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Biomass flow in massai grass fertilized with nitrogen under intermittent stocking grazing with sheep[1]

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ABSTRACT - This study evaluated the biomass flow of massai grass in regrowth subjected to different nitrogen levels (control – no fertilization; 400; 800; and 1200 N kg ha^{-1} year^{-1}) and under rotational stocking with sheep, in a completely randomized design with repeated measures over time. The leaf elongation rate increased with increasing nitrogen levels (N) and the fourth grazing cycle presented a lower value compared with the others. The stem elongation rate responded linearly with increasing levels of N, but it was not influenced by grazing cycles. The senescence rate of leaves remaining before grazing and after grazing were not influenced by the nitrogen fertilization or amended with successive grazing cycles. The phyllochron was influenced only by the nitrogen fertilization, with a decreasing linear response with nitrogen levels. Quadratic response was observed for the average length of leaves with increasing N levels and the grazing cycle 4 presented the lowest value for this variable. For each kilogram N ha^{-1} year^{-1}, increases of 0.161 and 0.1604 kg ha^{-1} day^{-1} were verified in the herbage growth and accumulation rates, respectively. Nitrogen fertilization favors the biomass flow of massai grass, promoting an expressive increase in the production and accumulation of forage.

Key Words: morphogenesis, nitrogen fertilization, *Panicum maximum* × *Panicum infestum*

Introduction

The maximization of biomass production of forages is a result of satisfactory conditions of the environment and of management, which are relevant for a successful production system. There are several species of forage with potential of response to intensive management; among them, the species *Panicum maximum* stands out, with cultivars of great adaptation to environment and management conditions. The massai grass, a natural hybrid (*Panicum maximum* × *Panicum infestum*), revealed a high yield potential in initial tests conducted by Embrapa Gado de Corte, so it proved to be an important grass for the intensification of pasture production systems.

The forage production is the major component that defines the carrying capacity of pastures, hence the relevance of the knowledge of its components to understand the influence of management strategies (fertilization, irrigation, adjustment of the animal stocking, and others). The increasing restrictions to the clearing of new areas for livestock generates the demand for forages with high biomass production in response to production factors, especially soil fertility, which is the most manipulatable by man. Within this production factor, nitrogen takes on a key role by promoting positive responses to the biomass flow (Garcez Neto et al., 2002; Alexandrino et al., 2004), production and nutritional value of the forage (Andrade et al., 2003), constituting an essential management practice for the persistence and productivity of forage plants.

The study on the biomass flow or morphogenesis, conceptualized by Chapman & Lemaire (1993) as dynamics of generation (genesis) and expansion of plant form (morphos) in time and space, is an important tool in the definition of management strategies that improve the production and efficiency of forage use, as well as its persistence, similarly to what is verified for many species of tropical forages lacking information on the biomass flow of the massai grass fertilized with nitrogen and grazed by sheep in successive cycles. Thus, the objective of the present study was to evaluate the massai grass fertilized with nitrogen managed under intermittent grazing with sheep, through study of the biomass flow.

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Material and Methods

The experiment was developed on a pasture of *Panicum maximum* × *Panicum infestum* var. Massai, belonging to the Núcleo de Ensino e Estudos em Forragicultura of the Centro de Ciências Agrárias of the Universidade Federal do Ceará - NEEF/DZ/CCA/UFC, in the city of Fortaleza, Ceará state, Brazil, in 2009. The city of Fortaleza is located at an average altitude of 21 meters, at geographical coordinates 03° 45' 47" S and 38° 31' 23" W, with rainy tropical climate Aw' (Figure 1), according to the Köppen classification.

The soil of the experimental area is classified as a yellow podzolic soil, whose source materials are sandy-clayey sediments of the barrier formation (EMBRAPA, 1999). The soil analysis (0-20 cm depth) performed at the beginning of the experiment showed the following chemical characteristics: 9 mg dm^{-3} P; 15.64 mg 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} Al^{3+}; 0.10 $cmol_c$ dm^{-3} 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+}; 0.4 mg dm^{-3} Cu^{2+}; 8.3 mg dm^{-3} Zn^{2+}; and 11.9 mg dm^{-3} Mn, corrected as recommended by CFSEMG (1999), for fertility levels suggested for grasses with high yield potential and high level of production.

