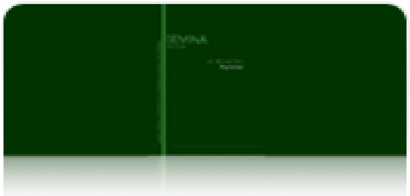

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Morphogenesis and structure of mombassa grass over different growth periods

Morfogênese e estrutura de capim-mombaça durante o estabelecimento

Marcio Odilon Dias Rodrigues[1*]; Antonio Clementino dos Santos[2]; Marcos Odilon Dias Rodrigues[1]; Rubens Ribeiro da Silva[3]; Otacilio Silveira Junior[1]

Abstract

This study aimed to evaluate the effect of nitrogen (N) fertilizer doses on morphogenic and structural characteristics of mombassa grass (*Panicum maximum* Jacq.) at three different periods of the lifespan of tillers. The experiment was conducted in Araguaína-TO, Brazil, from December 2014 to February 2015. It was installed in split plots in a randomized block design with four replications. The doses of N-fertilizer (0, 30, 60, 90 kg N.ha^{-1}) were the plots and the periods evaluated (1PER – first period from day 16 to 30; 2PER from day 31 to 45 and 3PER from day 46 to 60 after germination) were the subplots. The evaluated variables consisted of leaf appearance rate (LAR), leaf elongation rate (LER), stem elongation rate (SER), leaf senescence rate (LSR), phyllochron, tiller number, leaf emergence, and total leaf number. A Pearson correlation analysis was used to morphogenic and structural characteristics along with a regression analysis for all the variables. Overall, increasing N-fertilizer doses positively influenced the leaf appearance and leaf elongation rates, tiller density, and the number of live leaves per tiller. The 90-kg N.ha^{-1} dose enabled the best morphogenic and structural responses of the forage when compared to the other rates. Each period featured differently, with higher values of LSR, SER, and LER in 3PER when compared to those in 2PER and in 1PER. Therefore, the nutritional supply over the first weeks of tiller lives was defining to an increase in forage production in the remaining periods. In light of this, we observed that as LAR raise in the first days after germination, nutritional supplies are required from day 15 on, mainly nitrogen, so plants could continue their development since initial plant growth determines pasture productive vigor and longevity.

Key words: leaf appearance; tiller; (*Panicum maximum* Jacq.); growth period.

Resumo

Objetivou-se avaliar o efeito de doses de N-fertilizante sobre as características morfogênicas e estruturais no período de estabelecimento do capim-mombaça (*Panicum maximum* Jacq.) em três períodos da vida do perfilho. O experimento conduzido em Araguaína-TO de dezembro de 2014 a fevereiro de 2015, foi instalado em parcelas subdivididas em um delineamento de blocos casualizados, com quatro repetições, sendo as doses de N-fertilizante (0, 30, 60 e 90 kg N.ha^{-1}) a parcela e os períodos avaliados (1°PER- primeiro período do 16º ao 30º; 2°PER- segundo período do 31º ao 45º e 3°PER- terceiro período do 46º ao 60º dia pós germinação) a subparcela. Avaliou-se a taxa de aparecimento foliar (TApF), taxa de alongamento foliar (TAlF) e colmo (TAlC), taxa de senescência foliar (TSF), filocrono, número de perfilhos, surgimento de folhas e o número de folhas totais. Foi utilizada uma análise de correlação

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de Pearson entre as características morfogênicas e estruturais e, também, análise de regressão para todas as variáveis avaliadas. O incremento das doses de nitrogênio influenciou positivamente as taxas de aparecimento foliar, alongamento foliar, densidade de perfilhos e no número de folhas vivas por perfilho. A dose de 90 kg N.ha^{-1} possibilitou o melhor desenvolvimento morfogênico e estrutural da planta, quando comparada as demais doses; durante o período de estabelecimento foi identificado características diferentes da planta ao longo dos períodos, com maior TSF, TAlC e TAlF no 3°PER, quando comparado o 2°PER e 1°PER. Portanto, pode-se afirmar que o aporte nutricional nas primeiras semanas de vida do perfilhos foram determinantes para o aumento na produção de forragem nos demais períodos avaliados. Diante disto, conclui-se que a planta ao intensificar a TApF nos primeiros dias pós germinação, necessita, a partir do 15° dia, de fontes nutricionais para continuar a desenvolver-se, principalmente de nitrogênio, visto que o adequado crescimento inicial da planta determina o vigor produtivo do pasto e sua longevidade.

