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Morphogenic and structural characteristics of Marandu grass cultivated under grazing management and nitrogen fertilization

Características morfogênicas e estruturais do capim Marandu sob estratégias de manejo de pastejo e adubação nitrogenada

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Highlights:

The best results for the rest period were found in the range of 280 to 333 kg ha^{-1} of N.
The dose of 450 kg ha^{-1} of N provided the desired results when using a fixed rest period.
The rest period alleviated the process of senescence, especially given application of higher nitrogen doses.

Abstract

The goal of this study was to evaluate the morphogenic and structural characteristics of Marandu grass cultivated under grazing management and nitrogen fertilization. The experimental design was a completely randomized 4 × 2 split-plot design with four blocks. The treatments consisted of combinations of two rest periods (28 days - RP_{Fixed} - and height of 40 cm - RP_{Var}) and four nitrogen doses (0, 150, 300, and 450 kg N ha^{-1} year^{-1}) applied as ammonium sulfate. The following variables were analyzed: leaf appearance rate (LAR), phyllochron, leaf elongation rate (LER), stem elongation rate (SER), leaf senescence rate (LSR), leaf life span (LLS), average length of leaf blade (ALLB), sheath length (SL), number of live and dead leaves (NLL and NDL), and tiller population density (TPD). The variables LAR, LER, SER, ALLB and SL presented positive linear relationships with RP_{Fixed} and a quadratic relationship with RP_{Var}, considering the application of the N doses. As for phyllochron and LLS, a negative linear relationship was observed with RP_{Fixed} and a quadratic relationship with RP_{Var}. The N doses caused an effect on LSR, following the quadratic model for both rest periods studied. NLL and NDL exhibited linear effects on RP_{Var}. The best indexes for the rest period variable were obtained when nitrogen was applied in the range of 280 to 333 kg ha^{-1}, whereas the dose of 450 kg ha^{-1} of N provided desired results when using a fixed rest period. The rest period alleviated the process of senescence, especially given the application of higher nitrogen doses

Key words: *Urochloa brizantha* 'Marandu'. Intermittent stocking. Fixed and variable rest periods.

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Resumo

Objetivou-se avaliar as características morfogênicas e estruturais do capim Marandu submetido a estratégias de pastejo e adubação nitrogenada. Realizou-se o experimento em delineamento em blocos casualizados com parcelas subdivididas 4x2 com 4 blocos. Os tratamentos foram combinações entre dois períodos de descanso (28 dias - PD_{Fixo} - e altura de 40 cm - PD_{Var}) e quatro doses de nitrogênio (0, 150, 300 e 450 kg N ha^{-1} ano^{-1}), sendo o N aplicado na forma de sulfato de amônio. As variáveis analisadas foram: taxa de aparecimento foliar (TApF), filocrono, taxa de alongamento foliar (TAlF), taxa de alongamento de colmo (TAlC), taxa de senescência foliar (TSF), duração de vida foliar (DVF), comprimento médio de lâmina foliar (CMLF), comprimento de bainha (CB), número de folhas vivas e mortas (NFV e NFM) e densidade populacional de perfilhos (DPP). As variáveis TApF, TAlF, TAlC, CMLF e CB apresentaram comportamento linear positivo para PD_{Fixo} e quadrático para PD_{Var} com aplicação das doses de N. Filocrono e DVF apresentaram comportamento linear negativo para PD_{Fixo} e quadrático para PD_{Var}. A TSF apresentou efeito com as doses de N, enquadrando-se no modelo quadrático para ambas as formas de período de descanso. NFV e NFM apresentaram efeito linear para PD_{Var}. Os melhores índices para período de descanso variável foram obtidos quando houve aplicação de nitrogênio na faixa de 280 a 333 kg ha^{-1}, enquanto a dose de 450 kg de N ha^{-1} obteve resultados desejados quando se utiliza período de descanso fixo. O uso de período de descanso variável amenizou o processo de senescência, que fora impulsionado com a aplicação de maiores doses de nitrogênio.

Palavras-chave: *Urochloa brizantha* cv. Marandu. Lotação intermitente. Período de descanso fixo e variável.

