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GROWTH AND DEVELOPMENT OF MOMBASSA GRASS GROWN IN FULL SUN AND SHADE UNDER NITROGEN LEVELS

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ABSTRACT

The objective of this work was to evaluate the effects promoted by full sun and natural shading (25%) enviroemnts , under the productive components of *Panicum maximum* cv. Mombasa grown in diferent levels of nitrogen (0, 25, 50, 100 kg ha^{-1} cycle^{-1}). Urea was used as nitrogen source, applied on the surface. This study evaluated the following variables: number of total leaves (NTL), number of green leaves (NGL), number of dead leaves (NDL), leaf lifespan (LLS), sheath length (SL), stem elongation rate (SER), Phyllochron (PHYL), leaf appearance rate (LApR), leaf elongation rate (LElR), leaf senescence rate (LSR), average length of leaf blade (ALLB), leaf area index (LAI) and tiller population density (TPP). The shaded environment provided better conditions for sheath length and leaf elongation rate, however in full sun the tiller density was higher.

Palavras-chave:
Adubação
Fertilização
Panicum maximum cv Mombaça
Neossolo Quartzarênico
Silvipastoril

CRESCIMENTO E DESENVOLVIMENTO DO CAPIM MOMBAÇA CULTIVADO EM PLENO SOL E SOMBREADO SOB NÍVEIS DE NITROGÊNIO

RESUMO

Objetivou-se avaliar os efeitos promovidos pelos ambientes de sol pleno e sombreamento natural (25%), sob os componentes produtivos do *Panicum maximum* cv. Mombaça, submetidos a diferentes níveis de nitrogênio (0; 25; 50; 100 kg ha^{-1} ciclo^{-1}). Utilizou-se como fonte de nitrogênio a ureia aplicada em superfície. Variáveis avaliadas: número de folhas totais (NFT), número de folhas vivas (NFV), número de folhas mortas (NFM), duração de vida da folha (DVF), comprimento da bainha (CB), taxa de elongamento de colmo (TAlC), filocrono (FILO), taxa de aparecimento foliar (TApF), taxa de elongamento foliar (TAlF), taxa de senescência foliar (TSF), comprimento médio de lâmina foliar (CMLF), índice de área foliar (IAF) e densidade populacional de perfilhos (DPP). O ambiente sombreado proporcionou melhores condições para comprimento da bainha e taxa de elongamento foliar, entretanto no sol pleno a densidade populacional de perfilhos foi superior.

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INTRODUCTION

Forage for use in in silvopastoral system should be chosen based on the tolerance and persistence characteristics in shaded environments, due to the occurrence of physiological adaptations of the plant, such as anatomical and specific leaf area changes, stem and leaf elongation to capture more available light, providing survival and acclimatization by means of light intensity variations, ensuring forage production. Studies of morphophysiological alterations contribute to pasture management (GOBBI *et al*., 2011).

In the shaded context, little is known about forage growth and performance, creating a large gap for management measures to be adopted in silvopastoral systems. Thus, a focus on leaf emission and expansion becomes crucial to define specific grazing methods to this type of environment.

The use of forage plants in pasture is a complex and interdependent process and aims mainly at maximum leaf production to achieve the maximum management of grazing animals. However, it is necessary to understand the dynamics of emission and flow of forage tissues that are responsible for plant development. Thus, understanding the main morphophysiological factors that are directly associated with the potential for conversion of biomass to animal product, becomes essential to also respect the ecophysiological relationships of the ecosystem (SILVA *et al*., 2009).

Morphogenesis is an important tool in the study to increase pasture productivity. Its objective is to quantify the dynamics of the tissue emitted by the forage plant, therefore determining growth, resulting in important data that guide the researcher in decision making in relation to pasture management (SANTOS *et al*., 2014).

Morphophysiological evaluation becomes essential for grazing management adequacy, aligning growth rates with the grazing cycles, therefore enhancing a more refined management adjustment.

The edaphoclimatic variations exert a fundamental influence on the forage productive potential and on its structural and morphological components, so it is able to reduce the number of tillers, leaf area index, leaf elongation rate, pseudo-stem elongation rate, etc. Tissue cell division capacity is strongly influenced by nitrogen supply, supporting the rapid increase in leaf area (LOPES *et al*., 2014; RODRIGUES *et al*., 2014). Biomass flow is a condition that dependents on production factors such as water, radiation, temperature and nutrients. In addition, they are important for maintaining pasture perennity after successive grazing. Among the most responsible nutrients for tissue formation is nitrogen, which constitutes the molecule of the chlorophyll and amino acid. Its continuous and increasing flow towards meristematic regions allows the increase in forage production and regrowth vigor (SANTOS *et al*., 2014).

Several studies has reported nitrogen fertilization (RODRIGUES *et al*., 2017; TEIXEIRA *et al*., 2014). Its significant effect on the increase in dry matter production and also in plant growth rates results in the reduction in the grazing cycles, allowing the verticalization of livestock production (ESCARELA *et al*., 2017). However, due to the emergence of new variations in production systems, it is necessary to meet the new demands regarding the adequacy of technologies already consolidated in livestock. Little is known about the efficiency of the use of nitrogen fertilization in systems with restrictions on some production factor such as light in silvopastoral systems. Thus, the need for nitrogen fertilization for qualitative and quantitative improvements is evident.

The objective of this work was to evaluate the growth and development of Mombasa grass under the effects of nitrogen fertilization grown in full-sun and shade conditions.

MATERIAL AND METHODS

The experiment was carried out in the Silvopastoral Sector of the School of Veterinary Medicine and Animal Science – EMVZ at the Federal University of Tocantins - UFT, in the municipality of Araguaína, state of Tocantins (latitude 7° 5’43.74” S, longitude 48° 12’22.69” W, at 259 m above sea level). The climate in the area is Aw, tropical climate with dry winter and hot and humid summer, with rainfall from October to April, annual average rainfall of 1,863 mm, relative humidity 78% and average temperature 25ºC (KÖPPEN, 1948; SILVA, 2013).

