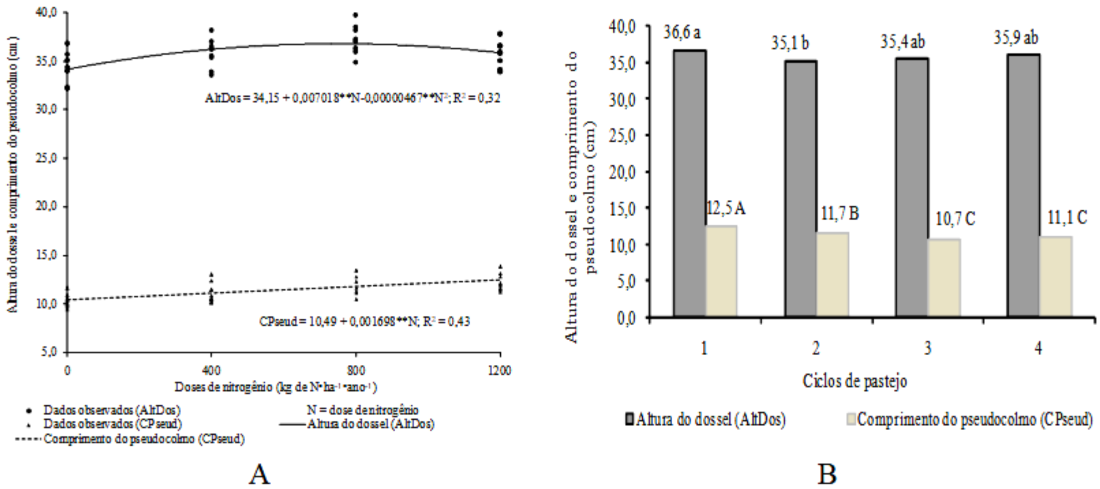
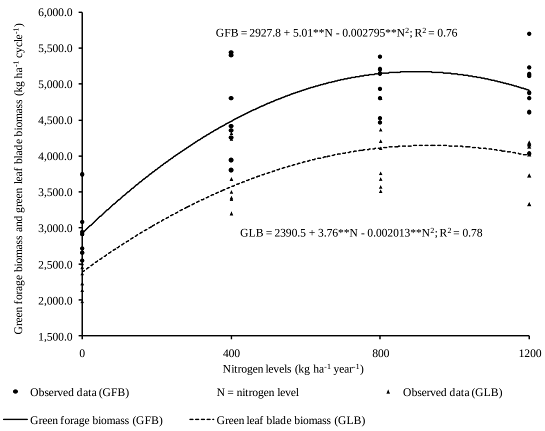


Figure 2. Canopy height (CH) and Pseudo stem length (PseudL) as a function of nitrogen fertilization (A) and over the grazing cycles (B) in *Panicum maximum* cv. Massai. Significant at the level of 1% (**); means followed by equal letters (lowercase and uppercase) for CH and PseudL, respectively, do not differ (P> 0.05), by Tukey’s test.

The decrease in the pseudo stem length in the last grazing cycles was possibly due to exteriorization of the ligule of the leaf to be expanded below the previously exposed leaf. Thus, it favors the stabilization and the decrease in the length of the pseudo stem in the successive grazing cycles, a reflex of the morphological adaptation of the plant, with a more pronounced response in the successive grazing cycles. From the highest levels of nitrogen fertilization (equivalent to 1,100 kg ha^{-1} year^{-1}), diminutive increments (0.81%) were observed for the pseudo stem length in comparison to the level equivalent to 1,200 kg ha^{-1} year^{-1} of nitrogen.

Despite the increasing response observed for the pseudo stem length, the response pattern revealed by this variable, with small increments, added to the decumbent growth of the grass at higher nitrogen levels (Lopes *et al.*, 2011a) associated with the high stocking density adopted (0.35 sheep m^{-2} day^{-1}), resulted in a decrease in the canopy height of the massai grass in the present study at levels greater than 751.4kg ha^{-1} year^{-1} of N and reflected the mechanism of phenotypic plasticity of the forage plant to frequent and intense defoliation.