Introduction

Marandu grass (*Urochloa brizantha* 'Marandu') is a forage grass from Africa that is considered to be a viable alternative for pasture systems of the Cerrado biome because of good biomass production, tolerance to acidic soils, and resistance to the spittlebug (EUCLIDES et al., 2008). Despite such importance, in Brazil, research on Marandu grass has been conducted to develop technologies aimed at increasing the productivity efficiency in pasture areas (RUDEL et al., 2015).

Plant morphogenesis is defined as the dynamics of organ growth and development over time and it is influenced by environmental factors. The morphogenic and structural evaluation of plants provide information on the ideal pasture conditions for more efficient and sustainable animal production in pastures (SILVEIRA et al., 2010).

Nitrogen fertilization does not present satisfactory results if adopted separately, requiring a set of good management practices to guarantee pasture productivity and persistence, reducing its degradation (FIALHO et al., 2012). For example, the strategy of grazing management provides good productive indexes, especially for rotation systems.

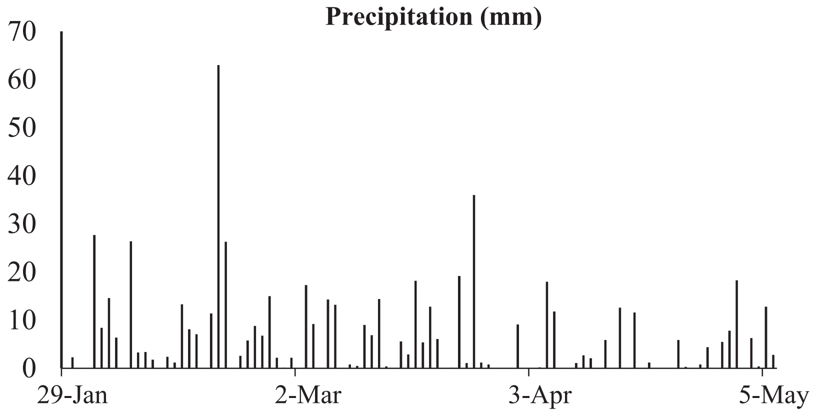
In Brazil, fixed rest periods from 28 to 42 days have been used in the rainy season. However, such strategies might not be the most appropriate because of the different environmental conditions that can exist in this interval, such as rainfall and light intensity. Because the leaf appearance rate is influenced by a series of environmental factors, it is necessary to adopt strategies that respect the eco-physiology of forage for ideal production in pastoral systems (SILVA; NASCIMENTO JUNIOR, 2007). Pre-grazing height can be used as a parameter to establish the ideal harvest time (VOLTOLINI et al., 2010).

The goal of this study was to evaluate the morphogenic and structural characteristics of Marandu grass submitted to two grazing management systems and nitrogen fertilization regime.

Material and Methods

The study was conducted at the Federal University of Tocantins - UFT, Araguaina - TO, at 07°12′28″S and 48°12′26″W, from January 2015 to May 2015. Cuts were performed from February 2015 to May 2015, and the average results of the cycles of each treatment are presented. The natural vegetation of the region is characterized as the Cerrado/Amazon ecotone. The average altitude is 277 m and the climate of the region is Aw (tropical humid summer, with well-defined dry and rainy seasons) according to Alvares et al. (2013). The average annual precipitation is 1828 mm and the average temperature is 26 °C, with an annual relative air humidity of 76%. Figure 1 shows the precipitation data during the experimental period.

Figure 1. Precipitation data from January to May 2015.



Source: INMET (2015).

The soil of the area is classified as Typic Orthic Quartzarenic Neosol (EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA - EMBRAPA, 2013). Samples were collected from the 0-20 cm depth layer for initial analysis of soil fertility. The results are described in Table 1.

Table 1. Chemical characterization of the soil before the experiment.

pH $CaCl_2$	OM	P	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H+Al	SB	CEC_e	$CEC_{pH7.0}$	m	V
	g dm^{-3}	mg dm^{-3}	----------------------------$cmol_c$ dm^{-3}----------------------------								------%------	
4.78	17.0	13.1	0.08	1.44	0.61	0.05	3.34	2.12	2.17	5.46	2.30	38.83

SB = Sum of bases; OM = Organic matter; CEC_e = Effective cation exchange capacity; $CEC_{pH7.0}$ = Cation exchange capacity at pH 7.0; m = Aluminum saturation; V = Base saturation.