Fertilization with phosphate (simple superphosphate), potassium (potassium chloride) and micronutrients (FTE BR-12) was carried out according to the soil analysis results. The applications of nitrogen (urea) and potassium were split. The nitrogen dose for each treatment was split into two portions: the first half was applied soon after the removal of the animals from the paddock, and the second half in the half of the rest period, according to each level evaluated. In all applications of nitrogen, the urea was diluted in water so as to give better balancing of application, given the small amount of fertilizer per plot, which hindered the application in the solid form, with subsequent irrigation to prevent possible burning of the leaves. In the application, a backpack sprayer with spray volume standardized was used according to the field test previously performed. Potassium was made available in three applications, the first (160 kg K_2O ha^{-1}, corresponding to 132.8 kg K ha^{-1}) was undertaken at the beginning of the experiment with the first portion of nitrogen; the second and the third applications of potassium (160 and 160 kg K_2O ha^{-1}, respectively) were performed along with the first dose of nitrogen immediately after the removal of animals in subsequent grazing cycles. The supply of phosphorus (250 kg P_2O_5 ha^{-1}, corresponding to 110 kg ha^{-1} P) was performed at once, along with the first portions of potassium and nitrogen, at the start of the experiment. By this time, micronutrients were also provided (50 kg FTE BR-12 ha^{-1}).

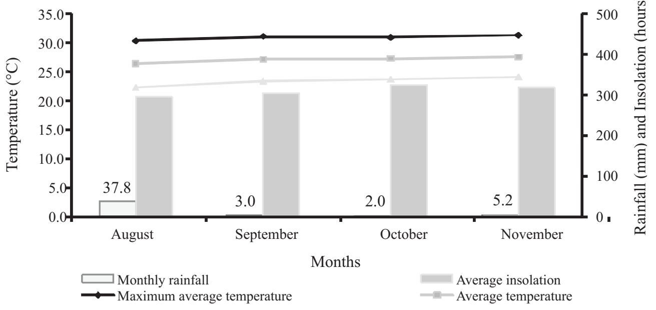


Figure 1 - Climatic data during the experimental period in Fortaleza, Ceará state (Brazil) in 2009.

The nitrogen levels examined were: control - no nitrogen fertilization; 400; 800; and 1200 kg nitrogen ha^{-1} $year^{-1}$. The experiment consisted of a completely randomized split-plot design, with repeated measures over time along four successive grazing cycles (two fixed repetitions × four grazing cycles, totaling eight repetitions per treatment in the study). The nitrogen levels were analyzed in the plots, and the grazing cycles, in the subplots.

The massai grass pasture was managed under low-pressure fixed sprinkler irrigation (working pressure < 2.0 kgf cm^{-2}), with water depth of 7.0 mm day^{-1} at irrigation schedule of 3 days and irrigation time (Ti) of 8 hours, held at night, aiming at better uniformity of the water depth applied. For determining the parameters above, an initial assessment of the irrigation system was performed, as done throughout the experimental period.

The rest period adopted varied according to the nitrogen levels according to the differentiated growth rate of the forage for each level of nitrogen evaluated (22; 18; 16; and 13 days for the levels 0.0 – control; 400; 800 and 1,200 kg N ha^{-1} $year^{-1}$, respectively). The rest period for each level examined was set from studies developed by Lopes (2010) with massai grass fertilized with nitrogen, using the variable phyllochron (verified by the author) to determine the rest period, according to the number of green leaves per tiller, of approximately 1.5 leaves per tiller produced in the regrowth for the management of that grass. The post-grazing height was determined based on the residual leaf area index (LAI) close to 1.5.

Sheep (½ Morada Nova × ½ undefined breed) were used to lower the pasture height up to the recommended residual height, divided into paddocks of 42.3 m^2. The mob-grazing technique (Gildersleeve et al., 1987) was used to perform the grazing by employing groups of animals for rapid defoliation (duration from 4 to 18 hours), simulating a management under rotational stocking. As the animals grazed, the pasture height was monitored using a ruler until the canopy reached the recommended residual height of around 15 cm, corresponding to the residual LAI of the removal of animals from the paddock of approximately 1.5 as previously determined.

At each experimental unit (paddocks of 42.3 m^2), nine tillers were identified with a ring of different color for subsequent monitoring. The marked tillers were evaluated every three days, by recording the final length of fully expanded and emerging leaves and the length of the senescent portion of expanded leaves, height and length of the pseudostem and the number of green leaves per tiller. Tiller population density (TPD, tillers m^{-2}) was determined at the same time of previous measurements (every three days), through the counting of tillers present in three frames of 0.0625 m^2.

The variables evaluated were leaf elongation rate (LER, cm $tiller^{-1}$ day^{-1}); stem elongation rate (SER, cm $tiller^{-1}$ day^{-1}); phyllochron, in days; number of green leaves per tiller (NGL, leaves $tiller^{-1}$), counting the number of new expanded leaves as those in which the ligule was exposed and counting as 0.5 leaves when it was not exposed, by sampling 30 tillers per paddock at random; senescence rate of leaves remaining before grazing (SRLBG, cm $tiller^{-1}$ day^{-1}) counting only leaf blades produced before each grazing cycle and constituents of the residual leaf area; senescence rate of leaves remaining after grazing (SRLAG, cm $tiller^{-1}$ day^{-1}), counting only new leaf blades produced during the current rest period; average length of leaves (ALL, cm); herbage growth rate (HGR, kg ha^{-1} day^{-1}); and herbage accumulation rate (HAR, kg ha^{-1} day^{-1}).

