

## Research Paper

# How does the sward condition in late winter influence the Marandu palisade grass (*Urochloa brizantha* cv. Marandu) structure during spring and summer?

*¿Cómo afecta la altura de una pastura de *Urochloa brizantha* cv. Marandu al final del invierno su estructura durante la primavera y el verano?*

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## Abstract

Height and mowing of a sward in late winter can change its structure during the subsequent spring and summer seasons, which influences plant growth and animal performance. This work was conducted to evaluate the structural characteristics of *Urochloa brizantha* (syn. *Brachiaria brizantha*) cv. Marandu (Marandu palisade grass) during spring and summer in relation to the following sward conditions in late winter: short (15 cm), medium (23 cm), tall (31 cm) and tall (31 cm)/mowed to 8 cm. Stages of the grazing period (beginning, middle and end) in spring and summer were considered measures repeated over time. Leaf area index was lower in the tall pasture than in the other pastures and was lower at the beginning than at the end of the grazing period. Dead material mass was highest in the tall pasture, intermediate in the short and medium pastures and lowest in the tall/mowed pasture. Live stem mass was higher at the end than at the beginning and middle of the grazing period for the short, medium and tall/mowed pastures, contrary to that observed in the tall sward. At the end of the grazing period, tiller number did not vary among pastures. The tall pasture in late winter presents a limiting structure to animal consumption. Short and tall/mowed pastures in late winter show a favorable structure for forage plant growth and, probably, animal performance.

**Keywords:** Forage mass, grazing height, herbage bulk density, leaf area index, tiller number, tropical grasses.

## Resumen

La altura y el corte de una pastura al finalizar el invierno pueden cambiar su estructura durante las siguientes estaciones de primavera y verano, influyendo en el crecimiento de las plantas y la producción animal. En un experimento de pastoreo realizado en la Universidad Federal de Uberlândia, Minas Gerais, Brasil, se evaluaron las características estructurales de *Urochloa brizantha* (sin. *Brachiaria brizantha*) cv. Marandu durante la primavera y el verano en función de 4 condiciones de altura de la pastura al final del invierno: altura baja (15 cm); mediana (23 cm); alta (31 cm); y alta (31 cm) en combinación con corte a 8 cm. En estas estaciones se realizaron mediciones al comienzo, mediados y final del período de pastoreo, las cuales se consideraron como mediciones repetidas en el tiempo. El índice de área foliar fue menor en el pasto alto, siendo igualmente menor al inicio que al final del período de pastoreo. La masa de materia muerta fue mayor en el pasto alto, intermedia en los pastos corto y mediano, y menor en el pasto alto/cortado. La masa de tallos vivos fue mayor al final que al inicio y a mediados del período de pastoreo para los pastos corto, mediano y alto/cortado, contrario a lo observado en el pasto alto. Al final del período de pastoreo, el número de brotes no varió entre los tratamientos. Se concluye que cuando el pasto es alto al final del invierno, su estructura en primavera y verano probablemente no favorecen el consumo por el animal. En

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contraste, los pastos corto y alto/cortado al final del invierno presentan una estructura favorable para el crecimiento del forraje y, probablemente, también para la producción animal.

**Palabras clave:** Altura para pastoreo, densidad forrajera, gramíneas tropicales, índice de área foliar, masa forrajera, número de brotes.

## Introduction

Sward structure indicates the spatial arrangement of the aerial parts of forage plants in a pasture (Da Silva and Carvalho 2005) and can be characterized by its mass, bulk density and morphological composition, leaf area index and number of tillers. In recent years, researchers have been trying to develop pasture management strategies for controlling and modifying sward structure, to favor herbage production (Santos et al. 2013) and high intake rate of forage by grazing animals (Mezzalana et al. 2014).

In this sense, on deferred pastures it is recommended that the canopy be short and forage mass be reduced during the grazing period, which usually ends in late winter (Santana et al. 2014). This sward structure would allow good incidence of light at the base of the plants, which would stimulate the appearance of new tillers from early spring (Costa et al. 2016; Pessoa et al. 2016), favoring a more intense and rapid pasture regrowth and possibly resulting in sward structural characteristics more suitable for animal grazing during the rainy season.