The topography in the experimental area is flat, with 3% slope from the south to north. Soil is classified as a typical Arctic Quartzarenic Neossol (EMBRAPA, 2013).

The experiment was carried out in a completely randomized design with four replications in a 2x4 factorial arrangement, two luminosity levels (full sun and 25% natural shade) and four nitrogen levels (0, 25, 50, 100 kg ha^{-1} cycle N).

The experiment was carried out under two shading strips, one of native vegetation and the other under continuous full sun. The vegetation is Cerrado-Amazonian transition, and enriched with Mombasa grass, broadcasted sown at sowing rate of 2.0 kg ha^{-1}. The native area had been thinned to 25% shade with the aid of a luximeter. On the other hand, the full-sun area was implanted by completely removing the native vegetation and planting Mombasa grass at sowing rate of 1.6 kg ha^{-1}.

Urea was used as N source (45% N) at the four nitrogen levels, using broadcast application on the surface per cycle, at the beginning of the rest period, after the plant had emitted 3.5 leaves (usually 25 days after cutting), totaling six applications for each treatment over the experimental period. Phosphate maintenance fertilization was done in total area, using 60 kg ha^{-1} year^{-1} P_2O_5, single superphosphate source 18% P_2O_5, 16% Ca^{2+} and 8% S, in a single application and potassium 25 kg ha^{-1} cycle^{-1} K_2O as potassium chloride (58% K_2O), together with the nitrogen source (RIBEIRO *et al*., 1999).

Before the beginning of the experimental period, soil sampling was performed. Soil analyses were performed at the EMVZ/UFT Soil Laboratory, used to characterize and determine liming (TABLE 1).

During the experimental period, from November 1, 2013 to May 22, 2014, the accumulated precipitation was 1,678.8 mm (Figure 1).

Table 1. Chemical Characteristics of the Typical Arctic Quartzarenic Neossol at the experiment setting.

	OM	pH	P	K	Ca	Mg	K	Al	H+Al	t	V	m
	g dm^{-3}		mg dm^{-3}		cmol$_c$dm^{-3}						%	
Sol	4.77	3.60	0.79	1.0	0.72	0.36	0.003	0.59	5.21	1.67	17.20	35.28
Shade	2.04	4.02	0.82	2.00	1.13	0.40	0.005	0.17	4.68	1.54	24.70	30.48

Enviroment:shaded or full-sun environment, from 0 to 20 cm and 20 to 40 cm; O.M.: organic matter; pH in $CaCl_2$; P: phosphorus (Mehlich-1); K^+: potassium; Ca^{2+}: calcium; Mg^{2+}: magnesium; $H^+ + Al^{3+}$: potential acidity; SB: sum of bases; T: cation exchange capacity; t:effective cation exchange capacity; V: base saturation; m: aluminum saturation.

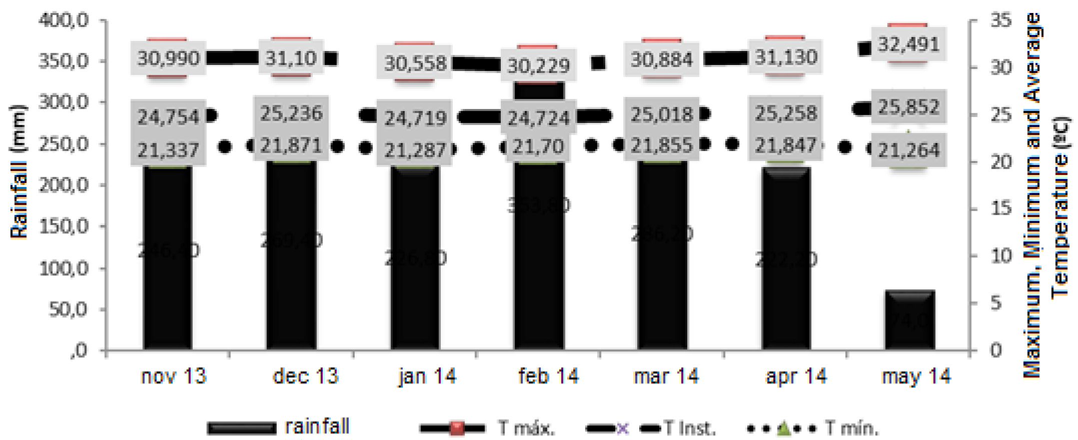

Figure 1. Rainfall accumulation (mm) and maximum, medium and minimal temperature (ºC) over experimental period (01/11/13 to 20/05/14). Source: INMET Araguaína – TO

The harvesting point of the treatments of the plant samples was set at the average expansion of 3.5 leaves per tiller (ALEXANDRINO *et al*., 2005; CÂNDIDO *et al*., 2005), configuring a resting period in variable time.

In each marked tillering, the following were measured: the length of the stem (culm plus sheath), from the ground to the ligule of the last fully developed leaf; expanded leaf blade length, measured from the ligule through the central rib to the end of the living leaf segment; length of the expanding leaf blade, which is the length of the former leaf ligule to the apex of the expanding leaf (SANTOS *et al*., 2004).

Two readings per cycle were taken. The first was done three days after the previous cycle harvest, and the final one on the harvest of the current cycle (SANTOS *et al*., 2004; SANTOS *et al*. 2014).

The average estimate of leaf expansion per tiller was made by marking seven tillers per plot at the beginning of each rest period.