Palavras-chave: Aparecimento foliar. Perfilho. (*panicum maximum Jacq.)*. Período de estabelecimento.

Introduction

In the Amazon region, poorly developed pastures show reduced productivity over the first years of growing, mostly because of overgrazing, none or insufficient nutrient replenishment, and inadequate forage species for the local edaphoclimatic conditions (JUNIOR et al., 2013). Mombassa grass, a perennial forage of caespitosus growth, is characterized by its high mass production (yield) and good nutritional quality. Thus, it is used in intensive systems, especially in rotational management, where intense flows of dry matter exportation occur by grazing. Therefore, the use of a high production grass (e.g. mombassa) requires soil nutrient maintenance and adequate management. These measures must begin at the implementation stage, considering the strong demand for maintenance of productivity.

Pasture growth is of extreme importance for a good canopy closure, with phenotypes formed by vigorous tillers capable of maintaining themselves in the vegetal community. It should be stressed that the initial management aims to ensure sprouting in the posterior cycles, increasing pasture productivity with high-quality dry matter and forage-use efficiency and, simultaneously minimizing losses by senescence (LOPES et al., 2013). Nitrogen management throughout fodder growth promotes an increase in biomass, defining leaf appearance and elongation as fundamental components for the phenotypic plasticity of tillers. This concept is also valid for the entire plant community generating new tillers (SANTOS et al., 2014; PEREIRA et al., 2011).

Morphogenic variables, which directly contribute to leaf biomass, assume a proven importance since the tiller portion, which is represented by the foliar tissues, constitutes the fraction of greater qualitative attributes. Consequently, it becomes the favorite component for grazing animals. In this sense, edaphoclimatic and management conditions may determine each tiller component responses, which, in turn, drive the flow of produced biomass. Leaf elongation rate (LER) stands out among the morphogenic components for being directly associated with plant tissue synthesis. Therefore, LER elevates leaf proportion and, consequently, increases photosynthetically active foliar area, thus intensifying forage accumulation (LOPES et al., 2014).

Over the growth period, the community of tillers is influenced by abiotic factors (nitrogen fertilization, temperature, and management). However, other factors should be considered to determine the components influencing the development of a community of tillers, such as intra and interspecific competition for nutrients, especially when nutrients are scarce in the soil and in the plant tissues (SHIPONENI, 2014). In fact, during this period, tiller undergoes alterations in its morphogenic characteristics, through abiotic and genetic factors, as the plant ages. The nitrogen fertilization effect can be observed in the characteristics of the main morphogenic components (LER, LAR, SER, and LSR) between two types of tillers (main and primary); causing a differentiated development among tillers of different ages (LOPES et al., 2014).

Several studies have evaluated the effect of nitrogen application on morphogenic and structural characteristics of pastures but only a few of them assess tiller growth dynamics. Regarding the aforementioned facts, one can highlight that studying the effect of N-fertilizer on morphogenic and structural characteristics at different tillering stages becomes of great importance, as it enables researchers to determine the effect of N on tillers during their first 60 days of life. Therefore, this study aimed to evaluate the effect of N-fertilizer doses on morphogenic and structural characteristics over the growth of mombassa grass, assessing three distinct tillering stages.

