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Morphogenesis and tiller density of Aruana grass managed at different heights under sheep grazing

Morfogênese e densidade de perfilhos do capim-Aruana manejado em diferentes alturas sob pastejo de ovinos

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Abstract

This study aimed to assess the morphogenic characteristics and tiller density of Aruana grass managed at different heights under sheep grazing. Aruana grass was managed at four mean heights (12, 15, 20, and 25 cm) distributed in a randomized block design with three replications, totaling 12 paddocks of 250 m² each. Twenty-four crossbred Dorper x Santa Inês lambs, with mean age and weight of 60 ± 15 days and 16.69 ± 2.70 kg, respectively, were randomly distributed in the treatments. Five tillers were demarcated per paddock for measuring morphogenic variables. A representative area in the paddock was used for counting the number of tillers. No differences ($P > 0.05$) were observed for leaf appearance rate, leaf elongation rate, stem elongation rate, leaf senescence rate, final leaf length, and leaf life span between the assessed heights. Phyllochron was longer at the height of 25 cm when compared to 15 and 20 cm (19.35, 12.11, and 12.75 days, respectively). The number of live leaves was higher at heights of 12, 15, and 20 cm when compared to 25 cm (3.99, 4.35, 4.15, and 2.86, respectively). The number of basal and aerial tillers presented no variation ($P > 0.05$) between canopy heights. Management heights from 15 to 20 cm allowed a higher number of live leaves and a shorter phyllochron in Aruana grass pastures managed for sheep. Canopy height management did not influence other morphogenic characteristics and tiller density.

Key words: Leaf appearance. Leaf life span. Phyllochron. Number of live leaves.

Resumo

O objetivo com o trabalho foi avaliar as características morfogênicas e a densidade de perfilhos do capim-Aruana manejado em diferentes alturas sob pastejo de ovinos. Em 12 piquetes de 250m² cada, o capim-Aruana foi manejado em quatro alturas médias (12, 15, 20 e 25 cm), distribuídas em um delineamento experimental de blocos casualizados, com três repetições para cada tratamento. Utilizou-se vinte e quatro borregas mestiças das raças Dorper x Santa Inês com idade e peso médio de 60 (± 15)

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dias e 16,69 (± 2,70) kg, respectivamente, distribuídas aleatoriamente nos tratamentos. Para mensuração das variáveis morfogênicas, foram demarcados cinco perfilhos por piquete. Para contagem do número de perfilhos, foi escolhida uma área representativa do piquete. Não foram observadas diferenças (P > 0,05) para a taxa de aparecimento foliar, taxa de alongamento foliar, taxa de alongamento do colmo, taxa de senescência foliar, comprimento final de folha inteira e duração de vida das folhas entre as alturas avaliadas. O filocrono foi maior na altura de 25 cm quando comparado às alturas de 15 e 20 cm (19,35, 12,11 e 12,75 dias, respectivamente). O número de folhas vivas foi superior nos tratamentos de 12, 15 e 20, quando comparados ao de 25 cm (3,99, 4,35, 4,15 e 2,86, respectivamente). O número de perfilhos basais e aéreos não variaram (P > 0,05) entre as alturas de dossel. Alturas de manejo entre 15 e 20 cm permitem maior número de folhas vivas e menor filocrono em pastagens de capim-Aruana manejada para ovinos. A altura de manejo do dossel não influenciou nas demais características morfogênicas e densidade de perfilhos.

Palavras-chave: Aparecimento foliar. Duração de vida da folha. Filocrono. Número de folha viva.

Introduction

Livestock grazing viability depends on the correct exploitation of pasture and its resources (GOMIDE; GOMIDE, 1999). The importance of determining the height, animal load, and dynamics of plant morphogenesis process is related to the influence of these factors on canopy structure and, consequently, the quantity and quality of the harvested forage. Among the management criteria, pasture height is an essential tool for ideal system conduction.

Pasture height is an important tool and indicator of management because it can be easily verified under field situations, besides showing a direct relationship with plant morphogenesis and structure. The lower the management height is, the higher the amount of light received at the plant base, stimulating the appearance of new vegetative tillers (SOUSA et al., 2013). However, a higher management height may guarantee a higher forage mass during winter, but with many stems and dead tissues (VILELA et al., 2012). Moreover, pasture height is associated with morphophysiological parameters, being effective as a management tool and variable according to the animal species to be explored.