No interaction was observed (P> 0.05) between nitrogen levels x grazing cycles for the variables: green forage biomass (GFB), green leaf blade biomass (GLB), dead forage biomass (DFB) and green stem biomass (GSB). The influence of nitrogen fertilization on the variables GFB, GLB (Figure 3A) and GSB (Figure 4A) was observed (P< 0.05) revealing a quadratic response to nitrogen levels, but for DFB such influence was not observed (P> 0.05), presenting a mean value of 1,335.6 ± 299.3 kg ha^{-1} cycle^{-1}, reflecting the absence of effect of this nutrient on leaf senescence. Similar values were observed (P> 0.05) for GFB and GLB in grazing cycles 1, 2 and 3, with grazing cycle 4 revealing a higher value (P< 0.05) than grazing cycles 2 and 3 for these biomass yields (Figure 3B).



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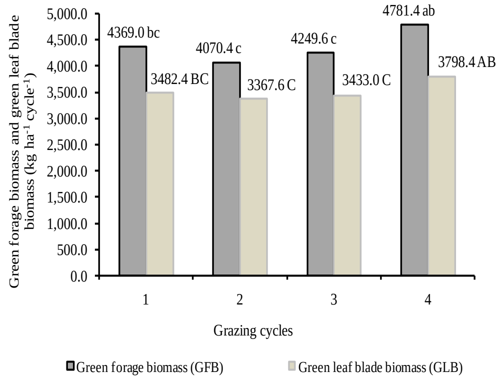

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Figure 3. Green forage biomass (GFB) and green leaf blade biomass (GLB) as a function of nitrogen fertilization (A) and over the grazing cycles (B) in *Panicum maximum* cv. Massai. Significant at the level of 1% (**); means followed by equal letters (lowercase and uppercase) for GFB and GLB, respectively, do not differ (P> 0.05) by Tukey's test.

The higher nitrogen availability accelerates the plant metabolism, which can increase forage losses by anticipating the maturity and senescence of the first leaves, in response to increased competition for photoassimilates (Gomide *et al.*, 2003). In the present study, this effect was not observed, since the rest period adopted for the forage varied according to the level of nitrogen applied, in which for the higher levels the grasses were managed under shorter periods of rest and vice-versa, thus, neutralizing the effect of this nutrient on promoting leaf senescence, with the consequent supply of better-quality forage.