On the other hand, commonly deferred pasture has high forage mass, with high percentages of stem and dead material in the transition period between winter and spring (Silva et al. 2016). In this pasture condition, increased shading at the base of the plants compromises tiller production (Matthew et al. 2000; Santana et al. 2014). Thus, during spring and summer, the pasture would have a lower percentage of live leaf lamina, as well as a high percentage of dead material, remaining from winter, a sward structure which is unfavorable for animal production.

To avoid this problem, Souza et al. (2015) suggested mowing deferred pastures with high sward surface height in late winter in order to remove old and dead forage quickly. However, the mowed forage, unless removed, can reduce the incidence of light at the base of the plants and, thus, inhibit the appearance of new tillers. If this occurs, the pasture may have a lower number of tillers and a lower herbage bulk density, which may limit animal intake (Fonseca et al. 2013).

Given the above, this work was based on the hypothesis that height and mowing of pasture in late winter modulate sward structure in subsequent seasons. Therefore, this study was conducted to characterize, during spring and early summer, the sward structure of Marandu palisade grass, previously deferred, as a function of its sward surface height and mowing in late winter.

## Materials and Methods

From January 2013 to February 2014, the experiment was conducted at the Experimental Farm 'Capim Branco' of the Federal University of Uberlândia, in Uberlândia, Minas Gerais, Brazil (18°53'19" S, 48°20'57" W; 776 masl). The experimental area consisted of a pasture of *Urochloa brizantha* (syn. *Brachiaria brizantha*) cv. Marandu (Marandu palisade grass) divided into 12 paddocks (experimental units) of 800 m<sup>2</sup>, in addition to a reserve area.

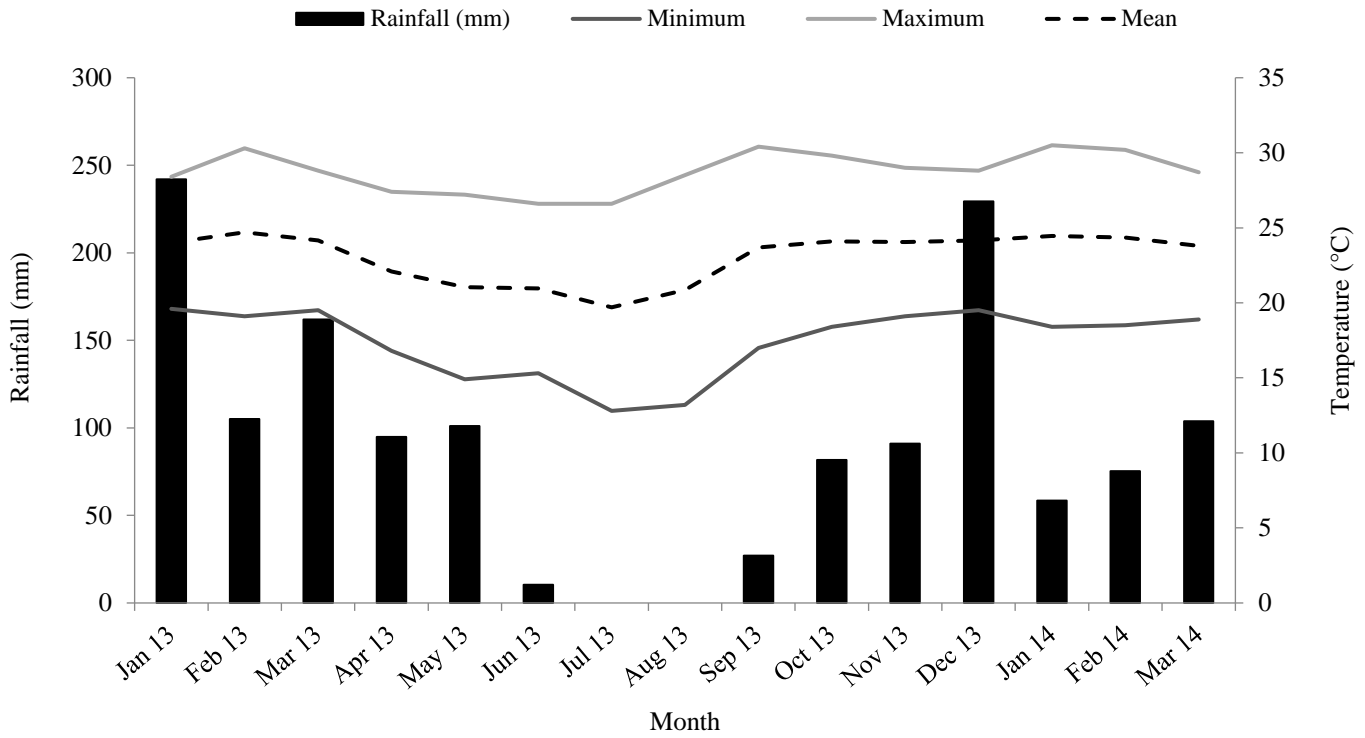
The climate of the region, according to Köppen's classification, is an Aw tropical savanna type, with dry winter season (Alvares et al. 2013). Information regarding the climatic conditions during the experimental period was monitored at a meteorological station 100 m from the experimental area (Figure 1).