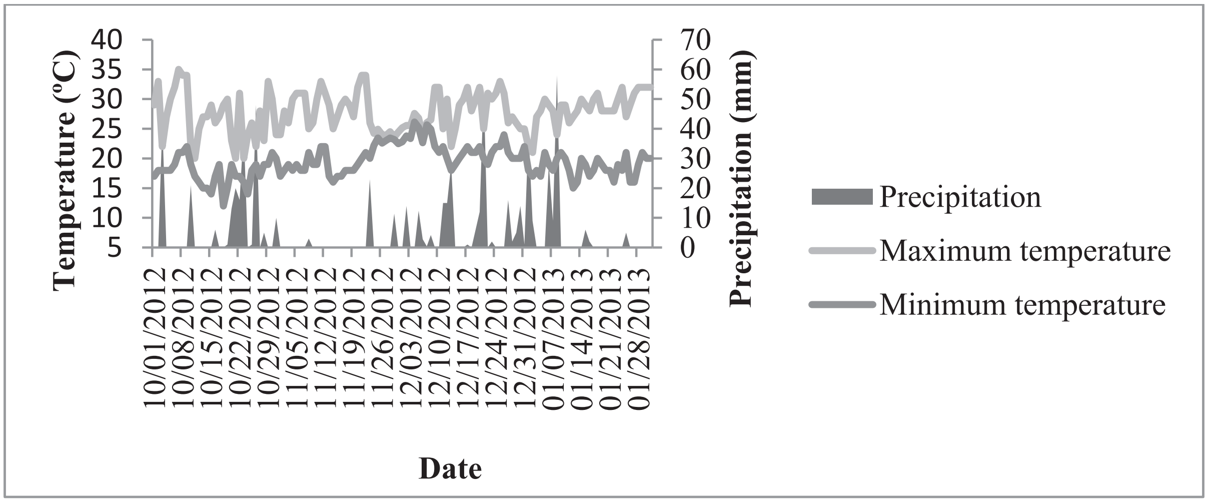
Morphogenesis consists of the dynamics of generation and expansion of plant organs in time and space, characterizing canopy structure (LEMAIRE; CHAPMAN, 1996). Knowing the structural behavior of forage plants allows an adequate management recommendation to maximize pasture utilization, given the possibility of visualizing the seasonal forage production curve and directing possible management strategies to be adopted in production systems (ALEXANDRINO et al., 2011).

Among the forage plants used in current production systems, *Panicum maximum* Jacq. cv. Aruana has a high carrying capacity and high nutritional value (SILVA et al., 2009). The open and erect leaf architecture associated with high forage yield and excellent acceptability by animals makes Aruana grass an ally of Brazilian livestock (POMPEU et al., 2010). Aruana grass has been widely disseminated and recommended for sheep production systems due to its palatability and canopy structure (BIACHINI et al., 1999). Another factor that enhances the use of the Aruana grass by sheep is the height management, which can be smaller due to species particularities. However, few studies have investigated the adequate use of Aruana grass for sheep aiming at a balance in the plant-animal system given that pasture height influences its structure and hence its morphogenic characteristics. In this sense, this study aimed to assess four heights of Aruana grass managed for sheep grazing under continuous stocking and its reflection on morphogenic variables and tiller density.

Material and Methods

The experiment was carried out from November 2012 to January 2013 at the Sheep and Goat Research and Teaching Unit of the Federal University of Technology – Paraná (UTFPR), located in Dois Vizinhos, PR, at the geographical coordinates 25°42′ S and 53°03′ W and altitude of 520 m above sea level (NATIONAL INSTITUTE OF METEOROLOGY - INMET, 2013). The soil is classified as a clay textured dystrophic Red Latosol, according to Brazilian Agricultural Research Corporation - Embrapa (1999). The regional climate is classified as Cfa, i.e., a subtropical humid mesothermal climate with a mean annual precipitation of 1,953 mm and mean annual temperatures of 25.2 (maximum) and 14.7 °C (minimum) (ALVARES et al., 2013). Figure 1 shows the maximum and minimum temperatures and precipitation during the experimental period.

Figure 1. Meteorological data during the experiment.



Aruana grass (*Panicum maximum* Jacq. cv. Aruana) had been established for two years in the area when the experiment was carried out using 12 paddocks of 250 m^2. Four management heights were intended: 10, 15, 20, and 25 cm, but pasture heights of 12, 15, 20, and 25 cm (treatments) were reached. These treatments were distributed in a randomized block design with three replications. The initial leveling of heights was performed with a brush cutter. An adaptation period of 21 days was set after treatment heights were established. After adaptation, the experimental period lasted 63 days, divided into three periods of 21 days for data collection. Fertilization of 48.6 kg N ha^{-1} was carried out at the beginning of each period based on soil analysis.