Data were subjected to analysis of variance, mean comparison test and regression analysis. The nitrogen fertilization × grazing cycle interaction was presented when significant ($P<0.05$) by the F-test. The grazing cycles were compared by Tukey's test ($P<0.05$). The effect of the nitrogen fertilizer levels was evaluated by a regression analysis. The selection of the models was based on the significance of the linear and quadratic coefficients, through a Student's t-test ($P<0.05$) and on the coefficient of determination. As a tool to aid statistical analyses, the procedures MIXED and GLM of software SAS (Statistical Analysis System, version 9.0) were adopted.

Results and Discussion

No interaction was observed ($P>0.05$) between the factors (nitrogen levels × grazing cycles), for the number of green leaves per tiller (NGL) or influence ($P>0.05$) of the isolated factors with mean values of 1.65±0.063 and 1.65±0.027 leaves $tiller^{-1}$, for the nitrogen levels and grazing cycles, respectively.

The similarity in the values of this variable is explained by the method used for the management, using a variable rest period according to the nitrogen level, from the phyllochron determined by Lopes (2010), in a study with this grass subjected to nitrogen levels in a greenhouse. In other words, the number of green leaves per tiller for the grass management during the experiment was recommended, with the rest period varying in response to the differentiated phyllochron of the evaluated nitrogen levels.

The measure of the number of green leaves per tiller was performed as a target variable for management, since it was previously determined. Thus, results regarding the number of green leaves confirm the method used in the present study, justifying its use as a criterion to determine the rest period of a grazing area (Fulkerson & Donaghy, 2001).

No interaction ($P>0.05$) between nitrogen levels and grazing cycles was observed for the leaf elongation rate (LER), but it was influenced ($P<0.05$) by both factors separately. The leaf elongation rate increased ($P<0.05$) with the levels of nitrogen fertilizer (400; 800; and 1,200 kg ha^{-1} $year^{-1}$) (Figure 2) and changed ($P<0.05$) between grazing cycles with the first three cycles, revealing higher values than the fourth cycle (Figure 3). A lower value ($P<0.05$) of LER was verified in grazing cycle 4 (3.47 cm $tiller^{-1}$ day^{-1}), accounting for the lower residual LAI (residual LAI of 1.67; 1.52; 1.55 and 1.37 for the grazing cycles 1; 2; 3 and 4, respectively), once the pasture regrowth is impaired at lower residual LAI, reflecting the lower rate of photosynthesis of the canopy.

The pasture restoration under lower residual LAI demands greater mobilization of organic reserves, once the regrowth from organic reserves is more costly for the plant than the regrowth via photosynthesis of remaining leaves. The difference between the residual LAI of the first and of the fourth grazing cycle shows the difficulty in controlling the pasture physiological condition through its height, since a difference of 0.7 cm (15.4 to 14.7 cm for first and fourth cycles, respectively) or 4.55% in the residual height resulted in reduction of 0.3 (1.67 to 1.37) or 17.96 % in the residual LAI.

An increasing linear response ($P<0.05$) was recorded for LER with increasing nitrogen levels, estimating values of 2.32 and 5.14 cm $tiller^{-1}$ day^{-1} for the levels of 0.0 and 1,200 kg N ha^{-1} $year^{-1}$, respectively. There was an increase of 121.55% for the level of 1,200 kg N ha^{-1} $year^{-1}$ relative to the lack of nitrogen fertilization (Figure 2). This indicates the significant role of this nutrient on the LER pattern and confirms the relevance of nitrogen fertilization in the increase of this variable (Garcez Neto et al., 2002;

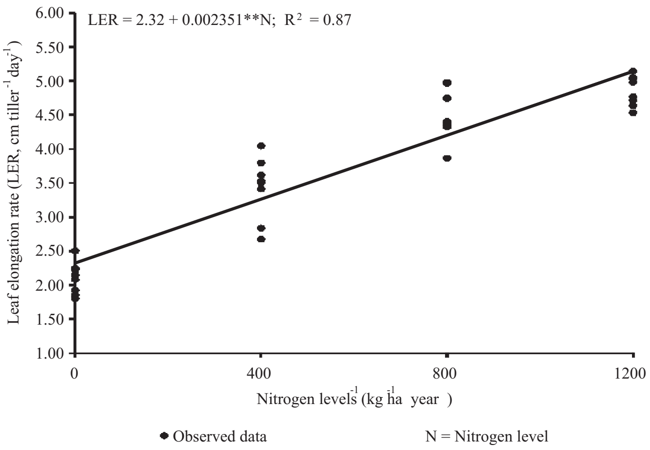
Alexandrino et al., 2004; Fagundes et al., 2005), which can be especially attributed to the increase in cell production (cell division) (Volenec & Nelson, 1984), a result of deposition of nutrients, especially nitrogen, in the areas of elongation and cell division of leaves (Skinner & Nelson, 1995). Also, according to Fagundes et al. (2005), the effect of nitrogen fertilization on the leaf elongation rate can be related to the great influence of nitrogen on physiological processeses of the plant, resulting in an increase of that variable.