After soil characterization, 1.0 t ha^{-1} of limestone (PRNT = 90%) was applied to the soil and the pasture was established with Marandu grass (*Urochloa brizantha* 'Marandu') in 2014. The area was divided into 6 × 3 m (18 m^2) plots that were subdivided into 3 × 3 m (9 m^2) subplots. Moreover, 80 kg ha^{-1} $year^{-1}$ of P_2O_5 and 100 ha^{-1} $year^{-1}$ of K_2O were homogeneously applied as simple superphosphate and potassium chloride, respectively (COMISSÃO DE FERTILIDADE DE SOLOS DO ESTADO DE MINAS GERAIS - CFSEMG, 1999). Phosphate fertilization was applied in a single application at the beginning of the experimental period, whereas potassium fertilization was divided into two applications.

The experimental design was a completely randomized 4 × 2 split-plot design, with four blocks, which consisted of combinations between two rest periods and four nitrogen doses. The following rest periods were considered: one collection at the end of 28 days (RP_{Fixed}) and another when the average height of the canopy in the subplot reached 40 cm (RP_{Var}). Nitrogen doses (0, 150, 300, and 450 kg ha^{-1} year^{-1} of N) were applied in the form of ammonium sulfate.

Morphogenic and structural characteristics were evaluated in five tillers per experimental unit, which were marked with colored nylon cord and monitored weekly. A 30 cm ruler was used to measure the distance of the last fully expanded leaf from the soil surface and leaf area, which was measured from the ligule to the tip. Thus, the following variables were estimated: leaf appearance rate (LAR), phyllochron, leaf elongation rate (LER), stem elongation rate (SER), leaf senescence rate (LSR), leaf life span (LLS), average length of leaf blade (ALLB), sheath length (SL), number of live and dead leaves (NLL and NDL), and tiller population density (TPD).

Data were submitted to descriptive statistical analysis for characterization and tested for normality, followed by an analysis of variance and, when significant ($P<0.05$), a comparison using the F test. In the variables that nitrogen dose effects were detected by the analysis of variance, regression analysis was performed using polynomial models, considering the adjustment for the level of significance of the F test and the coefficient of determination.

Results and Discussion

There was a significant difference ($P<0.05$) for LAR, phyllochron, NDL, SL, and ALLB between the rest periods. Only LSR, SER, phyllochron, and NDL showed an effect ($P>0.05$) for the interaction between nitrogen doses and rest periods (Table 2). Moreover, TDP did not show significant changes ($P>0.05$) with the nitrogen doses to fit the regression model.