Material and Methods

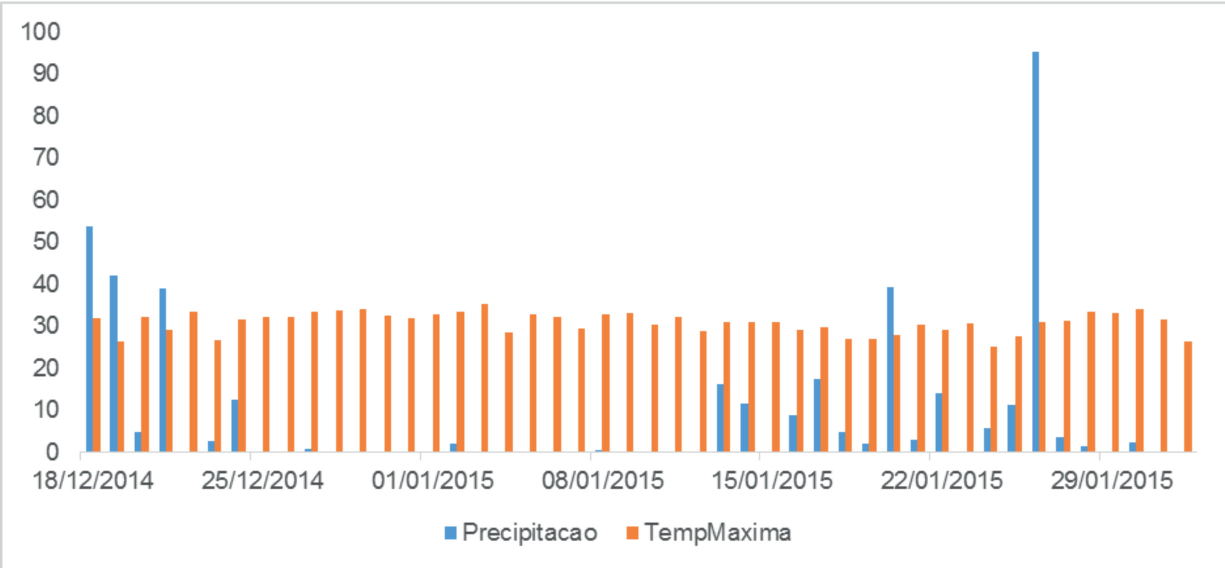
The experiment was conducted at the Federal University of Tocantins, which is in the city of Araguaína, Tocantins state - Brazil, from December of 2014 to February of 2015. The experimental area is located at the following geographic coordinates: 7° 6' 16" S and 48° 12' 3" W. The local climate is classified as AW (hot and humid), with well-defined seasons, average annual rainfall of 1800 mm and annual temperature of 25 ºC. The soil is classified as a typical Orthic Quartzarenic Neosol (Typic Quartzipsamment).

Eleven kg.ha^{-1} of *Panicum maximum* (Jacq.) pure viable seeds were sown on November 27, 2014. This experiment lasted for 60 days after germination, including plant stabilization period. Evaluations started on December 20, 2014 (15 days after emergence) and ended on February 1, 2015 (a total of 45 days). During this period, no standardization cutting was performed, i.e. continuous growth of mombassa grass was maintained during the stabilization period.

Treatments consisted of four nitrogen doses(0, 30, 60, and 60 kg ha^{-1}) during three evaluation periods in a split plot scheme, where the plots represented the doses and the subplots the periods, with 4 replications, totalizing 48 experimental units of 8 m^2 each. The periods were determined as follows: first period (1PER) (from day 16 to 30 after germination), second period (2PER) (from day 31 to 45 after germination), and third period (3PER) (from day 46 to 60 after germination). Phosphate fertilizations were carried out at sowing using simple superphosphate, aiming to raise P level to 20 ppm. Potassium fertilization was conducted 15 days after germination, using potassium chloride, to increase the level of K_2O in the soil to 30 ppm. Potassium fertilizer was applied along with ammonium sulfate as nitrogen fertilizer. This nitrogen source contains 21 and 28% nitrogen and sulfur in its composition, respectively, what characterizes it as a nutrient complex. Additionally, the chemical characteristics of the soil were analyzed before the experiment implementation as follows: pH ($CaCl_2$) 5.5, P (mg dm^3) 0.96, K (Cmol$_c$ dm^3) 5.0, Mg (Cmol$_c$ dm^3) 1.5, Al (Cmol$_c$ dm^3) 0.21, H + Al 4.3, S (Cmol$_c$ dm^3) 8.3, CEC (Cmol$_c$ dm^3) 12.6, and V (%) 65.0.

Six tillers were identified in each of the experimental units. Tillers were visually chosen to represent the community of plants in each experimental unit. Each tiller was identified by a ring of a specific color for posterior monitoring. Every three days, tillers were measured for the final length of expanded and emergent leaves, the senescent fraction of expanded leaves, and the number of live leaves per tiller. These evaluations began on the 15th day after tillers emerged. Figure 1 displays the weekly results of maximum temperature and rainfall during the experimental period.

Figure 1. Maximum temperature and weekly-accumulated rainfall during the experimental period.



Leaf appearance, pseudostem length, expanded and growing leaf blade lengths, number of leaves per tiller, number of living, dead, and senescing leaves were measured (OLIVEIRA, 2007). We also assessed the elapsed time between the appearance of two consecutive leaves (phyllochron: day leaf^{-1}), leaf appearance rate (LAR: tiller leaves day^{-1}), leaf elongation rate (LER: mm day^{-1}), stem elongation rate (SER: mm day^{-1}), and leaf senescence rate (LSR: mm day^{-1}). Regarding structural characteristics, we evaluated the days of leaf life (DLL) and the number of tillers per square meter (m^2) by a nondestructive counting of tillers within a metal frame (0.5-m^2).