The leaf elongation rate is of great relevance in the biomass flow of plants, once it is directly associated with biomass production. This way, the increase in the LER leads to increased proportion of leaves and consequent larger photosynthetically active leaf area, promoting a greater biomass accumulation probably due to the better relationship between carbon and nitrogen for the regrowth.

There was no interaction (P>0.05) between the factors (nitrogen levels × grazing cycles) for the stem elongation rate (SER), or difference (P>0.05) between grazing cycles evaluated with an average of 0.039±0.0044 cm tiller^{-1} day^{-1} (Figure 4). The lack of difference in the stem elongation rate with successive grazing cycles, given the judicious management of the pasture over successive grazing cycles with the rest period adjusted according to the applied nitrogen level, reveals a positive characteristic of the massai grass for use in intensive production systems, especially for small ruminants, with the forage primarily responding with production of leaf biomass, not increasing the stem over the cycles, reflecting the proper management of the pasture and grazing.

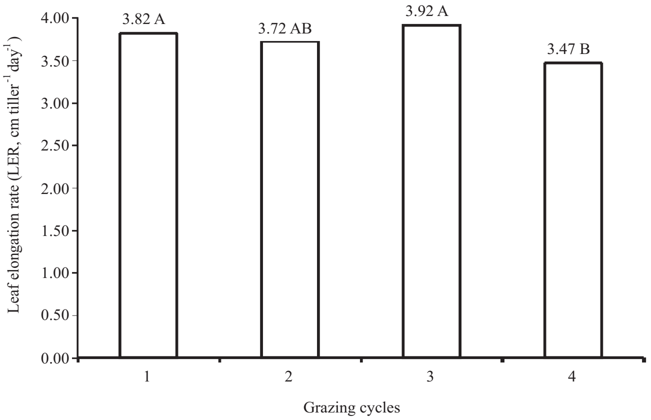
The stem elongation rate increased (P<0.05) with the increasing levels of nitrogen, with values estimated at 0.0218 and 0.0552 cm tiller^{-1} day^{-1} for the levels of 0 and 1,200 kg Na ha^{-1} year^{-1}, respectively (Figure 5). Despite the increasing response observed for the SER, it is worth mentioning that the values of this variable were petty when compared with increases in the LER, minimizing the stem participation in the total biomass.

The stem elongation rate has proven relevance for the pasture growth, since it ensures the maintenance of the canopy architecture when it reaches a higher biomass, keeping an appropriate distance between the leaves and preventing an increase in the light extinction coefficient (Sugyiama et al., 1985). On the other hand, it is worth highlighting the negative effects caused by increased proportion of stem in total biomass, with direct reflection on the forage quality (reducing the forage quality) by decreasing the leaf/stem ratio, thus reducing the nutritional value of the biomass produced (Cândido et al., 2006; Silva et al., 2007a) and its use by grazing animals (Silva et al., 2007b).



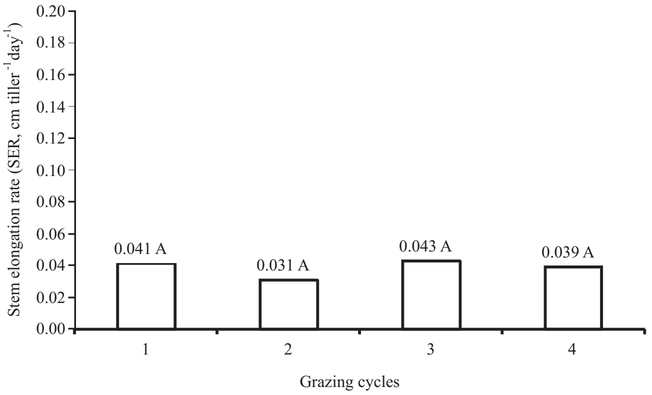
** Significant at 1%.

Figure 2 - Leaf elongation rate (LER) according to nitrogen levels in *Panicum maximum* × *Panicum infestum* var. Massai under intermittent stocking with sheep.



Means followed by the same letter are not significantly different (P>0.05) by Tukey's test.

Figure 3 - Leaf elongation rate (LER) according to grazing cycles in *Panicum maximum* × *Panicum infestum* var. Massai under intermittent stocking with sheep.