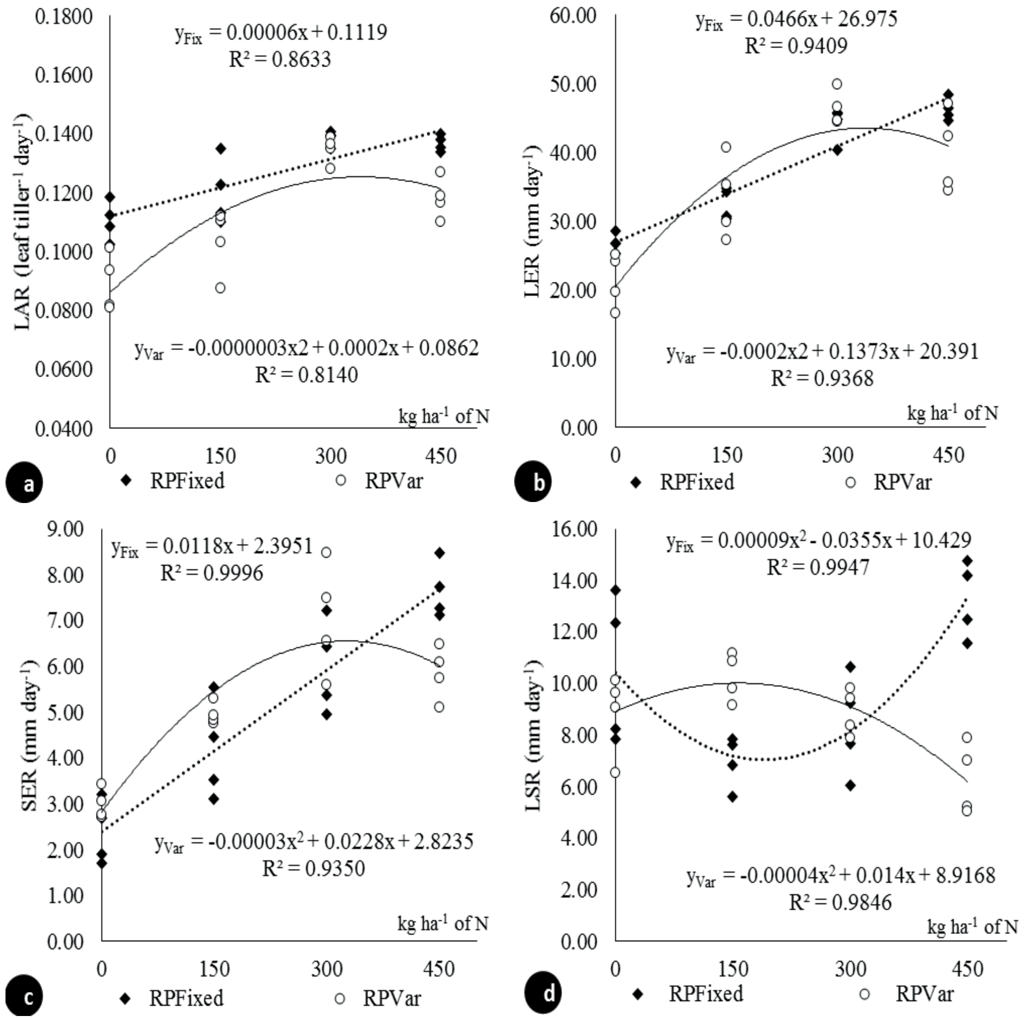
Table 2. Averages, coefficients of variation (CV), and P values of morphogenic and structural characteristics of Marandu grass submitted to different rest period strategies.

			P value		
Variable	**RP_{Fixed}**	**RP_{Var}**	**RP**	**RP x D**	**CV (%)**
LAR	0.1265	0.1114	>0.0001	0.0595	4.97
LER	37.47	35.25	0.0654	0.0372	8.53
LSR	9.78	8.56	0.0574	0.0003	17.82
SER	5.04	5.21	0.4466	0.0014	11.57
LLS	42.7	44.15	0.2037	0.1666	7.03
Phyllochron	8.76	9.76	>0.0001	0.0007	3.28
NLL	4.96	4.72	0.0636	0.3024	6.65
NDL	1.77	2.50	0.0001	0.0136	16.11
SL	202.54	277.68	>0.0001	0.3909	12.59
ALLB	231.92	262.71	0.0003	0.0838	6.92
TPD	480.25	431.75	0.0577	0.4076	14.34

The LER was influenced by the nitrogen doses for both RP_{Fixed} and RP_{Var} (Figure 2a). RP_{Fixed} presented a positive linear effect (P<0.01), with values of 0.11119 to 0.1389 leaf tiller^{-1} day^{-1} considering the range of N doses of 0 to 450 kg ha^{-1}, which represents an increase of 24% from the highest dose to the lowest one. The importance of LAR in morphogenesis is recognized because this characteristic directly interferes with three structural components of grass: tiller population density, the blade:stem ratio, and number of live leaves. When evaluating residue heights with N doses in Marandu grass, Sales et al. (2014) found a quadratic adjustment, indicating that 300 and 200 kg ha^{-1} of N caused reductions in LAR for the heights of 5 and 15 cm, respectively.

RP_{Var} showed a quadratic effect (P<0.01) for LAR, reaching a maximum of 0.1195 tiller leaf^{-1} day^{-1} with a dose of 333.33 kg ha^{-1} of N. The values obtained from LAR in this experiment were in accordance with those found by Silva et al. (2009), who obtained an average value of 0.12 leaf tiller leaf^{-1} day^{-1} for Marandu grass. Nevertheless, a lower N dose (169 kg ha^{-1} of N) was necessary to reach the maximum value of LAR when compared with the present study, which was conducted under greenhouse conditions.