The statistical analysis was performed according to the following criteria and methods: regression analysis for the fitting of linear and quadratic models, variance analysis (ANOVA) for analysis of the behavior of variables separately throughout time (three periods). The comparison test for repeated measurements was applied to identify which period differs with each other. In addition, the variance analysis for repeated measurements was used to determine statistical differences throughout time for the tested doses. The significance levels were of 5 and/or 1%. The statistical analyses were processed using the software SAS 6.04 (SAS Institute, Inc., Cary, NC, USA).

Results and Discussion

The doses of N fertilizer influenced LAR values ($P<0.05$), as well as an interaction ($P<0.01$) between N doses and periods in all periods except for 3PER. In 2PER, the lowest LAR was of 0.10 tiller leaves. day^{-1} for the 0-kg.ha^{-1} dose; yet in 2PER, the highest LAR was of 0.29 tiller leaves.day^{-1} for the 90- kg.ha^{-1} dose (Table 1). In the present study, the highest doses obtained results superior to those found in the literature. Patês et al. (2007), studying nitrogen effects on Tanzania grass, observed significant results (0.17 leaves.day^{-1}) by applying 100 kg.ha^{-1}. Additionally, Masturcello et al. (2015), assessing the effect of nitrogen doses on massai grass in the northeastern region of Brazil, reported a LAR of 0.8 leaves.tiller^{-1} for a rate of 80-kg.ha^{-1}. According to the authors, these inferior results might have occurred due to little rainfall, typical of that region, what directly influences plant morphogenesis. On the other hand, the northern region of Brazil has high rainfall rates for the studied period here.

When comparing the highest dose with control (no fertilization), LAR reductions of 41.37, 33.33, and 21.42% were observed in the first, second, and 3PERs, respectively. Such fall can be found in studies on brachiaria grass, being of 26 and 23% when comparing no soil fertilization with 240 and 300 kg.ha^{-1} of N-fertilizer, respectively (GOMES et al., 2012). According to Teixeira et al. (2014), nitrogen promotes the synthesis of new cells, which results in the appearance of new leaves. Similarly, Gomes et al. (2012) reported that N-fertilizer provides a positive and linear increase in LAR during the germination of *Brachiaria ruziziensis*, resulting in 0.21, 0.26, and 0.39 leaves day^{-1} for 0, 200, and 200 kg.ha^{-1} N rates, respectively.

Table 1. Leaf appearance rate (LAR) (leaf.tiller^{-1}) and stem elongation (SER) (mm.day^{-1}) of Mombaça grass as a function of nitrogen fertilizer doses.

Variable		Treatments				Equations	R^2
		0	30	60	90		
		kg de N.ha^{-1}					
LAR	1°	0,17Ac	0,24Ab	0,26Aab	0,29Aa	$\hat{y} = 0,1854 + 0,001284N$	0,91
	2°	0,10Bb	0,12Bab	0,15Ba	0,15Ba	$\hat{y} = 0,107 + 0,0006N$	0,88
	3°	0,11Ba	0,12Ba	0,12Ba	0,14Ba	y = 0,12	-----
SER	1°	2,08Cb	4,36Cab	5,05Ca	3,89Cab	y = 3,85	-----
	2°	0,72Bb	1,39Bb	2,06Bab	4,57Ba	$\hat{y} = 0,7204+0,038N$	0,75
	3°	3,61Ad	6,43Ac	9,26Ab	12,0Aa	$\hat{y} = 3,6101+0,0943N$	0,86

R^2: coefficient of determination; 1st: first period; 2nd: second period; 3rd: third period. Lowercase letters in the lines and uppercase letters in the columns differentiate at 5% and 1% significance.

SER was influenced by the evaluated periods (P<0.01) and doses of N-fertilizer (P<0.05) (Table 1), presenting interaction between PER and N-doses (P<0.01). Contrarily, in 1PER, tillering stage had only a slight influence on SER. The highest results for SER (12.0 mm.day^{-1}) were found when the 90-kg dose was applied during 3PER. The same trend was seen for the other N rates, presenting 9.26, 6.43, and 3.61 mm.day^{-1} for doses of 60, 30, and 0 kg N.ha^{-1}, respectively. For the post-germination period, SER is not considered an important factor for management, however, as the tillers develop, it becomes an important factor to be controlled through management, as observed in the stem elongation dynamics between 1PER, characterized by lower results, and the third period, characterized by lower results.