Means followed by the same letter are not significantly different (P>0.05) by Tukey's test.

Figure 4 - Stem elongation rate (SER) according to grazing cycles in *Panicum maximum* × *Panicum infestum* var. Massai under intermittent stocking with sheep.

Moreover, the intense elongation of stems negatively influences the feeding behavior of grazing animals (Chacon & Stobbs, 1976) and the forage intake (Silva et al., 1994b), due to the physical limitation imposed by increased stem participation and also due to the selectivity of animals for leaf blades (Benvenutti et al., 2006). This way, the animal performance and production are compromised (Almeida et al., 2000), and the use efficiency of the produced forage is impaired (Silva et al., 1994b).

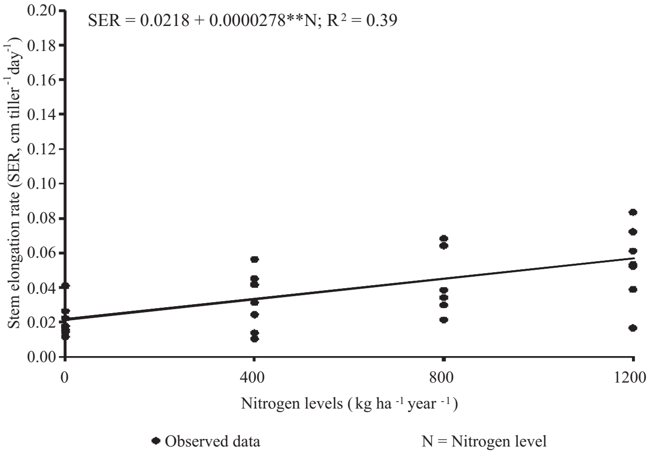
No interaction was detected ($P>0.05$) between nitrogen levels and grazing cycles for the senescence rate of leaves remaining before grazing (SRLBG) and after grazing (SRLAG). The variables were neither influenced ($P>0.05$) by nitrogen fertilization, with mean values of 0.00938±0.012 and 0.0131±0.027 cm tiller^{-1} day^{-1}, respectively, nor changed ($P>0.05$) by successive grazing cycles, with mean values of 0.0095±0.0046 and 0.0133±0.0086 cm tiller^{-1} day^{-1}, respectively (Figure 6), a result of the reduced competition for light inside the canopy along the cycles, which minimizes the forage loss due to senescence.

Also, low values for the senescence rate of leaves remaining before grazing verified in massai grass is justified by the use of residual LAI that minimized the occurrence of senescence along the successive grazing cycles.

The similar result observed for SRLAG with increasing nitrogen levels, with values close to zero, reflects the effective management of the forage, with the rest period adjusted according to the nitrogen level applied (Lopes, 2010).

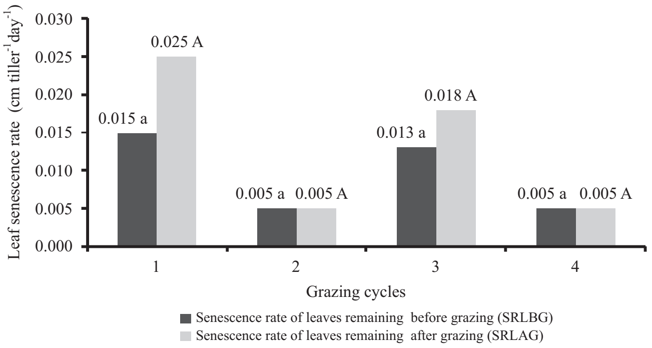
With the plant growth responding differently to the increasing nitrogen levels, with high leaf appearance and elongation rates, the pasture management aiming at a greater effectiveness in the production and use of produced biomass should have an adjustment of the rest period according to the level of nitrogen applied, as observed in the present study. The senescence rate of leaves remaining after grazing is an indicative of the adjustment of defoliation frequency to the canopy physiology, once a pasture managed for a high efficiency of use of the produced forage should prevent the senescence of leaves formed in the regrowth, i.e., should present a SRLAG equal or close to zero (Cândido et al., 2006).

The phyllochron was only influenced ($P<0.05$) by the nitrogen fertilization, without interaction ($P>0.05$) between nitrogen levels and grazing cycles. A mean value of 8.96±0.122 days leaf^{-1} (Figure 7) observed for the phyllochron according to grazing cycles reflects the good structure of the forage, able to respond efficiently to the resources of the environment and to the judicious management of pasture and grazing through the experimental period, given the similarity of climatic conditions during the



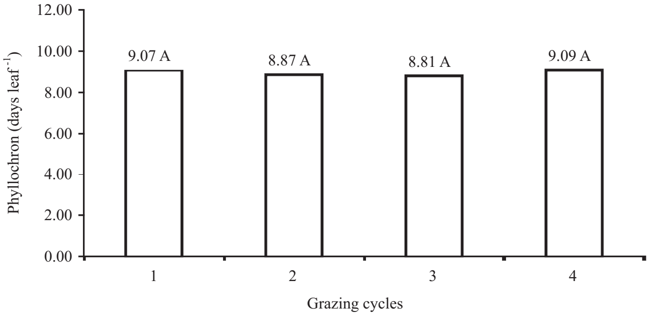
**Significant at 1%.