Figure 2. Effect of nitrogen fertilization on leaf appearance rate (a), leaf elongation rate (b), stem elongation rate (c), and leaf senescence rate (d) of Marandu grass under different rest periods.

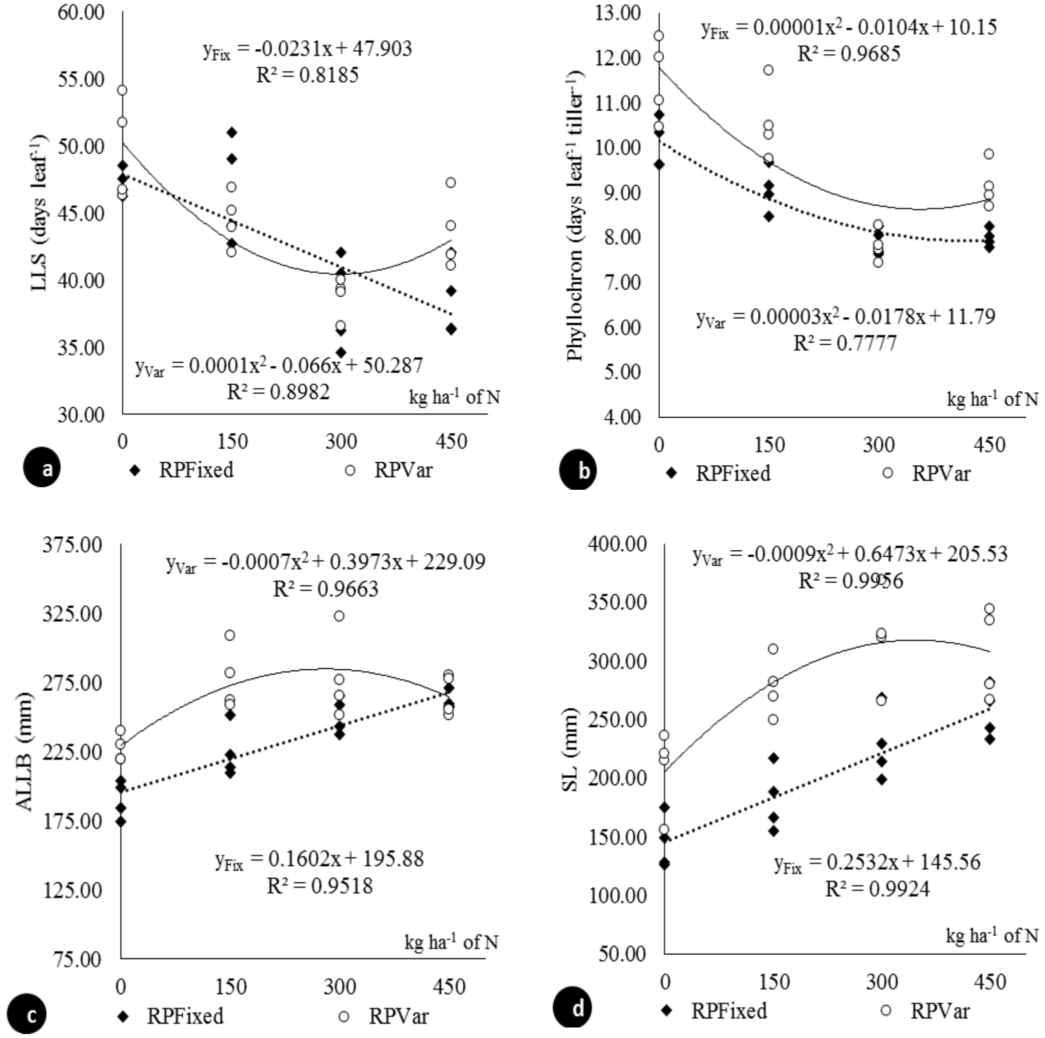


There was influence of N doses on leaf elongation rate and stem elongation rate of Marandu grass. Both the LER and SER (Figures 2b and 2c) were adjusted to the linear positive model for RP_{Fixed} (P<0.01) and quadratic positive model for RP_{Var} (P<0.01). RP_{Fixed} presented minimum and maximum values of 26.97- and 47.94 mm day^{-1}, respectively, for LER, and 2.39- and 7.70 mm day^{-1}, respectively, for SER, which represented increases of 77.8% and 222.2% for the highest dose and for the control treatment, respectively. Silva et al. (2013), when evaluating morphogenic characteristics of three cultivars of *Urochloa brizantha* under different nitrogen doses, verified a better performance of Marandu grass for the relationship between LER and SER, with a value of 6.42, which is a variable of great important for better forage production quality. As for the rest period, this variation ranged from 11.28 to 6.22 in RP_{Fixed}, demonstrating the influence of the N supply on the development of the plant, which considerably increased stem elongation. Considering the quadratic model, RP_{Var} presented an LER of 43.96 mm day^{-1} at the maximum dose of 343.25 kg ha^{-1} of N. It is important to point out that LER is a crucial characteristic that influences ALLB, interfering with the final production of dry mass (DIFANTE et al., 2011).

The LSR adjusted to the quadratic regression model (Figure 2d) and it was significantly influenced (P<0.01) by the application of nitrogen in the soil for the studied rest periods. It increased for RP_{Fixed} and decreased for RP_{Var}. From the calculation of the regression equations, it was demonstrated that LSR presented a minimum value of 6.93 mm day^{-1} for RP_{Fixed} and a maximum value of 10.14 mm day^{-1} for RP_{Var}, corresponding to the doses of 197.22 and 175.0 kg ha^{-1} of N, respectively. Thus, RP_{Var} contributed to reduced effects caused by senescence because of increasing doses of N. This is because of the collection near the maximum point of live leaf production, in addition to the lower light competition in the older leaves when compared with RP_{Fixed}. Zanine et al. (2018) verified that pastures managed at 90% light interception presented LSR and SER lower than those managed at 95% light interception, showing that the lower light competition contributed to lower growth of the plant stem.