The variables were, as follow: stem length (Stem), in cm; average length of leaf blades (ALLB), in cm; number of total leaves (NTL) in leaves tillers^{-1}; number of green leaves per tiller (NGL) in leaves tiller^{-1}; stem elongation rate (SElR), in mm tiller^{-1}day^{-1}; leaf elongation rate (LElR), in mm tiller^{-1}day^{-1}; leaf appearance rate (LApR) in leaves tillers^{-1} day^{-1}; leaf senescence rate (LSR) in mm tillers^{-1}day^{-1} (ALEXANDRINO *et al*., 2004; SANTOS *et al*., 2004).

Twenty tillers were collected at harvest, then they were taken to the laboratory for biomass flow and separated into stems, expanded leaves and expanding leaves to determine the relationship between weight and length of these fractions. After that, those data were combined with data of leaf elongation rate (LElR) and stem elongation rate (SElR), senescence rate (LSR), tillers density (TD) and leaf area index (LAI) allowing the elaboration of curves and equation of forage accumulation rate (FAcr), production indicative (SANTOS *et al*., 2004).

Each treatment was read once a week until it reached 1.5 new leaves per tiller. After, the readings were daily, and determining the exact moment of the harvest point with 2.5 new green leaves per tiller, obtained by the average of the instantaneous readings in the 24 tillers read in each treatment. Prior to the beginning of the experimental period, the forage standardization cut was performed at 0.30 m height, when the experimental period started, aiming to establish the postharvest residue managed in all cycles at 0.30 m height (SANTOS *et al.,* 2014; SILVA, 2013).

In the 2013/2014 farming period, six cycles were collected per treatment in each of the 32 experimental units in which the characteristics of *Panicum maximum* cv. Mombasa grass were evaluated.

Assistat 7.7 beta software was used for analysis of variance (ANOVA) to test the effects of full-sun and shaded environments (SACRAMENTO *et al*., 2013). The dependent variables of nitrogen levels were analyzed by regression. Nitrogen levels were submitted to the test of Tukey at 5% significance level.

RESULTS AND DISCUSSION

The average number of total leaves (NTL) in the six cycles of the sun environment, estimated by the regression equation, was significant ($p < 0.001$) and showed a linear response, in which the supply of 1 kg nitrogen increased by 0.004 leaf cycle^{-1}, ranging from 5.97 to 6.37 leaf tillers^{-1} (Figure 2). However, under shading, the forage presented a linear decrease of 1 kg of nitrogen to 0.0014 leaf cycle^{-1} ($p < 0.001$), ranging from 6.7762 to 6.6362 leaf tiller^{-1} (Figure 2).

In the work of Macedo et al. (2010), the NTFL was 4.59 to 7.58 leaves tillers^{-1}.

The average number of green leaves (NGL) in the six cycles of full sun environment, estimated by the regression equation was significant ($p < 0.001$), linear model, where nitrogen supply (1 kg ha^{-1} cycle^{-1}), promoted an increase of 0.0048 leaf tiller^{1} ranging from 4.6171 to 5.0971 leaf tiller^{1} (Figure 3).

In natural shading, the average NGL was significant ($p < 0.001$), linear model, and each kilogram of nitrogen allowed an increase of 0.0037 leaf tiller^{-1}, ranging from 5.6176 to 5.2476 leaf cycle^{-1} (Figure 3).

The shaded environment exceeded by 16.48% the full sun (4.8257 and 5.7782 leaf tiller^{-1}, full sun and shaded environment, respectively), considering

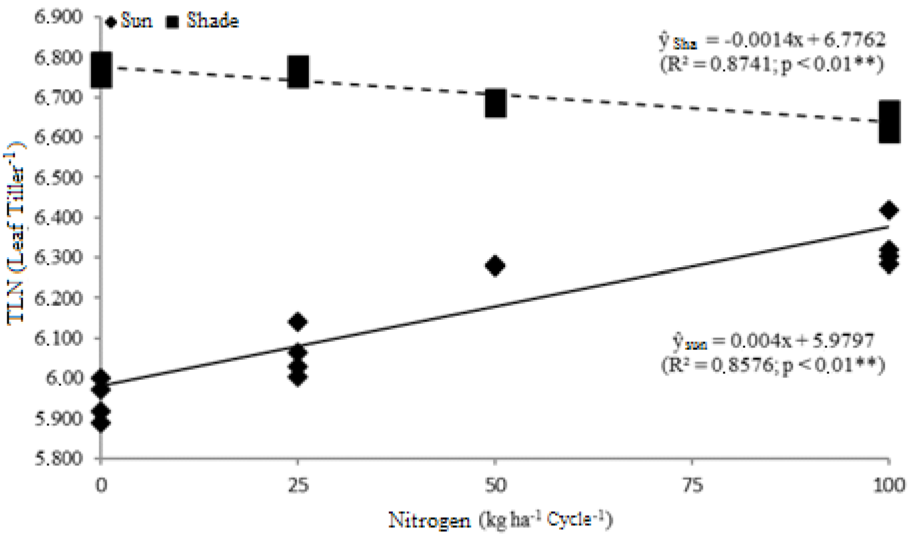

Figure 2. Number of total leaves (NTL) in Mombasa grass, sun and shaded grown (25%) under nitrogen levels in six cycles. ** Significant at the 1% probability level.