Twenty-four crossbred Dorper x Santa Inês lambs with a mean age of 60 ± 15 days and mean weight of 16.69 ± 2.70 kg were randomly distributed in the treatments to maintain forage height, being two tester lambs per paddock. Grazing method consisted of the continuous stocking with variable stocking rate, using the technique described by Mott and Lucas (1952). Control of heights was monitored using a ruler graduated in millimeters at ten points per paddock and three times a week. Regulatory animals of the same species, breed, and age were used when necessary (Table 1).

Five tillers were demarcated per plot using colored threads to assess the morphogenic characteristics, totaling fifteen tillers per treatment distributed in a transect, according to the methodology of Carrère et al. (1997). These transects were distributed inside the paddocks at locations representing the mean height. Tillers were assessed twice a week with a ruler graduated in millimeters. New tillers were demarcated at the end of each period, following the same criteria described. Stem length and number of mature and growing leaf blades (cm) were classified according to their condition (senescent or not and intact or defoliated) at each assessment, according to the methodology proposed by Lemaire and Chapman (1996): leaf appearance rate (LAR), defined as the number of leaves emerged per tiller divided by the number of days of the assessment period; phyllochron (PHY), which is the inverse of the leaf appearance rate; leaf elongation rate (LER), obtained by the sum of all leaf blade elongation divided by the number of days of the assessment period; stem elongation rate (SER), which is the sum of all stem elongation divided by the number of days of the assessment period; leaf senescence rate (LSR), defined as the ratio between the sum of the senesced leaf blade lengths in the tiller and the number of days of the assessment period; number of live leaves (NLL), obtained by counting the number of expanding and expanded leaves, not considering the senescent leaves of each tiller; final leaf length (FLL), obtained by measuring only fully expanded leaves of the assessed tillers from their insertion in the fully expanded ligule to the leaf apex, not considering leaves in expansion; and leaf life span (LLS), defined as the period from leaf appearance to its death, which is estimated by the equation LLS = NLL × PHY.

Table 1. Mean heights of *Panicum maximum* Jacq. Aruana pasture managed at different heights under lamb grazing.

Height	12	15	20	25
		Adaptation		
μ 1–6 days*	12.0	15.0	20.1	25.1
μ 7–13 days	12.3	14.7	20.4	25.4
μ 14–21 days	12.2	14.7	20.3	25.2
Mean	12.2	14.8	20.3	25.2
		1st period		
μ 1–6 days	12.2	14.7	20.3	25.2
μ 7–13 days	11.7	15.2	19.7	24.8
μ 14–21 days	11.8	15.1	19.8	24.8
Mean	11.9	15.0	19.9	24.9
		2nd period		
μ 1–6 days	11.8	15.1	19.8	24.8
μ 7–13 days	12.4	14.7	20.3	24.9
μ 14–21 days	12.3	14.7	20.1	25.0
Mean	12.2	14.8	20.1	24.9
		3rd period		
μ 1–6 days	12.2	14.7	20.1	25.0
μ 7–13 days	11.6	15.3	19.8	25.1
μ 14–21 days	11.6	15.5	20.1	25.2
Mean	11.8	15.2	20.0	25.1
Overall mean	**12.03**	**14.95**	**20.08**	**25.03**

μ* = mean of the week.

A frame with an area of 0.0625 m^2 was used to count the tillers on the 15th after the beginning of each period to determine the population density of basal and aerial tillers. For this, two assessments were performed per paddock considering an area representative of the mean height of treatments.

The data were submitted to analysis of variance and F-test at 5% significance. A regression analysis was also performed using the statistical program R (R CORE TEAM, 2013).

Results and Discussion

Leaf appearance rate (LAR), leaf elongation rate (LER), leaf senescence rate (LSR), final leaf length (FLL), leaf life span (LLS), and stem elongation rate (SER) were not influenced by pasture management heights (P>0.05; Table 2).

Table 2. Mean values for leaf appearance rate (LAR, leaf tiller^{-1} day^{-1}), leaf elongation rate (LER, cm tiller^{-1} day^{-1}), leaf senescence rate (LSR, cm tiller^{-1} day^{-1}), final leaf length (FLL, cm tiller^{-1}), leaf life span (LLS, day), stalk elongation rate (SER, cm tiller^{-1} day^{-1}), phyllochron (PHY, day leaf^{-1} tiller^{-1}), and number of live leaves (NLL) of *Panicum maximum* Jacq. Aruana pasture managed at different heights under lamb grazing.