Figure 5 - Stem elongation rate (SER) according to nitrogen levels in *Panicum maximum* × *Panicum infestum* var. Massai under intermittent stocking with sheep.



Means followed by the same letters (lower- and uppercases) for SRLBG and SRLAG, respectively are not significantly different ($P>0.05$) by Tukey's test.

Figure 6 - Senescence rate of leaves remaining before grazing (SRLBG) and after grazing (SRLAG) as a function of the grazing cycles on massai grass under intermittent stocking with sheep.



Means followed by the same letter are not significantly different ($P>0.05$) by Tukey's test.

Figure 7 - Phyllochron (PHY) according to grazing cycles in *Panicum maximum* × *Panicum infestum* var. Massai under intermittent stocking with sheep.

forage evaluation, not constituting a factor with significant influence on the response pattern of that variable.

The phyllochron presented reductions ($P<0.05$) at higher nitrogen levels, with values estimated at 11.85 and 6.07 days leaf^{-1} for 0.0 and 1,200 kg N ha^{-1} year^{-1}, respectively (Figure 8).

The response pattern observed in this study for the phyllochron, as reported in the literature (Martuscello et al., 2005; Mesquita & Neres, 2008; Pompeu et al., 2010), demonstrates the importance of nitrogen in reducing the time for appearance of two successive leaves on the tiller, since it increases the production of new cells (Volenec & Nelson, 1984), which has positive effect on leaf production. With this, the increasing nitrogen fertilization can anticipate the entry of animals to the pasture, which can result in a greater number of grazing cycles along the year, for the pastures supplied with higher nitrogen levels.

Importantly, the reduction in phyllochron with increasing nitrogen fertilization is due to the nitrogen effect on the growth rates, especially of the leaves (Garcez Neto et al., 2002). This effect promotes greater capacity of tissue replacement to the pastures and comsequently greater regrowth potential, since after defoliation a rapid recovery of photosynthetic apparatus allows for a greater competitive ability of individuals in the plant community (Martuscello et al., 2006). In this situation, nitrogen takes on an extremely important role to facilitate this recovery, because it is a nutrient that participates in several physiological processes of forage plants.

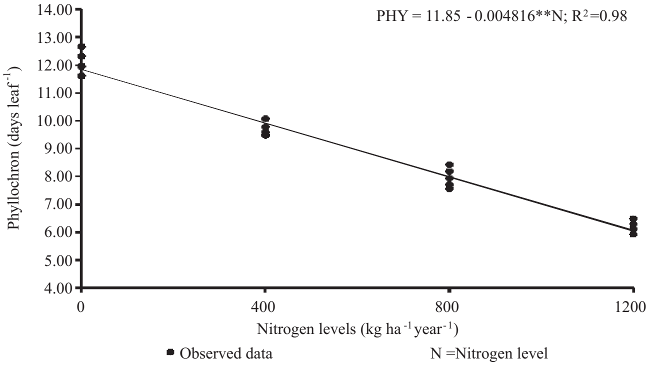
No interaction ($P>0.05$) between nitrogen levels and grazing cycles was observed for the average length of leaves (ALL), and the significance ($P<0.05$) was limited to isolated factors. Similar values ($P>0.05$) of ALL were recorded in the first three grazing cycles (Figure 9), indicating the forage stabilization and the careful management of grazing animals, besides the adequate availability of water, light and nutrients along the grazing cycles. A lower value ($P<0.05$) was verified for the ALL in the grazing cycle 4, justified by the lower leaf elongation rate (Figure 3) in this cycle, as a response to the lower residual LAI, as presented by the variable LER.

Quadratic response ($P<0.05$) was observed for the average length of leaves (ALL) with increasing nitrogen levels, revealing values estimated at 24.62 and 29.81 cm for levels 0.0 and 1,200 kg N ha^{-1} year^{-1}, respectively, reaching a maximum (35.22 cm) at the level of 700 kg N ha^{-1} year^{-1} (Figure 10).

This increase in the ALL up to the level of 700 kg ha^{-1} year^{-1} of nitrogen was mainly due to the increased leaf elongation rate which contributes with the recovery of leaf area after grazing, essential for the pasture continuity (Alexandrino et al., 2004).