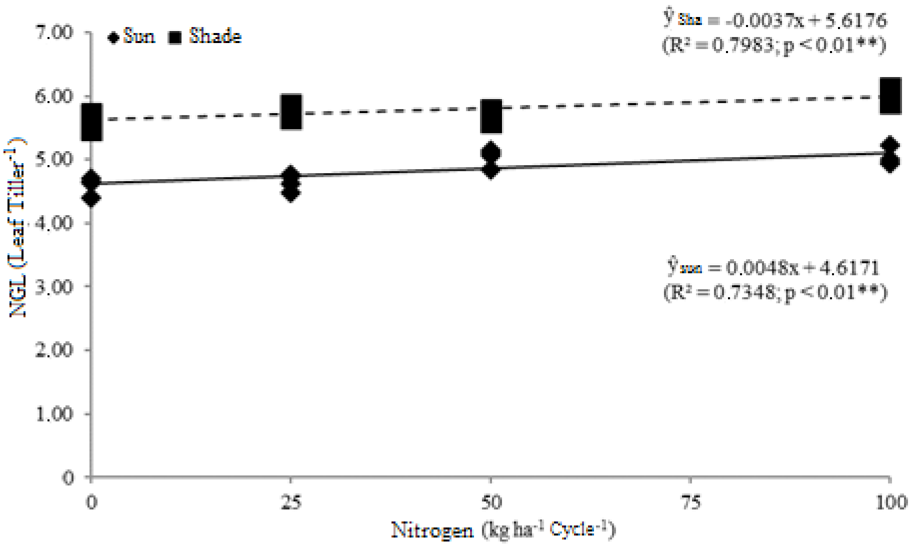

Figure 3. Number of green leaves (NGL) in Mombasa grass, in full-sun and shade (25%) under nitrogen levels in six cycles. ** Significant at the 1% probability level.

the overall mean of NGL.

Nitrogen is an important supporter of photosynthetic activities and in the formation of new stem and in special, leaf tissues. The increase in nitrogen supply generates a direct increase in the number of green leaves and total leaves as shown in the full sun area (COSTA *et al*., 2016). On the other hand, the higher nitrogen availability will raise the growth rate of the plant, which will elongate the stem which will shade the leaves, resulting in their senescence, thus, this issue becomes critical when in shaded system, enhancing the effects of the shade and reducing the number of green total leaves as the doses are increased (RODRIGUES *et al*., 2017).

In other studies, the minimum and maximum NGL is 3.95 to 5.33 leaves tiller^{-1} (MACEDO *et al*., 2010); 2.33 to 3.08 leaf tiller^{-1} (POMPEU *et al.*, 2010). However, maximizing the number of green leaves per tiller is a criterion for defining pasture management (OLIVEIRA *et al*., 2000).

The average number of dead leaves (NDL) in the six cycles in full sun environment, estimated by the regression equation, was significant ($p < 0.001$), linear model, where nitrogen supply (1 kg ha^{-1} cycle^{-1}), promoted a reduction of 0.003 leaf tiller^{-1}, ranging from 1.4024 to 1.1024 leaf tiller^{-1} (Figure 4).

In natural shading environment, the NDL mean was significant ($p < 0.001$), linear model, and each kilogram of nitrogen provided a reduction of 0.004 leaf tiller^{-1}, ranging from 1.1279 to 0.7279 leaf tiller^{-1} (Figure 4).

The full sun environment resulted in the death of 24.86% of leaves compared to the shading (NDL overall mean 1.2692 and 0.9537 leaf tiller $^{-1}$, full sun and shade, respectively). The increment in the proportion of green leaves in a tiller is a primordial factor and widely desired parameter for an appropriate grazing management, aiming to obtain increments in the animal performance (ESCARELA, *et al*., 2017).

In another study, the NDL ranged from 0.45 to 3.55 leaf tiller^{-1} (MACEDO *et al*., 2010).

The average leaf life span (LLS) in the six full-sun environment cycles, estimated by the regression equation was significant ($p < 0.001$), linear model, where nitrogen supply (1 kg ha^{-1} cycle $^{-1}$), promoted a reduction of 0.0673 days, ranging from 58.233 to 51.503 days (Figure 5).

In natural shading, the LLS mean was significant ($p < 0.001$), and each kilogram of nitrogen provided a reduction of 0.0615 day, ranging from 55.216 to 49.066 leaf cycle^{-1} (Figure 5).

The full sun environment outperformed the

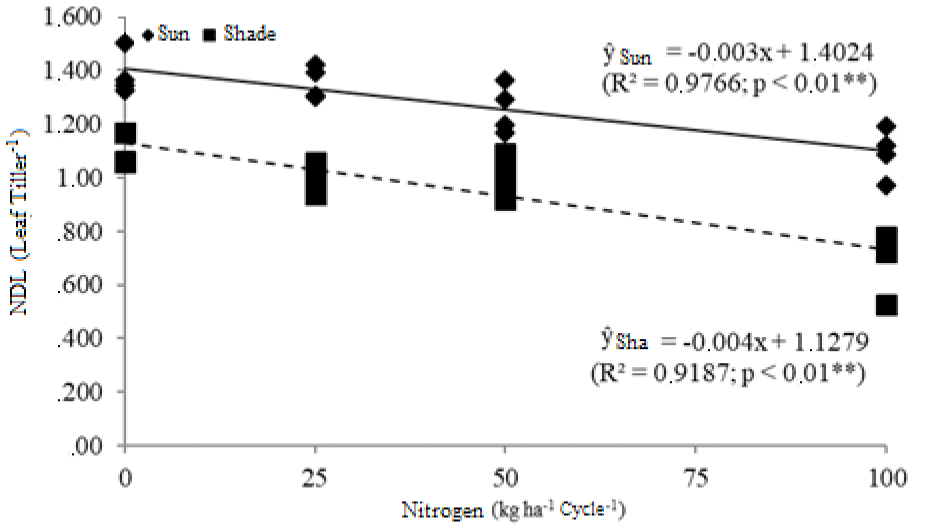

Figure 4. Number of dead leaves (NDL) in Mombasa grass grown in full sun and natural shade (25%) under nitrogen levels in six cycles. **Significant at 1% probability level.