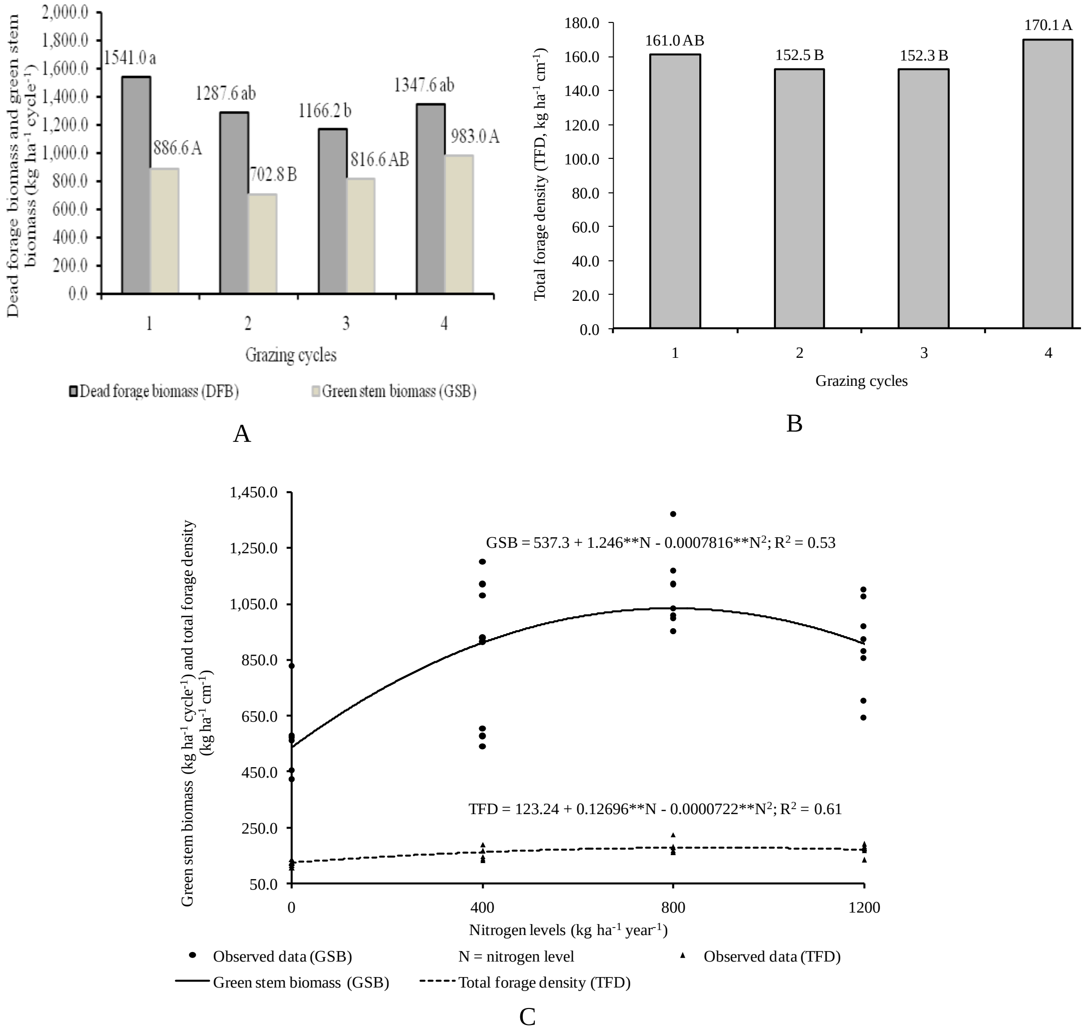


Figure 4. Dead forage biomass (DFB), green stem biomass (GSB) and total forage density (TFD) over the grazing cycles (A and B, respectively) and GSB and TFD as a function of nitrogen fertilization (C) in *Panicum maximum* cv. Massai. Significant at the level of 1% (**). Means followed by equal letters (lowercase for DFB and uppercase for GSB and TFD, respectively) do not differ (P> 0.05), by the Tukey's test.

There were maximum yields of 5,172.9; 4,146.3 and 1,033.9 kg ha^{-1} cycle^{-1} for GFB, GLB (Figure 3A) and GSB (Figure 4C), respectively, at levels 896, 934 and 797 kg ha^{-1} year^{-1} of N, respectively. For the variables GFB and GLB, there were increases of 76.7 and 73.4%, respectively, at the levels 896 and 934 kg ha^{-1} year^{-1} of N, respectively, in comparison to the absence of nitrogen fertilization.

The increase in leaf biomass provided by nitrogen fertilization in massai grass plants up to the level of 934 kg ha^{-1} year^{-1} can be explained in part by the leaf elongation rate (LER) (Pompeu *et al.*, 2010) since LER is positively related to forage production (Hortst *et al.*, 1978; Garcez Neto *et al.*, 2002). It should be noted that the increases observed in GFB and GLB can be attributed to the effect of N on the population density of tillers (increase of 46.5% in PDT at the level equivalent to 993.5kg ha^{-1} year^{-1} compared to the absence of N), given the effect of this variable on the referred yields (Martuscello *et al.*, 2006; Lopes, *et al.*, 2011a) in addition to the beneficial effect of N on root biomass production (Lopes *et al.*, 2011c), favoring a higher nutrient uptake and, consequently, a greater vegetative development of the plant (Alves *et al.*, 2008).

This effect of N on PDT, a reflex of the stimulation of growth points, associated with the significant increase in the flow of plant organs (Duru and Ducrocq, 2000) provided by this nutrient, reflects in an increase in leaf elongation rate (Alexandrino *et al.*, 2004, Pompeu *et al.*, 2010, Lopes *et al*., 2013), with a consequent increase in leaf area. Thus, the increases in green forage biomass and green leaf blade biomass up to the maximization at levels equivalent to 896 and 934kg ha^{-1} $year^{-1}$ of N, respectively, are justified. It is also worth mentioning the positive effect of nitrogen on gas exchanges, potentiating the photosynthetic rate of the forage plant (Pompeu *et al.*, 2010; Lopes *et al.*, 2011b).