LER values were higher in 3PER (19.23 and 28.02 mm day^{-1}) for the doses of 60 and 90 kg N.ha^{-1}, respectively (Table 2). The over performance of higher nitrogen doses can be associated with an increased release of nitrogen to plants, altering N flow within plant tissues and, consequently, LER and SER values (NETO et al., 2016). This outcome might occur due to the synthesis of structural macromolecules and enzymes, which act in tissue regeneration (SILVA et al., 2013). Conversely, the greater LER had no effect on LAR during this period, especially because of the increase in LER, 9.26 and 12 mm.day^{-1}, for doses of 60 and 90 kg N.ha^{-1} in 3PER, respectively. LER directly affects LAR; however, the increase of N in the soil also influences the increase of SER, which may not promote the increase of LAR because of counterbalance from increases in the sheath base (ALEXANDRINO et al., 2010).

As shown in Table 2, the lowest LER results occurred in 2PER, 4.77, 6.09, and 7.4 mm.day^{-1} for the doses of 0, 30, and 60 kg N.ha^{-1}, respectively. Regardless of the assessed dose, lower LER values were obtained in 2PER, to the order of 59.8 and 63.5% when compared to 3PER and 2PER, respectively. Distinct LER results were presented for each period, highlighting the tillering stage influence on the reductions of this variable. At 15 days of age, plants are growing intensively with high water absorption and relative growth. However, at about the 30th day, the allocation of substrates to leaf growth decreases; yet from the 45th to the 60th day after germination, LER values are larger if compared to the second period. This can be explained by the higher numbers of tillers (Table 3) and total leaves (Table 4), encouraging the plant to elongate its photosynthetically active tissues to increase light absorption, which is deficient in basal leaves. Medica et al. (2017), who made a morphological characterization of Marandu grass pastures under various defoliation frequencies, found similar results. According to these authors, N increases the photosynthetic efficiency and stimulates stem and leaf elongations. They also affirmed that longer cut intervals keep stem length unchanged since plants grow freely for an extended period. Additionally, older tillers elongate their stems to sustain heavier weight, reducing plant lodging. According to Gomide et al. (2003), who studied the development of mombassa grass at three distinct periods: seminal growth (C1), regrowth after cutting at day 16 (C2) and at day 37 (C3). These authors noted that the cutting on day 16 had no effect on LER; however, on the day 37, this rate decreased. On the other hand, LAR presented different trends according to the same authors.

Table 2. Leaf elongation rate (LER) (mm.day^{-1}) and leaf senescence rate (LSR) (mm.day^{-1}) of Mombaça grass as a function of nitrogen fertilizer doses.

Variable		treatments 0	30	60	90	Equations	R^2
		kg de N.ha^{-1}					
LER	1°	12,39c	17,9ab	17,69^a	14,34bc	ŷ = 14,97	-----
	2°	4,77c	6,09bc	7,4ab	9,80^a	y = 4,7807 + 0,0438N	0,81
	3°	5,52c	15,76bc	19,23ab	28,02a	y = 6,41 + 0,2402N	0,72
LSR	1°	0,29C	1,96C	1,23C	0,31C	ŷ = 0,94	-----
	2°	26,01B	30,51B	29,57B	23,44B	ŷ = 27,38	-----
	3°	39,85^a	34,94A	48,44^a	45,01A	ŷ = 42,06	-----

R^2: coefficient of determination; 1st: first period; 2nd: second period; 3rd: third period. Lowercase letters in the lines and uppercase letters in the columns differentiate at 5% and 1% significance.

In this study, leaf senescence rate (LSR) showed no effect from the applied N-fertilizer, which is in agreement with Lopes et al. (2013) and Lopes et al. (2014). According to Alexandrino (2010), the effect of N on LSR is unclear since it is dependent on plant physiological and endogenous N status. According to the same authors, N mobilization in the basal leaves occurs to benefit of top leaves, which can be explained by N supply inhibition or stimulation, intense shading of basal leaves, N recycling reductions when it is limiting to the plant.