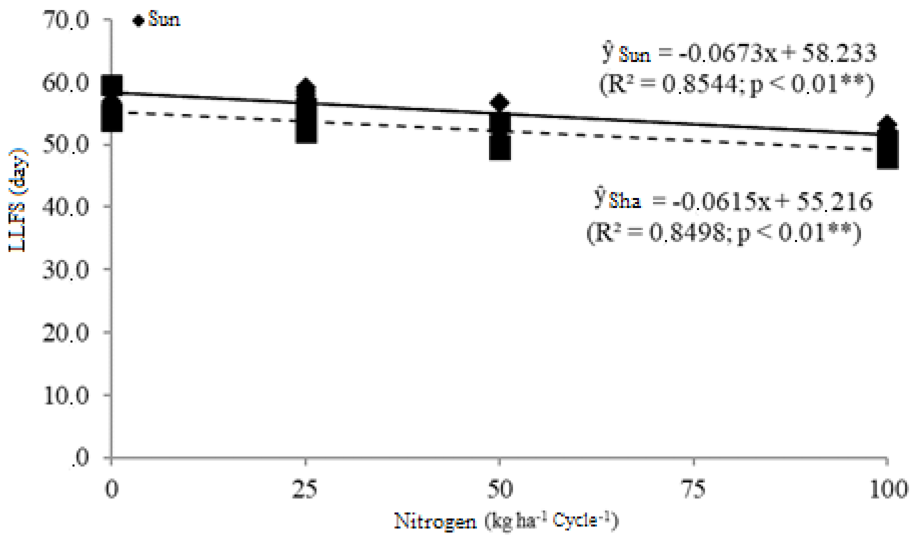

Figure 5. Leaf life span (LLS) in Mombasa grass grown in full sun and natural shading (25%) under nitrogen levels in six cycles. ** Significant at the 1% probability level.

shading by 5% on days of leaf span, (overall LLS mean 55.2905 and 52.5264 days for full sun and shade environments, respectively).

The mean of the sheath length (SL) in the six cycles in the full sun environment, estimated by the regression equation, was significant ($p < 0.001$), linear model, where nitrogen supply (1 kg ha^{-1} $cycle^{-1}$) promoted an increase of 0.7834mm $tiller^{-1}$, ranging from 199.94 to 278.28mm $tiller^{-1}$ (Figure 6).

In natural shading treatment, the SL mean was significant ($p < 0.001$), linear model, and each kilogram of nitrogen allowed an increase of 0.6195mm $tiller^{-1}$, ranging from 297.99 to 359.94mm $tiller^{-1}$ (Figure 6).

The shaded environment elongated the sheath by 27.96% over full sun (234.21 and 325.09 mm $tiller^{-1}$, full sun and shaded environments, respectively, considering the overall mean of the SL).

Other works report the minimum and maximum SL of 296.97 to 758.97 mm $tiller^{-1}$ (MACEDO *et al*., 2010); 156.3 to 166.8 mm $tiller^{-1}$ (POMPEU *et al*., 2010).

The phyllochron in the full sun environment, estimated by the regression equation, was unfolded into a quadratic model ($p = 0.0179$), reaching the minimum point of 10.858 day $leaf^{-1}$ with the application of 79 kg ha^{-1} $cycle^{-1}$ of Nitrogen (Figure 7).

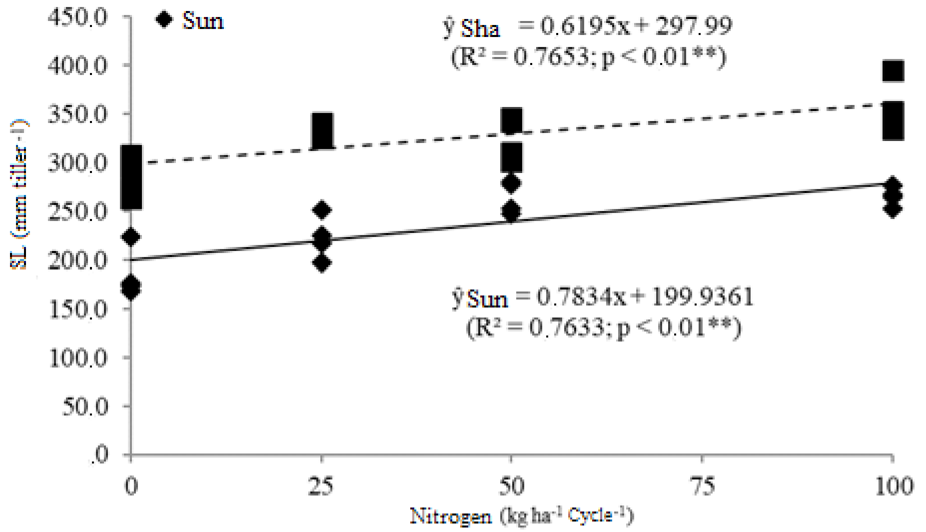

Figure 6. Sheath length (SL)in Mombasa grass grown in full sun and natural shade (25%) under nitrogen levels in six cycles. **Significant at 1% probability level.

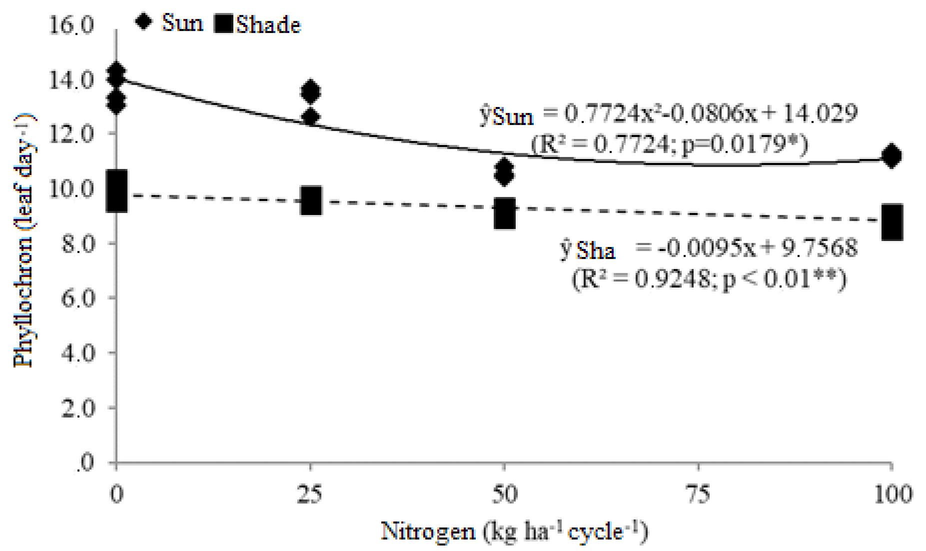

Figure 7. Phyllochron (PHYL), in Mombasa grass, grown in full sun and natural shading (25%) under nitrogen levels in six cycles. ** Significant at the 1% probability level.