Among the components of total biomass, the green leaf blade is the most relevant fraction in the photosynthetic potential of the pastures, besides being the essential structural variable for grazing animal performance, since it is the fraction with better nutritional composition and greater acceptability by the animals.

GSB and DFB yields fluctuated ($P< 0.05$) between the grazing cycles, but there was no change pattern defined for both variables over the cycles (Figure 4A). The variation verified for GSB is a reflex of the variation observed in the pseudo stem length (Figure 2B) and tillering of the grass throughout the cycles, respectively (r= 0.50** and r= 0.50**). The variation observed for DFB was due to the change in tiller mortality during the grazing cycles due to decapitation and trampling of the grass by the grazing animals, as foliar senescence was practically negligible and was not altered with successive grazing cycles.

The increase in stem biomass up to the level equivalent to 797 kg ha^{-1} $year^{-1}$ of N, can be attributed in part to the increase in the pseudo stem length provided by nitrogen fertilization, a reflex of the effect of N on the stem elongation rate (Alves *et al.*, 2008).

The increase in forage biomass provided by the increase in the stem biomass compromises the quality of the forage (Silva *et al.*, 2007a) and its use by grazing animals (Silva *et al.*, 2007b), due to the reduction in the voluntary intake of dry matter by the animal (Cândido *et al.*, 2006), caused by the thickening of the secondary cell wall of the vegetable, with consequent accumulation of lignin and less digestible structural carbohydrates. Thus, maintaining pastures for a long rest period is not beneficial, as it may result in increases in stem biomass, which causes undesirable changes in the quality of the forage produced (Gomide *et al.*, 2007).

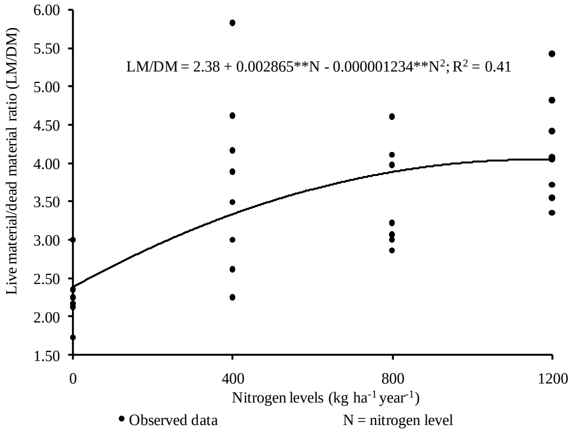
No interaction was observed ($P> 0.05$) between the nitrogen levels x grazing cycles for total forage density (TFD), revealing a quadratic response ($P< 0.05$) for this variable as nitrogen fertilization increased, reaching a maximum value of 179.1 kg ha^{-1} cm^{-1} at the level equivalent to 879.2 kg ha^{-1} $year^{-1}$, with an increase of 45.4% for that level in comparison to the absence of nitrogen fertilization (Figure 4C), which is explained by the maintenance of a high population of live tillers in the pasture, leading to a more compact canopy architecture.

TFD was similar ($P> 0.05$) between grazing cycles 1, 2 and 3, with a higher value for cycle 4 ($P< 0.05$) when compared to cycles 2 and 3 (Figure 4B). This response is due to the greater increase in biomass than in canopy height over the cycles, resulting in a more compact and dense pasture.

Forage density is a structural variable of the pasture, subjected to the influence of grazing intervals, where longer intervals are associated to higher total biomass densities, but usually with lower leaf biomass density (Stobbs, 1973). In the present study, the increase in nitrogen fertilization compensated for the smaller rest period adopted, reflecting in an increase in total forage density up to the maximization at the level equivalent to 879.2 kg ha^{-1} $year^{-1}$, even in shorter rest periods, ratifying the relevance of nitrogen fertilization as a strategy that allows to increase the forage density, mainly the production of leaves in the canopy profile, as the nitrogen has a positive influence on the appearance rate (Silva *et al.*, 2009) and leaf elongation (Martuscello *et al.*, 2005; Martuscello *et al.*, 2006; Pompeu *et al.*, 2010; Lopes *et al.*, 2013) in forage grasses.