Nitrogen fertilization presented a linear effect (P<0.01) in RP_{Fixed} and a quadratic effect (P<0.01) in RP_{Var} for leaf life span and phyllochron (Figures 3a and 3b). The minimum values estimated for LLS and phyllochron in the variable rest period were observed for the application of 330 kg ha^{-1} of N and 296.66 kg ha^{-1} of N in the soil, respectively, with an LLS of 39.39 days and phyllochron of 8.71 days. Silva et al. (2009) found similar results, where LLS and phyllochron presented a quadratic effect with values of 36.1 days and 6.8 days leaf^{-1}, respectively, for Marandu grass. RP_{Fixed} showed a reduction of approximately 21.7% in LLS (47.90 and 37.50 days) and 22.2% in phyllochron (9.87 and 7.66 days) when comparing the higher N dose with no fertilization (control). With these results, each application of 43.3 kg ha^{-1} of N reduces one day in LLS, whereas the application of 204.1 kg ha^{-1} of N promotes the reduction of one day in the phyllochron for RP_{Fixed}.

Figure 3. Effect of nitrogen fertilization on leaf life span (a), phyllochron (b), leaf length (c), and sheath length (d) of Marandu grass cultivated under grazing management strategies.



The phyllochron is the time interval, in days, between the appearance of one leaf to that of another (RODRIGUES et al., 2012); therefore, it presents inverse results when compared with LAR. The increase in the concentration of N in the plant stimulates the metabolic processes and vegetative production through cell division, causing less time for new leaves to appear. However, this effect promotes reduction in leaf life, as the forage plant, in addition to being in an active process of tissue renewal, does not keep the leaves closer to the ground because of shading, loss of its photosynthetic function, as well as senescence.

Regarding the behavior of the average length of the leaf blade and sheath length, there was an effect ($P<0.01$) of nitrogen doses in both rest periods evaluated (Figure 3c and 3d). Thus, it was observed that data dispersion was better suited to the quadratic polynomial distribution for RP_{Var} and linear for RP_{Fixed} for ALLB and SL, respectively.