The mean temperatures and monthly precipitation were used to calculate soil water balance (Thornthwaite and Mather 1955), considering a soil water storage capacity of 40 mm (Figure 2).

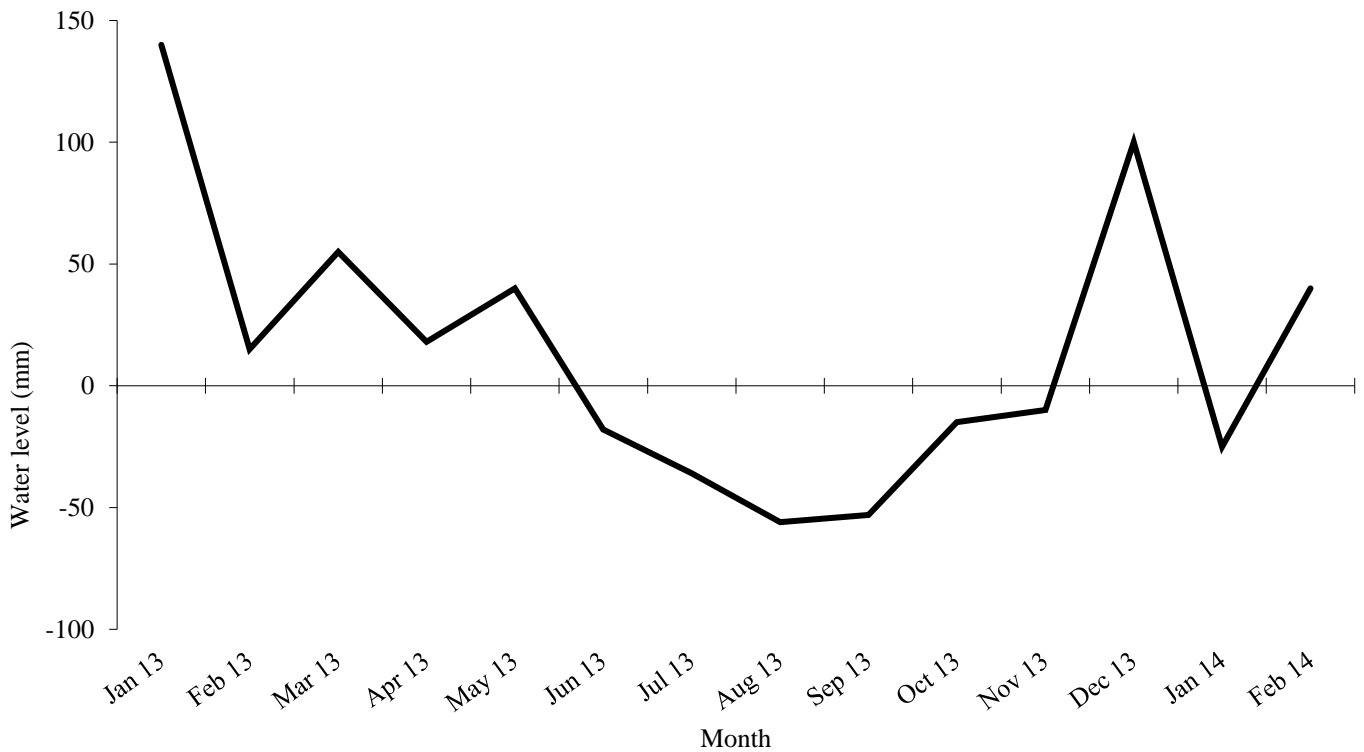
Soil samples were collected from the 0–20 cm layer at the beginning of the experiment and yielded the following characteristics: pH in water: 6.1; P: 4.5 mg/dm<sup>3</sup> (Mehlich-1); K<sup>+</sup>: 138.8 mg/dm<sup>3</sup>; Ca<sup>2+</sup>: 5.1; Mg: 1.9; and Al<sup>3+</sup>: 0 cmol/dm<sup>3</sup>. Based on these results, 55 kg P/ha (as single superphosphate) and 50 kg N/ha (as urea) were applied in January 2013. Two other applications of 70 kg N/ha (as urea) occurred on 15 March 2013 and 12 January 2014.