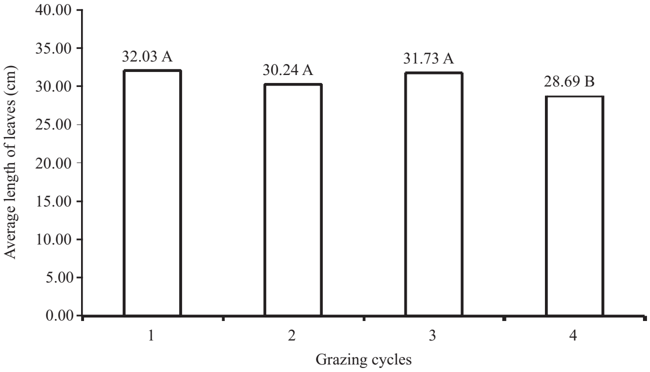
The response verified for the leaf length at high levels of nitrogen may be related to the phenotypic plasticity of the forage to frequent and intense defoliations under high instantaneous stocking density. The different pattern of the forage under high nitrogen levels can be observed by monitoring the pre-grazing LAI, which increased up to the level equivalent to 810.1 kg N ha^{-1} year^{-1} (LAI = 8.6), with reduction at higher levels.

This pattern of response for that variable reflects the lower ALL in the last levels of nitrogen, once the LER responded increasingly and the number of green leaves per tiller was similar between evaluated levels. Given this, the type of management previously described leads to plants with shorter leaf sheaths, with ligules below the defoliation



** Significant at 1%.

Figure 8 - Phyllochron according to nitrogen levels in *Panicum maximum* × *Panicum infestum* var. Massai under intermittent stocking with sheep.



Means followed by the same letter are not significantly different ($P>0.05$) by Tukey's test.

Figure 9 - Average length of leaves according to grazing cycles in *Panicum maximum* × *Panicum infestum* var. Massai under intermittent stocking with sheep.

height, and more horizontal tillers, allowing the canopy to keep green leaf tissues below the grazing horizon, thus preserving an assimilative apparatus for growth after defoliation (Lemaire, 1997).

This plant response can be completely reversed as soon as the defoliation ceases, or at least becomes less frequent. In this case, the sheath length of new leaves formed increases gradually until that value before defoliation, and blades are once again longer and more erectly positioned.

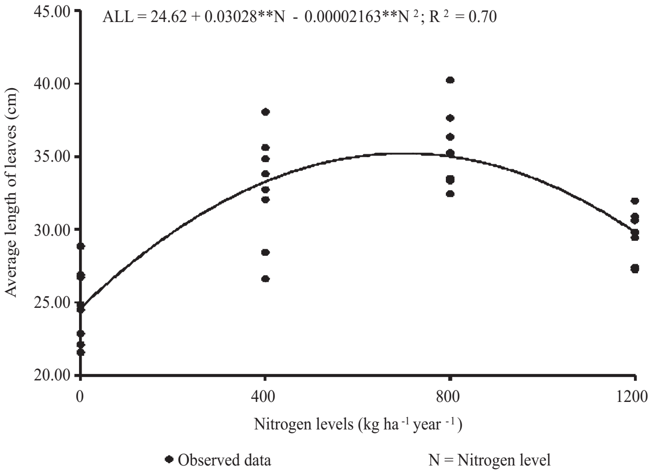
Examining the morphogenetic characteristics of mombasa grass in response to nitrogen levels (0, 50, 100 and 200 mg N dm^{-3} soil), Garcez Neto et al. (2002) found that an increase in the leaf blade size can be simultaneously explained by nitrogen fertilization, by significantly increasing the number of dividing cells, and the cutting height, by defining a longer sheath length.

There was a significant interaction ($P<0.05$) between nitrogen levels and grazing cycles for the herbage growth rate (HGR) and herbage accumulation rate (HAR). Both variables presented higher values ($P<0.05$) at higher nitrogen levels, but no difference ($P>0.05$) was detected between the grazing cycles for non-fertilized pastures and others supplied with 400 kg ha^{-1} year^{-1} N (Table 1). In the level of 800 kg ha^{-1} year^{-1} of nitrogen, both HGR and HAR were greater in grazing cycles 3 and 4, probably due to the increase and later stabilization of tillering in those cycles, since tiller population density values of 3,456; 4,312; 5,208; and 5,464 tillers m^{-2} were verified in cycles 1, 2, 3 and 4, respectively, for the pasture supplied with 800 kg nitrogen ha^{-1} year^{-1}.

For the HGR and HAR, an increasing linear response ($P<0.05$) was verified with the increasing levels of nitrogen fertilizer, revealing values estimated at 95.26 to 288.46 kg ha^{-1} day^{-1} (HGR) and 93.54 to 286.02 kg ha^{-1} day^{-1} (HAR) for the levels from 0.0 to 1,200 kg ha^{-1} year^{-1} nitrogen, respectively (Figures 11 and 12, respectively). The level of 1,200 kg ha^{-1} year^{-1} nitrogen promoted an increase of 202.8% in HGR and 205.8% in HAR, in relation to the treatment without fertilization.