No interaction was observed ($P> 0.05$) between nitrogen levels x grazing cycles for the live material / dead material ratio (LM/DM). A quadratic response ($P< 0.05$) was observed for the LM/DM ratio with the increase in N levels, reaching a maximum value (LM/DM= 4.0) at the level equivalent to 1,161 kg ha^{-1} year^{-1}, with an increase of 68.1% for this variable in comparison to the absence of nitrogen fertilization (Figure 5A). This response was due to the increase in GFB, without a corresponding increase in DFB, justifying the increase in the LM/DM ratio until reaching the maximum value at the nitrogen level mentioned above.

Still regarding LM/DM ratio, it is worth mentioning that the variation (P< 0.05) presented during the grazing cycles (Figure 5B), with higher values (P< 0.05) in the two last cycles when compared to the first one is explained mainly by the increase in GSB, since there was practically no senescence and most of the GFB was consumed at each grazing.



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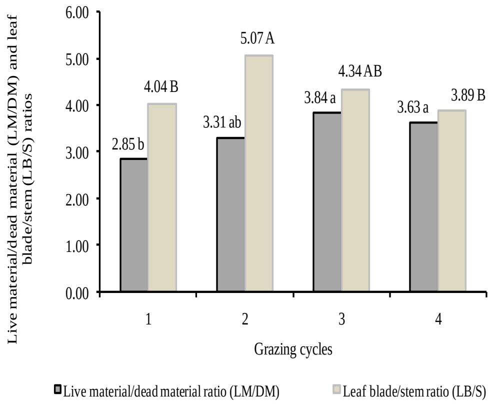

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Figure 5. Live material/dead material ratio (LM/DM) as a function of nitrogen fertilization (A) and LM/DM and leaf blade/stem (LB/S) ratios over the grazing cycles (B) in *Panicum maximum* cv. Massai. Significant at the level of 1% (**); means followed by equal letters (lowercase for LM/DM and uppercase for LB/S) do not differ (P> 0.05) by Tukey's test.

No interaction was observed (P> 0.05) between nitrogen levels x grazing cycles for the leaf blade / stem ratio (LB/S), nor was there a response (P> 0.05) of this variable to nitrogen fertilization, showing a mean value of 4.33 ± 0.92, justified by the increase in stem biomass as the leaf biomass increased with higher nitrogen levels (Pompeu *et al.*, 2010). A difference was observed (P< 0.05) between the grazing cycles for the LB/S ratio, being higher in grazing cycles 2 and 3 (Figure 5B), which is explained by the inferiority in the stem biomass produced in these grazing cycles.

It is worth to infer, however, that the elongation of the stem and consequent increase in the pseudo stem length in the massai grass, reflecting in an increase in the stem biomass, did not generate a great reduction in the LB/S ratio, since the leaf blade production also revealed a positive response as nitrogen fertilization was increased. The negative effects of stem production on the LB/S ratio were thus neutralized, given the consistency of leaf biomass increase in response to N levels, not compromising this ratio. The high values observed for LB/S ratio in the present study indicate a high quality of the forage produced, demonstrating the high potential of the massai grass for leaf production, providing greater grazing efficiency, since according to Sollenberger and Burns (2001), the percentage of leaves, leaf biomass and the accessibility of the leaf to the animal are of great relevance for the consumption of the forage by the grazing animal.

CONCLUSION

Nitrogen fertilization provides considerable increases in the biomass components of greater qualitative relevance in the massai grass, besides providing satisfactory responses on the pre-grazing structure of its canopy. The grazing cycles exert minor changes to the structure of massai grass canopy, showing that this forage is very adapted to sheep grazing. To maximize the biological response of the massai grass, one recommends the nitrogen level equivalent to 934kg ha^{-1} year^{-1}, under intensive management.

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