Management of pastures was as follows: 4 January–3 April 2013, all paddocks continuously stocked with sheep at a variable stocking rate, to maintain 4 average sward surface heights (15, 25, 35 and 45 cm); 4 April–21 June 2013 (79 days), all pastures stockpiled (deferment period); 22 June–25 September 2013 (96 days), all pastures grazed by sheep (grazing period in winter) (Figure 3).

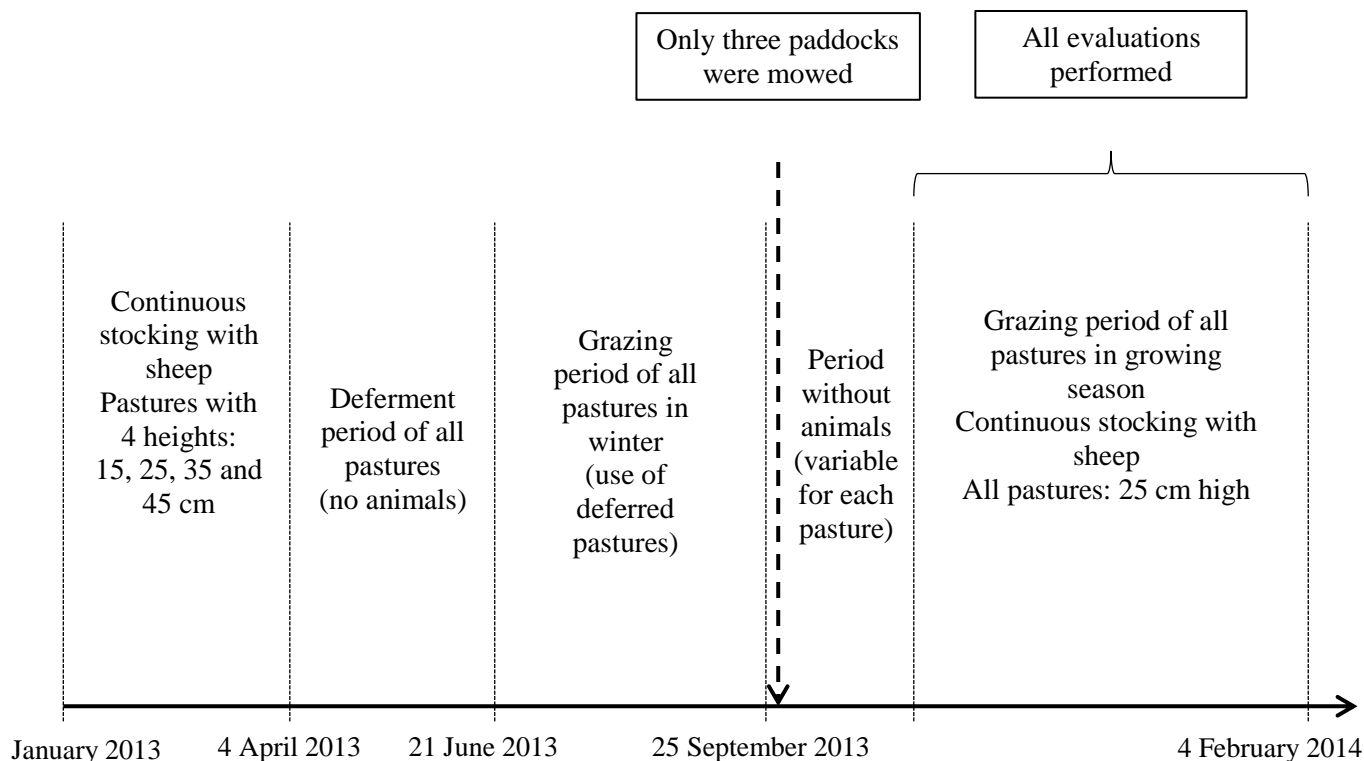
During the transition between late winter and early spring, pastures initially deferred at 15, 25 and 35 cm were characterized as short (15.1 cm and 4,600 kg DM/ha), medium (23.2 cm and 5,940 kg DM/ha) and tall (31.4 cm and 7,640 kg DM/ha), respectively. The pasture deferred at 45 cm was 31.3 cm tall with forage mass of 7,200 kg DM/ha, similar to the 35 cm deferred pasture in late winter. Therefore, in order to produce a difference in conditions for these 2 deferred pastures, pastures deferred at 45 cm were mowed at 8 cm height on 27 September 2013, and the mown forage was not removed from the area. This provided