Variable	Forage height (cm)				MSE*
	12	15	20	25	
LAR^{ns}	0.07	0. 10	0.09	0. 07	42.1
LER^{ns}	1.07	1.17	1.27	0.77	49.9
LSR^{ns}	0.29	0.31	0.47	0.25	128.0
FLL^{ns}	11.92	13.60	14.23	12.53	33.7
LLS^{ns}	30.76	27.50	31.84	34.49	62.2
SER^{ns}	0.18	0.11	0.16	0.16	149
FIL^1	14.83	12.11	12.75	19.35	1.87
NFV^1	3.99	4.35	4.15	2.86	0.28

*Mean standard error.
^{ns}No significant difference (P>0.05); ^{1}significant difference (P<0.05).
PHY = $47.3785 - 4.1867x + 0.1227x^2$; $r^2 = 0.99$.
NLL = $-1.38509 + 0.70305x - 0.02133x^2$; $r^2 = 0.99$.

The non-significance of management height on LAR may be due to a small difference in management height of Aruana grass or the inherent morphophysiological characteristics of the plant and/or environment to which the pasture was exposed. Even under the most adverse environmental conditions or management, LAR is the last variable to be affected. According to Lemaire et al. (2008), in order to maintain tillering development, the economy of photoassimilates would be initiated by reducing tiller density, followed by decreases in leaf length and life span. That is, there is a reduction in the number of tillers and hence LAR to guarantee plant survival under low canopies. Therefore, LAR determines substantial differences in pasture structure due to its effect on tiller size and density (NABINGER; PONTES, 2001). Another factor that may have contributed to a low LAR is that the increase in sheath length of successive leaves in erect growth pastures, such as Aruana grass, leads to a higher delay in leaf appearance (LEMAIRE; CHAPMAN, 1996; GARCEZ NETO et al., 2002).

A negative correlation was observed between LER and LAR so that the lower the LAR is, the higher the LER (SBRISSIA; SILVA, 2001), which could be observed in this study. Skinner and Nelson (1995) suggested that leaf elongation is highly influenced by nitrogen supply. However, no difference was observed because fertilization was the same for all treatments, reinforcing the non-significance of results as a function of management heights. The functional plant response may also contribute to limit leaf elongation since each genotype has genetic programming to express its characteristics according to the genotype-environment interaction (OLIVEIRA et al., 2007). The results obtained for LAR and LER corroborate the studies conducted by Oliveira et al. (2007) with *Panicum maximum* cv. Tanzania and Luna et al. (2014) and Garcez Neto et al. (2002) with *Panicum maximum* cv. Mombasa, in which no effects were found for cut intensity.

The leaf senescence rate showed no difference between treatments. Studies have indicated that LSR is influenced by the season, with the highest values in the summer (ZANINI et al., 2012). In this sense, the highest elongation rates, tissue renewal and, consequently, higher senescence observed in this study was possible due to the favorable climate conditions (light and temperature) provided by the season the experiment was carried out.

The final leaf length did not affect forage height, probably due to its relationship with LAR and LER. According to Lemaire et al. (2008), the higher the LAR, the shorter the time available for leaf elongation, which would significantly affect FLL. In this case, because any of the influencing variables did not affect grazing height, FLL also had no significant effect (P>0.05). The negative relationship between LAR and FLL, as described by Nabinger and Pontes (2001), can also corroborate these results because the higher the LAR is, the lower the FLL.

Leaf life span may have been affected by several factors, such as cutting or grazing, climate conditions, plant development stage, and characteristics inherent to the forage species (GARCEZ NETO et al., 2002). This behavior can be better understood when analyzed together with the leaf senescence process (GARCEZ NETO et al., 2002). Once senescence is established, nutrients are remobilized to younger leaves, which reduces the photosynthetic activity of older leaves and leads to a reduction in LLS (OLIVEIRA et al., 2007), corroborating the observations of this study.

Grazing management has been the most used way to control SER, as a high leaf to stem ratio is desired (CORSI et al., 1996). Therefore, SER is also an important morphogenic variable because it causes changes in canopy structure (SILVA; SBRISSIA, 2010). Lower SER values observed in this study corroborate the results obtained in *Panicum* cultivars found by Luna et al. (2014), which may be associated with a low cutting/grazing height.