Considering the aforementioned information, the tillering stage affected LSR. In 1PER, lower LSR values were registered, which might have occurred due to a higher contribution of N at the beginning of 1PER; therefore, plants increased their LER and LAR without the need to translocate N from older leaves to the growing shoots, influencing LSR reductions. However, Masturcello et al. (2015) observed a significant increase in LSR as N doses increased. According to these authors, plants facing N scarcity can present low LSR to keep tissues alive as metabolism decreases. Therefore, the death of tissues can influence nitrogen fertilization. However, based on the results obtained in the present research, during the first tillering stage (1PER) (Table 2), the increase in N doses via fertilization, and the intense synthesis of tissues, have no effect on LSR.

TNL (Table 4) was a decisive factor for the increase of LSR in 3PER. From day 45 to day 60 (3PER), the number of leaves per tiller stabilized, increasing leaf senescence. According to Santos et al. (2014), as tillers reach leafing stability, for each new leaf emerged, a totally grown leaf enters senescence. Interestingly, leaf number stability was observed when the canopy was able to intercept 95% incident light, which reduces leaf biomass accumulation and increases both stem and dead matter accumulation rates. Based on this, prolonged regrowth cycle may affect forage mass production, with increments in the stem and senescent material proportion, besides a reduction of leaf tissue fraction (SILVA et al., 2015).

Regarding phyllochron, significance was found in the evaluated periods ($P<0.01$) and in the doses of N-fertilizer. Nevertheless, no interaction was verified between the studied factors. For the regression model, an increasing linear effect was observed for all the evaluated periods ($P<0.05$) (Table 3). Lower phyllochron values (3.32 days.leaf^{-1}.tiller^{-1}) were observed for the 90 kg N.ha^{-1} dose in 1PER. The highest results for phyllochron were observed using the 0 kg N.ha^{-1} dose, being of 6.26, 9.91, and 11.12 days.leaf^{-1}.tiller^{-1} for the first, second, and third periods, respectively. When comparing the doses of 0 and 90 kg N.ha^{-1} in 1PER, the timing for the appearance of one leaf was 82.53% longer for the control. Nitrogen fertilization performed between the months of January and March, when environmental conditions are favorable (adequate temperature and rainfall), was a decisive factor in phyllochron reductions since forage production is inversely proportional to phyllochron values.

The better results of LAR and LER enabled phyllochron reduction when doses of N-fertilizer were increased. Teixeira et al. (2014) reported similar results while studying nitrogen fertilization strategies on *B. decumbens*. The authors found phyllochron results of 16 days.leaf^{-1}.tiller^{-1}, which are superior to the results obtained here. Nonetheless, the elevated rates observed are justified by the adopted management with long resting periods (above 60 days). This management is typical of deferred pasture, which was defining in phyllochron increases if compared to the present study. Therefore, the growth period can influence agronomic characteristics of pasture and, consequently, the period of leaf emergence.

Phyllochron increases started on the day 30, possibly because of an intense elongation of leaf sheaths. This fact is also reported by Santos et al. (2014) while working with different doses of dairy liquid residue (10, 50, 100, 200, and 400 m^2 ha^1) in mombassa grass development. According to these authors, an increase in leaf sheath length resulted in higher phyllochron results. The highest results of phyllochron, between the days 45 and 60 after germination, may have influenced tillering and LAR, which followed the same trend in this period. During autumn, plant density can have a negative impact on phyllochron results, increasing progressively throughout winter. This is mainly due to a higher interval between cuttings and abiotic factors (PEREIRA et al., 2011). In this sense, low rainfall and high temperatures (Figure 1), mainly during the last week of evaluation (01/25/2015 to 02/01/2015) may have influenced the phyllochron increase. Thus, the lack of nitrogen fertilization near the sealing period reduces resprouting speed and consequently, phyllochron increases during 3PER (TEIXEIRA et al., 2014).

The number of living leaves per tiller is defined genetically. For mombassa grass, it is estimated that 4.5 leaves emerge, which determines the optimum point of pasture harvest (SANTOS et al., 2014). Therefore, based on the phyllochron, we can infer that, in 1PER, plants would take 15 days to complete their growth cycle when fertilized with the highest dose (90 $kg.ha^{-1}$). On the other hand, the growth cycle of plants with no fertilization (0 $kg.ha^{-1}$) would take 27 days. In 3PER, these results could be up to 50, 44, 39 and 34 days for the doses of 0, 30, 60, and 90 Kg $N.ha^{-1}$, respectively. This proves the effect of increased N doses and of the tillering stage on the total number of days, it takes to complete a cycle.