In relation to the smallest phyllochron estimated in full sun, the natural shading promoted an average reduction of 13.97% in the number of days to form two successive leaves (mean of 9.34 day leaf^{-1} in the shade).

In other studies, the minimum and maximum PHYL was 10.27 to 19.70 day leaf^{-1} (MACEDO *et al.*, 2010); 12.56 to 19.68 day leaf^{-1} (POMPEU *et al.*, 2010).

The leaf appearance rate (LApR), in the six cycles in the full sun environment, estimated by the regression equation, was linearly significant ($p < 0.001$), where the nitrogen supply (1 kg ha^{-1} cycle^{-1}) promoted an increase of 0.0002 leaf tiller^{-1}day^{-1}, (Figure 9).

In natural shading, LApR was linearly significant ($p < 0.001$), and each kilogram of nitrogen allowed an increase of 0.0002 leaf tiller^{-1} day-1 leaf, ranging from 0.1114 to 0.1314 leaf tiller^{-1} day^{-1} (Figure 8).

The shaded environment provided LApR of 11.45% higher than the full sun (0.106 and 0.1197 leaf tiller^{-1}day^{-1}, full and shaded environments, respectively considering the overall mean of LApR). The rate of leaf appearance is a function of genotype and the influence of environmental factors, so the increase in the appearance of new leaves under shade is a result of the effects of Mombasa grass adaptation to this type of environment (OLIVEIRA *et al.*, 2017).

Masturcello *et al.* (2015) found similar results for leaf appearance rate. The authors found 0.8 leaves per tiller day^{-1} to 80 kg ha^{-1} nitrogen.

The leaf elongation rate (LER) in the full sun environment, estimated by the regression equation, was significant ($p = 0.0183$), reaching the maximum LER of 60.45 mm tiller^{-1}day^{-1}, with application of 68 kg ha^{-1} cycle $^{-1}$ of Nitrogen (Figure 9).

In the shade environment, LER mean was significant ($p = 0.0281$), quadratic model, estimating the maximum LER of 98.72 mm tiller^{-1}day^{-1}, with application of 64 kg ha^{-1} cycle^{-1} of Nitrogen (Figure 9).

Shade provided better conditions for leaf elongation, exceeding the full sun by 38.77%, considering the maximum LER of the environments.

In other studies, the minimum and maximum LER were 25.03 to 70.86 mm tiller^{-1} day^{-1} (MACEDO *et al.*, 2010); 1.51 to 25.6 mm tiller^{-1}day^{-1} (POMPEU *et al.*, 2010); 22.55 to 64.55 mm tiller^{-1} day^{-1} (ALEXANDRINO *et al.*, 20110.

Leaf senesce rate (LSR) was not significant ($p \geq 0.05$), and showed an overall mean of 9.4638mm tiller $^{-1}$day^{-1}, for full-sun and shade environments (Table 2).

The leaf senescence rate (LSR) was not significant ($p \geq 0.05$), and presented an overall mean of 9.4638mm tillers^{-1} day^{-1}, both for full sun and natural shading (Table 2).

The stem elongation rate (SElR) in the six cycles of the full sun environment, estimated by

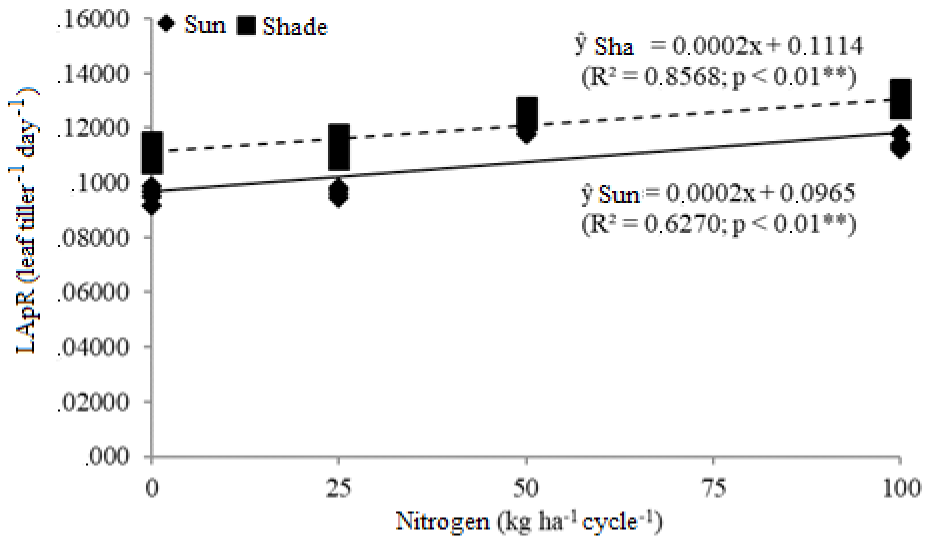

Figure 8. Leaf appearance rate (LApR), in Mombasa grass grown in full sun and natural shading (25%) under nitrogen levels in six cycles. ** Significant at the 1% probability level.