The number of live leaves and PHY were influenced (Table 2) by management height of Aruana grass. NLL reached its highest values in the treatments of 12, 15, and 20 cm, ranging from 3.99 to 4.35. A higher number of live leaves was observed in treatments managed in canopies of lower heights due to the translocation of plant nutrients. According to Bélanger et al. (1992), a higher translocation of photoassimilates to plant shoot is due to the defoliation. Also, this variable can express the potential of a plant to produce and assimilate carbon (POMPEU et al., 2010). In other words, the fact that the canopy was managed with a height of up to 20 cm allowed a preferential translocation of assimilates to the development of other plant organs, such as stems, to the detriment of increased leaf production (ALEXANDRINO et al., 2005).

Another factor that may have influenced a higher NLL in smaller canopies is the fact that younger leaves usually export a large proportion of assimilates to growing tillers, i.e., a higher defoliation intensity due to the selectivity of the sheep species leads to an increased appearance of new leaves and hence a higher transport of nutrients, generating new tiller (ROBSON et al., 1988; BÉLANGER et al., 1992). NLL is a genotypically stable variable directly influenced by LAR and LLS (NABINGER; PONTES, 2001).

In this study, PHY was shorter between heights of 15 to 20 cm and longer at the height of 25 cm, with values of 12.11, 12.75, and 19.35, respectively. According to Zanini et al. (2010), it is believed that in younger tillers, younger leaf blades run a shorter distance to expose themselves and, therefore, the time required for the visualization of a new emerged leaf was shorter, resulting in a higher LAR and lower PHY. The opposite can also be observed in the treatment of 25 cm, i.e., the path of the leaf blades in expansion until its emergence was longer, resulting in a longer PHY and lower LAR. These findings and statements corroborate Fournier et al. (2005) because the time interval required for the appearance of two consecutive leaves is directly related to the leaf elongation time, which is dependent on sheath length. Zanini et al. (2012) studied Aruana grass and identified a PHY stability of around 10 to 12 days per leaf when LER was higher than 1.3 cm tiller^{-1} day^{-1}.

The number of basal and aerial tillers was not influenced by pasture height (Table 3), with a mean value of 5245.7 and 6935.0 tillers m^{-2}, respectively. It can be explained by the management heights adopted due to the used animal species. Initial heights of 40 cm are usually adopted, but sheep use canopy height as a criterion to establish the grazing site, with a preference for grazing up to eye level (BAZELY, 1990). Thus, the used forage crop resulted in a higher forage tillering, with no difference between treatments. Another factor that may have contributed to this result is the tillering potential of Aruana grass, which could be partially explained by a high leaf appearance rate, which was also observed in Aruana grass by Alcântara et al. (1985) and Cecato et al. (2000).

Table 3. Density of basal and aerial tillers (tillers m^{-2}) of *Panicum maximum* Jacq. Aruana pasture managed at different heights under lamb grazing.

Tiller	Forage height (cm)				
	12	15	20	25	Mean
Basal^{ns}	5573.2	5436.4	4960.0	5013.2	5245.7
Aerial^{ns}	7293.2	6466.8	6826.8	7153.2	6935.0

^{ns}No significant difference (P>0.05).

Tiller density can be influenced by N fertilization. However, N doses were the same for all treatments in this experiment. According to Zarrough (1984), defoliation is another factor that affects tiller density, i.e., lower heights where grazing intensity is higher show a higher density of basal tillers, which is related to the balance between the tiller appearance rate and tiller senescence rate of the forage.

Because no difference was observed between LAR and LSR, no significant effect was observed on the density of basal tillers. However, when assessing aerial tiller, an inverse relationship was observed between LSR and tiller population density, i.e., the lower the LSR is, the higher the density of aerial tillers (SILVA; SBRISSIA, 2010). The direct relationship between LAR and tiller density determines the potential of tillering for a given genotype since each leaf formed on a stem represents the appearance of a new phytomer, i.e., the generation of new axillary buds (DIFANTE, 2003). According to Costa Araújo et al. (2015), the maintenance of similar heights probably did not generate changes in light penetration into the canopy, not influencing tiller density, which is in accordance with the results found here.

Conclusion

Management heights from 15 to 20 cm allowed a higher number of live leaves and a shorter phyllochron in Aruana grass pastures managed for sheep. Canopy height management did not influence other morphogenic characteristics and tiller density.

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