**Figure 1.** Monthly rainfall and average minimum, mean and maximum air temperatures at the experimental site from January 2013 to February 2014.



**Figure 2.** Monthly soil water balance (considering a soil water storage capacity of 40 mm) at the experimental site from January 2013 to February 2014.



**Figure 3.** Sequence of pasture management events that occurred during the experimental period.

4 sward conditions in late winter: short, medium, tall and tall/mowed, which corresponded to experimental treatments. The characteristics of the pastures were evaluated at the beginning, middle and end of the growing-season grazing period, which occurred in spring and early summer.

From 27 September 2013, the short, medium, tall and tall/mown pastures remained without animals (without grazing) for 46, 42, 14 and 44 days, respectively, until reaching 30 cm tall, when the growing-season grazing period began, occurring on different dates for each pasture condition: 12 November 2013, 8 November 2013, 11 October 2013 and 10 November 2013, respectively. Since the growing-season grazing period ended on 4 February 2014, the grazing periods for short, medium, tall and tall/mowed pastures lasted 84, 88, 116 and 86 days, respectively. During the growing-season grazing period, all pastures were continuously stocked at variable rates using a put-and-take method (Mott and Lucas 1952), in order to maintain an average sward surface height of about 25 cm (Da Silva et al. 2013), using Santa Inês × Dorper crossbred sheep, with an average live weight of 30 kg, which had access only to mineral salt.

The sward surface height, i.e. the distance from the soil surface to the apex of the highest live leaf lamina in the canopy, was measured weekly at 30 random points in

each experimental unit, using a graded rule and following a zig-zag path.

At the beginning (first week), in the middle (17–20 December 2013) and at the end (3 and 4 February 2014) of the growing-season grazing period, pasture evaluations were performed. The mass of the morphological components of the pastures was estimated by cutting at ground level all tillers contained within a square of 0.25 m<sup>2</sup>, at 3 locations per paddock and at average sward surface height. Each sample was weighed and divided into 2 subsamples. One was placed in a paper bag, weighed, dried in a forced-draught oven at 65 °C for 72 hours and reweighed. The other subsample was separated into its morphological components (live leaf lamina, live stem and dead material). The parts of the leaf lamina and stem that showed no signs of senescence were considered live leaf lamina and live stem. On the other hand, the parts of the stem and leaf lamina with senescence, i.e. yellowing or necrosis signs, were incorporated into the fraction of dead material. After this classification the components were placed in a forced-draught oven, dried for 72 hours at 65 °C and weighed and the mass of each morphological component was calculated.

Bulk densities of the pasture morphological components were calculated by dividing the mass of each

morphological component by the mean height of that particular pasture condition.

The number of basal and live tillers was quantified by counting the tillers contained within a rectangle of 25 × 50 cm. Three counts per experimental unit (paddock) were performed in places where the plants were representative of the average sward surface height.

From each paddock, 50 live leaf laminae were collected at random. A small portion of the ends of these leaf laminae (apex and base) was cut off and discarded, so that an approximately rectangular leaf segment remained. The width and length of each segment were measured and, by the product of these dimensions, leaf area of the leaf segments was obtained. The segments were placed in a forced-air oven at 65 °C for 72 hours and then weighed. Specific leaf area was calculated by dividing the areas of all leaf segments by their weights. Leaf area index was obtained by multiplying specific leaf area by live leaf mass of the pasture.