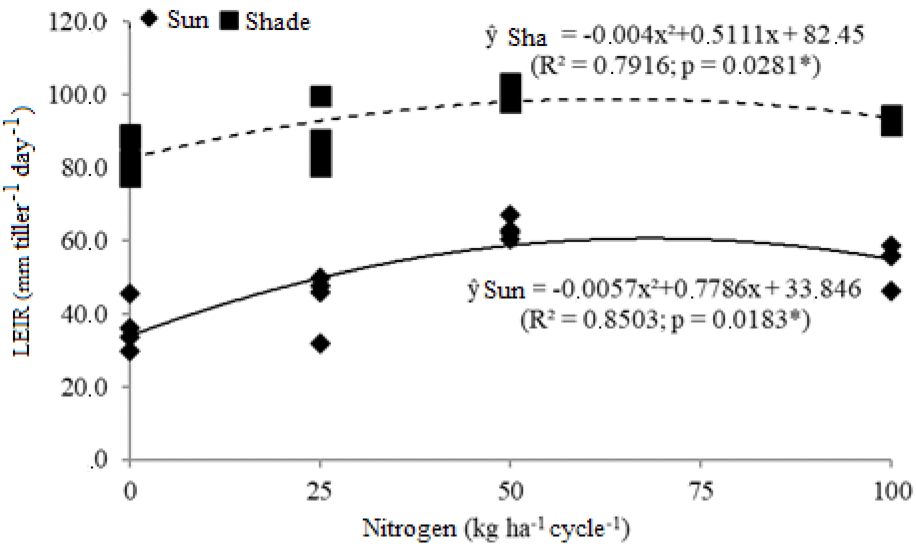

Figure 9. Leaf elongation rate (LElR), in Mombasa grass grown in full sun and natural shading (25%) under levels of nitrogen in six cycles. **Significant at 1% probability level.

Table 2. leaf senescence rate (LSR) of Mombasa grass grown in full sun and shading under nitrogen levels

Treatment	Nitrogen (kg ha^{-1} cycle $^{-1}$)					p	CV (%)
	0	25	50	100	Mean		
	LSR (mm tiller $^{-1}$day^{-1})						
Full sun	8.6883	8.9205	10.673	9.957	9.5602	≥0.05^{ns}	20.06
Shade*	9.2353	8.7269	10.228	9.2811	9.3675	≥0.05^{ns}	26.98

* Natural shading (25%). CV = coefficient of variation. ^{ns}Not significant by the test of Tukey at 5% probability (p).

the regression equation, was significant (p <0.001), linear model, where nitrogen supply (1 kg ha^{-1} cycle^{-1}) , increased by 0.0244 mm tiller^{-1} day^{-1}, ranging from 1.4415 to 3.8815 mm tiller^{-1} day^{-1} (Figure 10).

In natural shading, SElR was significant (p <0.005), linear model, and each kilogram of nitrogen allowed an increase of 0.0316 mm tiller^{-1} day^{-1}, ranging from 4.7457 to 7.9057 mm tiller-1 day^{-1} (Figure 10).

In other studies, the minimum and maximum SELR were 1.93 and 13.00 mm tiller^{-1} day^{-1} (MACEDO *et al*., 2010); 0.2 to 0.95 mm tiller^{-1} day^{-1} (POMPEU *et al*., 2010), 0.79 to 19.69 mm tiller^{-1} day^{-1} (ALEXANDRINO *et al*., 2011).

The stem elongation rate and leaf elongation rate are variables directly related to forage yield. In addition, they are associated with each other. Leaf elongation is directly influenced by the increase in sheath length; therefore, its full expansion is only reached with the externalization of the ligule. When the plant stimulates the stem and the sheath, the leaf limb will need to go through a longer path for its exposure, which leads to an increase in its rate of expansion which is common in shaded environments (SILVA *et al*., 2009).

In other studies, the minimum and maximum LSR were 3.40 to 30.04 mm tiller^{-1} day^{-1} (MACEDO *et al*., 2010); 14.96 to 35.54 mm tiller^{-1}day^{-1} (ALEXANDRINO *et al*., 2011).

The average leaf blade length (ALBL), in the six cycles in the full sun environment, estimated by the regression equation, was significant (p <0.001), linear model, where the nitrogen supply (1 kg ha^{-1} cycle^{-1}) promoted an increase of 0.7963 mm, ranging from 291.50 to 371.13 mm (Figure 11).

In natural shading, ALBL was not significant (p ≥ 0.05), presenting an overall mean of 417.93 mm (Figure 11).

In relation to maximum ALBL in full sun, the shaded environment provided a 11.20% higher shaded environment than that of full sun.

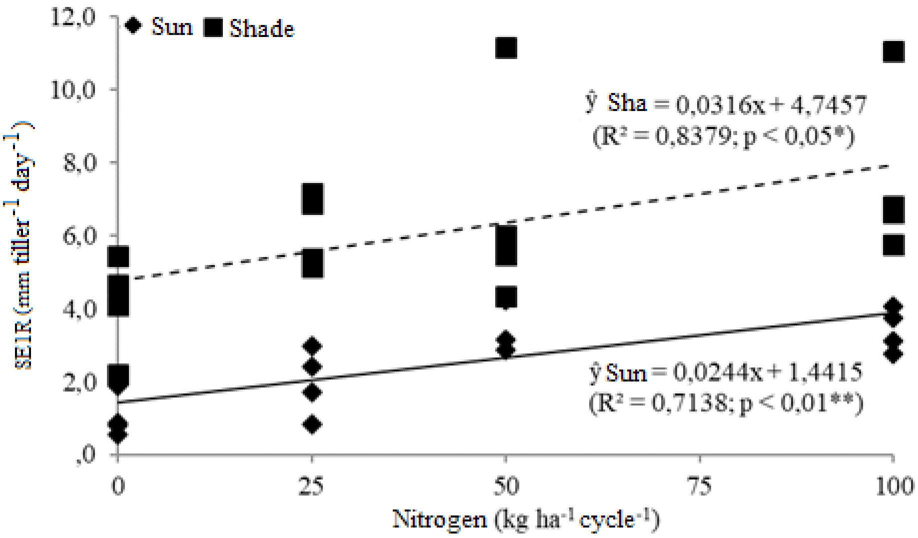

Figure 10. Stem elongation rate (SElR) in Mombasa grass grown in full sun and natural shading (25%) under nitrogen levels in six cycles. ** * Significant at the 1% and 5% probability level, respectively.