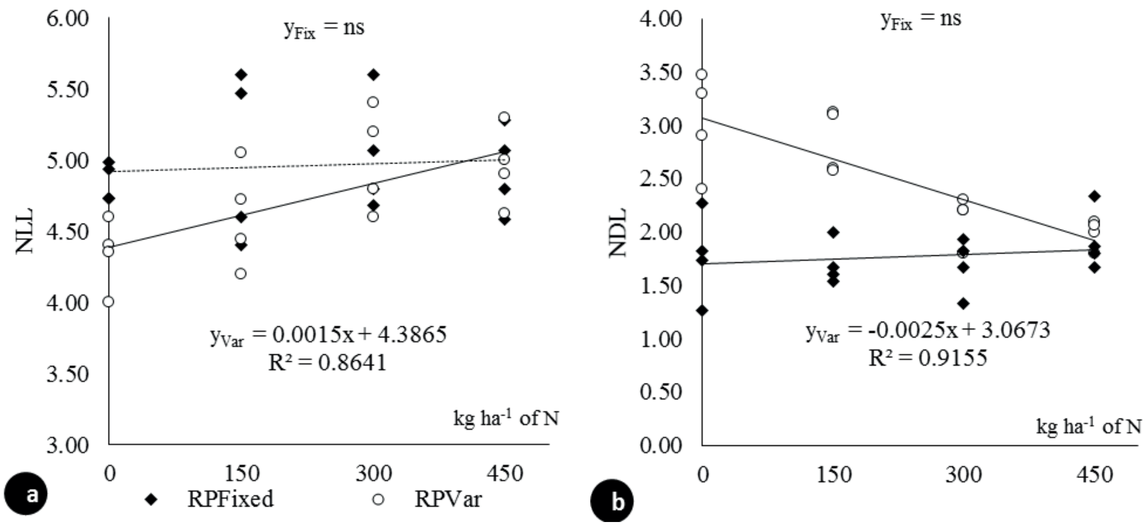
In RP_{Fixed}, ALLB and SL presented values of 19.59 cm and 14.56 cm, when there was no nitrogen fertilization, and 26.80 cm and 25.95 cm with 450 kg ha^{-1} of N fertilization, respectively, which correspond to increases of 36.8 % for ALLB and

78.2% for SL. Using the model, it was shown that to increase 1 cm, it is necessary to apply 63.42 kg ha^{-1} of N to ALLB and 39.49 kg ha^{-1} of N to SL. As for RP_{Var}, the maximum value was 25.23 cm of ALLB and 32.19 cm of SL, when the doses of 283.78 and 359.61 kg ha^{-1} of N were applied, respectively. The average length of leaf blade (ALLB) is a characteristic that is responsive to grazing intensity, with its larger size associated with higher grazing height because of the greater path that the leaf must travel through the sheath to be completely expanded (VOLAIRE et al., 2014). Maranhão et al. (2010) demonstrated that lower ALLB values are related to the lower LER. The same authors verified quadratic behavior of SL in *Urochloa decumbens* in relation to nitrogen fertilization, obtaining an average increase of 34% with the use of fertilization.

NLL and NSL (Figure 4a and 4b) were linearly influenced by doses of nitrogen only for RP_{Var} (P>0.01), with no significant effect on any model applied to RP_{Fixed} (P>0.05). While NLL presented a comparative increase of 15.3% (4.39 and 5.06) from the treatment without fertilization (control) to the highest tested dose, NDL was reduced by 36.8% (3.07 and 1.94). Thus, using rest periods with an increase in the nitrogen doses increased the availability of green mass production, reducing the senescent material, which is not used by cattle. Santos et al. (2011) verified that NLL and NDL of *Urochloa decumbens* 'Brasilisk' were not influenced by grazing heights of 10, 20, 30, and 40 cm, presenting an average of 4.36 for NLL and 2.15 for NDL. The authors stated that the environmental conditions did not influence significant changes in results, although they were genetically defined characteristics.

Therefore, the best results for the rest period were obtained when nitrogen was applied in the range of 280 to 333 kg ha^{-1}, whereas the dose of 450 kg N ha^{-1} provided desired results when using the fixed rest period. The rest period alleviated the process of senescence, especially by the application of higher nitrogen doses.

Figure 4. Effect of nitrogen fertilization on the number of live (a) and dead (b) leaves of Marandu grass cultivated under different rest periods.



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