Data were submitted to analysis of variance in a complete randomized design using the PROC MIXED of the SAS. The covariance matrices were chosen using the Akaike information criterion (Wolfinger 1993). The effects of grazing conditions, grazing period and their interaction were considered as fixed effects. Grazing periods were considered measures repeated over time. The means were compared by the Tukey test ( $P < 0.05$ ).

## Results

Among all variables analyzed, 3 were influenced ( $P < 0.05$ ) by sward condition at the late winter × grazing period interaction (Table 3): mass and bulk density of live stem

and tiller number. All other variables were influenced ( $P < 0.05$ ) by isolated factors (Tables 1 and 2).

During the grazing period, short, medium, tall and tall/mowed pastures had average sward surface heights of 24.2, 26.9, 22.6 and 24.2 cm, respectively. At the beginning, middle and end of the grazing period, average sward surface heights were 25.6, 25.9 and 21.9 cm.

During the whole growing-season grazing period, live leaf lamina mass and leaf area index (LAI) were lower in tall pastures (in late winter) than in other pasture conditions. On the other hand, mass and bulk density of dead material were greatest in the tall pasture, intermediate in the low and medium pastures and lowest in the tall/mowed pasture. Live leaf lamina bulk density was lower in tall pasture than in tall/mowed pasture (Table 1).

Live leaf lamina mass and LAI were lower at the beginning of the growing-season grazing period than at the middle and end of this period ( $P < 0.05$ ). However, the opposite was the case for mass and bulk density of dead material. Live leaf lamina bulk density increased progressively as the grazing period progressed ( $P < 0.05$ ; Table 2).

Stem bulk density (SBD) was greater at the end than at the beginning and middle of the grazing period for short, medium and tall pastures. In the tall/mowed pasture, it was greatest at the end, intermediate in the middle and lowest at the beginning of the grazing period. At the beginning of the grazing period, the tall pasture presented greatest SBD, while the tall/mowed pasture was lowest; short and medium pastures presented intermediate SBD values (Table 3). By the middle of the grazing period, tall/mowed pasture had greater SBD than remaining pastures and this difference persisted to the end of the study.

**Table 1.** Mean values for the structural characteristics of *Marandu palisade grass* in the growing season (spring and summer) according to sward condition in late winter.

Characteristic <sup>1</sup>	Sward condition in late winter <sup>2</sup>				s.e.
	Short	Medium	Tall	Tall/mowed	
LLLM (kg DM/ha)	1,063a <sup>3</sup>	1,192a	893b	1,134a	64.8
DMM (kg DM/ha)	1,842b	1,940b	2,331a	1,234c	227.0
LLLBD (kg DM/ha/cm)	43.9ab	44.7ab	41.6b	47.4a	0.8
DMBD (kg DM/ha/cm)	76.4b	71.8b	102.7a	51.0c	10.6
LAI	3.1a	3.6a	2.6b	3.3a	0.2

<sup>1</sup>LLLM: live leaf lamina mass; DMM: dead material mass; LLLBD: live leaf lamina bulk density; DMBD: dead material bulk density; LAI: leaf area index.

<sup>2</sup>Short pasture: 15.1 cm and 4,600 kg DM/ha; Medium pasture: 23.2 cm and 5,940 kg DM/ha; Tall pasture: 31.4 cm and 7,640 kg DM/ha; Tall/mowed pasture: 31.3 cm and 7,200 kg DM/ha.

<sup>3</sup>For each characteristic means followed by different letters differ by the Tukey test ( $P < 0.05$ ).

**Table 2.** Mean values for the structural characteristics of Marandu palisade grass pastures during the growing-season grazing period (spring and summer).

Characteristic <sup>1</sup>	Grazing period			s.e.
	Beginning	Middle	End	
LLLM (kg DM/ha)	845b <sup>2</sup>	1,143a	1,224a	115.0
DMM (kg DM/ha)	2,289a	1,691b	1,530b	230.9
LLLBD (kg DM/ha/cm)	33.0c	44.1b	56.1a	6.7
DMBD (kg DM/ha/cm)	88.7a	66.1b	71.6b	6.8
LAI	2.5b	3.4a	3.6a	0.3

<sup>1</sup>LLLM: live leaf lamina mass; DMM: dead material mass; LLLBD: live leaf lamina bulk density; DMBD: dead material bulk density; LAI: leaf area index.