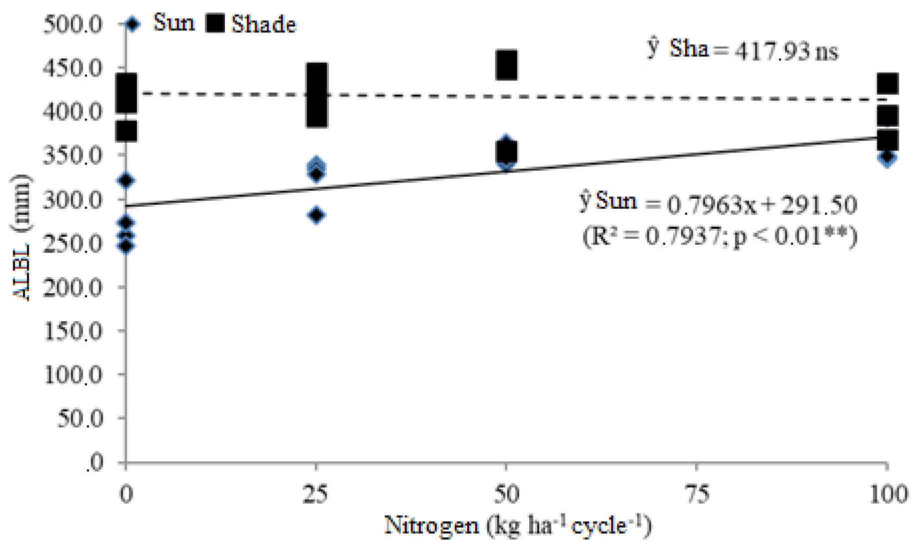

Figure 11. Average leaf blade length (ALBL) in Mombasa grass, grown in full sun and natural shading (25%) under nitrogen levels in six cycles. ** Significant at the 1% probability level.

Other studies reported a leaf limb length from 296.57 to 515.79 mm (MACEDO *et al.,* 2010). The average leaf length of Mombasa grass under shading is longer and little affected by the nitrogen doses. Under the condition of light restriction, the forages tend to break the stem and consequently the sheath, thus, the leaf blade length is also longer.

The leaf area index (LAI), in the six cycles of the full sun environment, estimated by the regression equation, was significant ($p < 0.001$), linear model, where the nitrogen supply (1 kg ha^{-1} $cycle^{-1}$), promoted an increase of 0.0326, ranging from 5.3941 to 8.6554 (Figure 12). In natural shading, LAI was significant ($p < 0.001$), linear model, and each kilogram of nitrogen allowed an increase of 0.0167, ranging from 4.3242 to 5.9942 (Figure 12).

The result demonstrates that within the ability of C4 plants to produce higher temperature and light supply, the light restriction caused limitations in its uptake by the aerial part of the plant, therefore reducing the photosynthetic rate and consequently the CO_2 metabolization. Additionally, the shaded

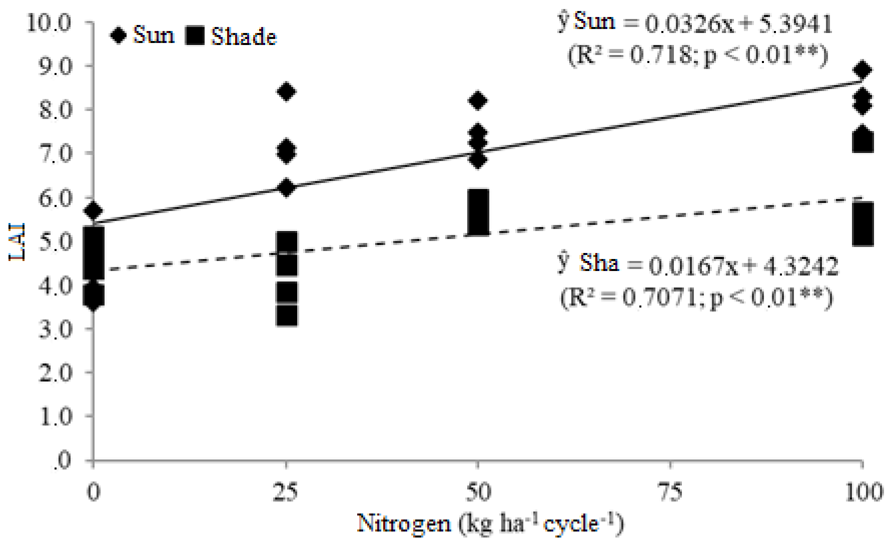

Figure 12. Leaf area index (LAI) in Mombasa grass, grown in full sun and natural shading (25%) under nitrogen levels in six cycles. ** Significant at the 1% probability level.

system has greater nutrient increase in the soil due to the greater nutrient cycling, which allows reducing the load of the external nutrient demand (SANTO *et al*., 2018).

CONCLUSIONS

- Regarding the productive performance and morphophysiological parameters of Mombasa grass under both systems, the recommended dose for shading at 25% shade and full sun should be 25 kg ha^{-1} and 100 kg ha^{-1} nitrogen, respectively.

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