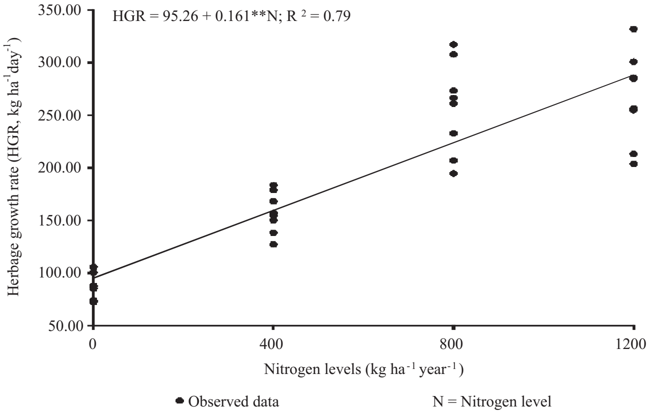
This increase observed for HGR at higher levels of nitrogen is explained by the increasing response pattern of the leaf elongation rate (LER) with nitrogen fertilization, once the LER had a positive linear correlation ($r = 0.91^{**}$) with the forage production rate.

The forage accumulation derives from the balance between the components of biomass flow individually and in the community. The values of HAR close to the values of HGR reflect the low senescence of massai grass, which was almost negligible (values close to zero) along the grazing cycles.



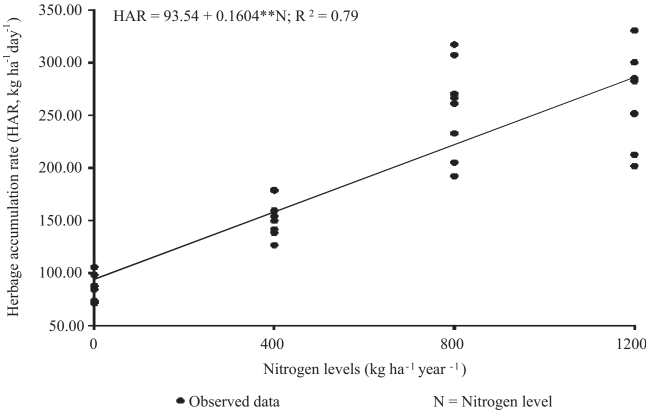
** Significant at 1%.

Figure 10 - Average length of leaves (ALL) according to nitrogen levels in *Panicum maximum* × *Panicum infestum* var. Massai under intermittent stocking with sheep.



** Significant at 1%.

Figure 11 - Herbage growth rate (HGR) according to nitrogen levels in *Panicum maximum* × *Panicum infestum* var. Massai under intermittent stocking with sheep.



** Significant at 1%.

Figure 12 - Herbage accumulation rate (HAR) according to nitrogen levels in *Panicum maximum* × *Panicum infestum* var. Massai under intermittent stocking with sheep.

Table 1 - Growth and accumulation of herbage in massai grass pastures fertilized with nitrogen and grazed by sheep under intermittent stocking

Cycles	Nitrogen levels (kg ha^{-1} year^{-1})			
	0	400	800	1200
	Herbage growth rate (HGR, kg ha^{-1} day^{-1})			
1	86.26Ac	152.24Ab	200.65Ca	208.28Ca
2	95.12Ad	141.96Ac	246.88Bb	316.39Aa
3	87.62Ac	175.78Ab	290.50Aa	285.22ABa
4	73.56Ac	158.45Ab	291.72Aa	255.53Ba
	Herbage accumulation rate (HAR, kg ha^{-1} day^{-1})			
1	84.65Ac	145.49Ab	198.43Ca	207.01Ca
2	94.88Ad	140.17Ac	246.88Bb	315.38Aa
3	87.39Ac	168.79Ab	288.75Aa	283.78ABa
4	73.01Ad	158.45Ac	291.72Aa	251.53Bb

Means followed by the same letter in the row (lowercase) and in the column (uppercase) are not significantly different ($P>0.05$) by Tukey's test.

In this context, the biomass production result of processes of canopy growth and development can have its effectiveness substantially enhanced with the use of fertilizers, especially nitrogen, given its positive effect on the biomass flow (Duru & Ducrocq, 2000).

Conclusions

Nitrogen fertilization favors the components of biomass flow of massai grass, providing a remarkable increase in production and accumulation of forage up to the level of 1,200 kg nitrogen ha^{-1} year^{-1}. However, these results should be associated with environmental and economic information to recommend the best level of nitrogen to be applied in intensive production systems of grazing sheep. Successive grazing cycles display little change in morphogenetic characteristics of massai grass.

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