An increase in the numbers of tillers took place in 3PER (Table 3) when compared to 2PER and 1PER. The emission of new tillers occurs in detriment to the already existing tillers. This is due to an increase in translocation between these individuals and a reduction in primary-tiller leaf lifespan (SANTOS et al., 2014). Since leaf lifespan is about 64 days (PENA et al., 2009), the increased number of tillers in 3PER influenced LSR increments, in which the basal leaves, i.e. the older leaves, died because of the onset of new tillers. It is important to highlight that in 3PER, leaves were about 60 days old.

For the number of tillers, an influence was verified in all evaluated periods ($P<0.01$) and for the applied doses of N-fertilizer ($P<0.05$), with an interaction between them ($P<0.01$). An increasing linear effect was observed for the second ($P<0.05$) and third periods ($P<0.05$). During the first period, there was significant adequacy to a quadratic model ($P<0.01$) (Table 3). In Table 3, one can observe that, regardless of the evaluated doses, the highest number of tillers was observed in 3PER, being of 750, 617, and 483 for the doses of 90, 60, and 30 kg $N.ha^{-1}$, respectively. These numbers are higher than were those found by Rosado et al. (2016), who studied tillering in mombassa grass under different doses and different sources of nitrogen fertilizer; they reported 350 $tillers.m^{-2}$ when submitted to a 120-$kg.ha^{-1}$dose. According to these authors, tiller density is influenced by several factors such as nitrogen sources and calcium supply, among which the latter is critical to the development of meristems.

Table 3. Phyllochron and tiller number of Mombaça grass as a function of nitrogen fertilizer doses.

Variable		Treatments				Equations	R^2
		0	30	60	90		
		kg de $N.ha^{-1}$					
Phyllochron	1°	6,26Ca	5,15Cb	4,23Cb	3,32Cb	$\hat{y} = 6,2639 + 0,0304N$	0,77
	2°	9,91Ba	8,7Bab	7,6Bbc	6,45Bc	$\hat{y} = 9,917 + 0,0385N$	0,87
	3°	11,12Aa	9,94Aab	8,77Aab	7,59Ab	$\hat{y} = 11,122+ 0,0392N$	0,90
Tiller number	1°	202Cb	238Ca	253Ca	243Ca	$\hat{y} = 202,21+1,6N-0,013N^2$	0,61
	2°	241Bc	287Bbc	332Bab	378Ba	$\hat{y} = 241,36+1,519N$	0,88
	3°	350Ad	483Ac	617Ab	750Aa	$\hat{y} = 350,87+4,452N$	0,76

R^2: coefficient of determination; 1^{st}: first period; 2^{nd}: second period; 3^{rd}: third period. Lowercase letters in the lines and uppercase letters in the columns differentiate at 5% and 1% significance.

The lowest number of tillers was observed when plants received no nitrogen fertilization (control). From 1PER to 3PER, an increase of 148 tillers was observed, which is inferior to the results obtained when plants were applied with the other doses. This fact can be accounted for by the scarcity of N in the soil and in the plant tissues, which affected the onset and development of new tillers, resulting in dry matter and dry pasture recovery reductions after defoliation (SILVA et al., 2013). In these conditions, edaphoclimatic variations and management strategies are insufficient to ascertain tiller production changes. That being said, the lack of N increased competition among tillers, with influences between neighboring plants, which can impose development standards in vegetation (SHIPONENI et al., 2014).

Table 4 shows the number of leaves appearing (NLA). Significant results were observed for the applied N-fertilizer doses (P<0.01) but not for the periods. NLA was superior when plants received 90 kg $N.ha^{-1}$ (6.58 $leaves.tiller^{-1}$), during the three periods, being higher than the results reported by Costa et al. (2016). These authors studied the efficiency of nitrogen for mombassa grass and observed an NLA of 5 $leaves.tiller^{-1}$ when plants were submitted to 100 mg N.kg $soil^{-1}$. Thus, the higher results found here could be associated with the leaf lifespan, which is influenced by nitrogen oversupply in the course of plant growth. Nitrogen is very important for the maintenance of the photosynthetic activity for longer periods, what increased the number of leaves (GARCEZ et al., 2002). Having said that, the use of nitrogen sources during pasture implementation is fundamental to the stimulation of the synthesis of new tissues, which is essential to the perenniality of forage canopy throughout the subsequent cycles. The opposite was observed for the 0-$kg.ha^{-1}$ dose, in which the lowest NLA occurred (4.62 $leaves.tiller^{-1}$) - during the three periods. These results indicate that for every three leaves appearing in the dose 90 kg $N.ha^{-1}$, no leaf onset when 0 kg $N.ha^{-1}$ is applied (Table 4).