<sup>2</sup>For each characteristic, means followed by different letters differ by the Tukey test ( $P < 0.05$ ).

**Table 3.** Structural characteristics of Marandu palisade grass pastures during the growing-season grazing period (spring and summer) relative to sward condition in late winter.

Stage of grazing period	Sward condition in late winter <sup>1</sup>				s.e.
	Short	Medium	Tall	Tall/mowed	
	Live stem bulk density (kg DM/ha/cm)				
Beginning	32.6bB <sup>2</sup>	35.8bB	39.4aB	17.0cC	4.9
Middle	32.0bB	33.8bB	33.5bB	43.7aB	2.7
End	46.1bA	43.2bA	45.9bA	56.3aA	2.9
	Live stem mass (kg DM/ha)				
Beginning	788bB	993aB	1,020aA	418cC	138.9
Middle	831bB	940bB	805bB	1,120aB	71.6
End	1,032bA	1,084bA	816cB	1,261aA	91.6
	Number of tillers/m <sup>2</sup>				
Beginning	560aC	448bC	392bC	417bC	37.1
Middle	724aB	745aB	631bB	727aB	25.7
End	956aA	884aA	964aA	912aA	18.9

<sup>1</sup>Short pasture: 15.1 cm and 4,600 kg DM/ha; Medium pasture: 23.2 cm and 5,940 kg DM/ha; Tall pasture: 31.4 cm and 7,640 kg DM/ha; Tall/mowed pasture: 31.3 cm and 7,200 kg DM/ha.

<sup>2</sup>Means within rows followed by the same lower-case letter and within columns followed by the same upper-case letter do not differ by the Tukey test ( $P > 0.05$ ).

Live stem mass (LSM) was greater at the end than at the beginning and middle of the grazing period for short and medium pastures. For tall pastures, LSM was greater at the beginning than at the middle and end of the grazing period, while LSM increased throughout the grazing period for tall/mowed pasture. While LSM was lowest in the tall/mowed pasture at the beginning of grazing, it was highest by the end of the grazing period (Table 3).

For all pasture conditions, tiller number increased during the grazing period. While short pasture had more tillers than other pastures at the beginning of this period, tiller numbers in all swards were similar by the end of grazing (Table 3).

## Discussion

This study has provided valuable information on the impacts of sward height at the end of winter on sward structure during the grazing period in spring and summer.

It was hypothesized that sward height of deferred pasture in late winter would have an impact on tiller production in spring and that mowing tall pasture at this time might stimulate tiller production. Interestingly, the short pasture had more tillers/m<sup>2</sup> at the commencement of grazing than the remaining 3 treatments, but by the end of the grazing period in early February tiller numbers were similar on all treatments. However, tiller numbers alone do not tell the whole story, as live stem mass at the commencement of grazing was greatest in medium and tall pastures and lowest in the mowed pasture. By the end of grazing, the mowed pasture had the greatest live stem mass and the tall pasture had the least.

Another interesting finding from the study was that presentation mass of green leaf material increased from 845 kg DM/ha at commencement of grazing to 1,224 kg DM/ha at the end of growing-season grazing, despite sheep numbers being manipulated to maintain a sward height of 25 cm. In contrast, stem mass declined during the same

period from 2,289 to 1,530 kg DM/ha. This situation developed despite the fact that sheep are known to actively select for green leaf.

During the entire grazing period, mean values for sward surface height did not vary by more than 10% of the goal (25 cm), remaining within the range recommended by Da Silva et al. (2013), which is 20–40 cm.

The greater tiller number in the short pasture at the beginning of the grazing period (Table 3) may have been a consequence of previous management of the pasture. This pasture was kept at 15 cm before the deferment period, which probably resulted in a higher incidence of light at the base of the plants, stimulating tillering (Matthew et al. 2000; Santana et al. 2014). Thus, even with the typical tiller mortality during the deferment period (Santos et al. 2018) and in winter (Da Silva et al. 2015b), the large number of tillers in this pasture before the deferment period was probably responsible for its greater tiller numbers at the beginning of the grazing period during the new growing season.