Table 4. Number of leaf appearance leaves (NLA) and number of total leaves (NTL) of Mombaça grass as a function of nitrogen fertilizer doses.

Variable		Treatments				Equations	R^2
		0	30	60	90		
		kg de $N.ha^{-1}$					
NLA	1°	1,48Ac	1,79Abc	2,10Aa	2,41Aa	y= 1,4833 + 0,0103N	0,87
	2°	1,60Ac	1,85Abc	2,14Aab	2,35Aa	y = 1,6046 + 0,0083N	0,80
	3°	1,54Aa	1,63Ba	1,72Ba	1,92Ba	ŷ = 1,70	------
NTL	1°	5,33Ca	5,58Ca	5,76Ca	5,83Ca	ŷ = 5,62	------
	2°	6,98Bb	7,39Bb	7,80Ba	8,21Ba	y = 6,9863 + 0,0136N	0,79
	3°	8,53Ac	8,9Abc	9,4Aab	9,91Aa	y = 8,5317 + 0,0154N	0,81

R^2: coefficient of determination; 1st: first period; 2nd: second period; 3rd: third period. Lowercase letters in the lines and uppercase letters in the columns differentiate at 5% and 1% significance.

Pearson linear correlation analysis of phyllochron for morphogenic and structural traits revealed a positive correlation with leaf age (P<0.01) and a negative with leaf appearance (P<0.01) (Table 5). Such results have been already expected because this synchronicity of DLL and phyllochron increases and LAR decrease is due to a longer emergence time between two sequential leaves, as the leaves age. In these conditions, LAR had an inversely proportional relation with DLL. It is worth highlighting that phyllochron also presents an inverse relationship with LAR, as prolongation of phyllochron results in lower LAR. Presumably, it is because plants prioritize stem and leaf elongations. Thereby, morphological studies during the initial tillering stages make evident the importance of a positive grass growth, so that productive vigor can occur in the following cycles. Additionally, the tiller community will determine the perennial nature of pasture production through the tiller density, LAR, LER, and phyllochron reduction.

According to Masturcello et al. (2015), the response of DLL can be better interpreted when analyzed in association with leaf senescence. These authors also reported the existence of a positive correlation between these variables. The same was observed in the present study, as LSR increased along with DLL, presenting a positive correlation of 0.79 (P<0.01) explained by the reaching of maturity by plants. In these conditions, a high portion of N is redirected to younger leaves, reducing significantly photosynthesis in older leaves (GOMES et al., 2012). LSR increased along with the TNL, particularly in 3PER, which was already expected since TNL is a morphogenic variable best correlated with DLL, being crucial to pasture management as it quantifies grass yield (COSTA et al., 2016).

Table 5. Estimates of the coefficients of simple Pearson linear correlation between the studied characteristics.

	DVF	Phyllochron	LAR	SER	TSF	LER	Tiller number	NTL
DVF	1							
Phyllochron	0,92**	1						
LAR	-0,93**	-0,90**	1					
SER	0,12ns	0,05ns	-0,07ns	1				
TSF	0,79**	0,66**	-0,71**	0,48**	1			
LER	-0,16ns	-0,15ns	0,15ns	0,60**	0,16ns	1		
Tiller number	0,43ns	0,27ns	-0,38ns	0,87**	0,72**	0,52**	1	
NTL	0,71**	0,53ns	-0,62**	0,60**	0,83**	0,14ns	0,83**	1

ns: non-significant; *, **: significant at 5 and 1%, respectively, by the t test; DLL: days of leaf life; LAR: leaf appearance rate; SER: stem elongation rate; LSR: leaf senescence rate; LER: leaf elongation rate; NT: number of tillers; and TNL: total number of leaves.

Conclusion

Mombassa grass morphogenic and structural characteristics changed as a function of the nitrogen fertilizer rates. The highest tested dose (90 kg.ha^{-1}) presented the best outcome.

Leaf appearance and stem and leaf elongation rates, as well as phyllochron, are important variables in evaluating pasture growth, being influenced not only by nitrogen supply but also by tiller lifespan. Nitrogen fertilizations between the second and third weeks after germination were determinant for a suitable pasture development, especially when submitted to high doses of N. This can be associated with the period within which plants intensify the synthesis of tissues. Thereby, nitrogen fertilizations near the 15th day of tillering are recommended for mombassa grass growth.

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