On the other hand, in the middle of the grazing period, the tall pasture had fewer tillers than the other pastures (Table 3). This may have been a reflection of fewer tillers in the tall pasture at the beginning of the grazing period. In fact, at the beginning of the grazing season, tiller numbers in tall pasture were 30, 12 and 6% fewer than in short, medium and tall/mowed pastures, respectively. This fact can also be attributed to previous management of this pasture, which was kept taller (45 cm) before the deferment period.

Tall pasture contained a high proportion of old and dead tillers from the winter, due to the low temperatures and rainfall during this season (Figures 1 and 2), resulting in greater mass and bulk density of dead material in the tall pasture (Table 1). Paiva et al. (2012) defined young tillers as up to 60 days old, mature tillers as 61–120 days old and old tillers as more than 120 days old. Furthermore, old tillers present greater dead leaf lamina percentage and lower live leaf lamina percentage than young tillers (Santos et al. 2018).

On the other hand, the tall/mowed pasture presented the lowest values for mass and bulk density of dead material (Table 1), as well as lower values for mass and bulk density of live stem at the beginning of the grazing period than other treatments (Table 3). These results occurred because mowing removed most of the old forage from winter including dead material and stem. Souza et al. (2015) compared sward structure of *Marandu palisade grass* in early summer after it was cut in winter with that of a sward only grazed by sheep under continuous stocking and found bulk density of dead material in the grazed sward was higher than in the mowed sward.

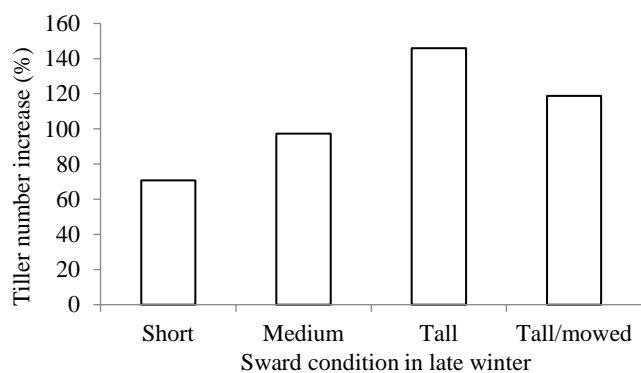
Live leaf lamina bulk density and live leaf mass were greater in the tall/mowed pasture than in tall pasture (Table 1), due to the greater number of tillers at the beginning (trend) and middle (significant) of the grazing period in the tall/mowed pasture than in tall pasture (Table 3). Souza et al. (2015), working with *Marandu palisade grass*, also found that in early summer, percentage and bulk density of live leaf lamina and leaf area index were higher in tall/mowed pasture than in tall pasture from late winter. These authors concluded that mowing of *Marandu palisade grass* with high forage mass in late winter improved the sward structure in early summer.

The tall pasture still had, at the beginning of the grazing period, many old tillers with more developed stems (Santos et al. 2018), coming from the previous winter. Therefore, in the tall pasture, the live stem mass was higher at the beginning than at the end of the grazing period (Table 3). On the other hand, live stem mass in the other pastures increased from beginning to end of the grazing period (Table 3). This occurred probably because an intense tillering renewal at the beginning of the grazing period increased the number of young tillers in the pastures. As young tillers have shorter stems (Paiva et al. 2012), this may have contributed to the lower mass and bulk density of live stem at the beginning of the grazing period (Table 3). However, by the middle and end of the grazing period, these young tillers were already developed and would have contributed to the greater mass of live stem in this sward condition (Table 3). Our results corroborate those of Sbrissia and Da Silva (2008) who evaluated *Marandu palisade grass* under continuous stocking and with 4 sward surface heights. In that work, tiller weight increased and tiller leaf:stem ratio decreased from early to late spring indicating that tillers developed during the spring. This argument would also explain the increase in live stem density in all pastures during the grazing period (Table 3). Pereira et al. (2010) also reported an increase in stem bulk density from late spring to summer in continuously stocked *Marandu palisade grass* swards fertilized with nitrogen.

It was hypothesized that tillering would be severely impaired due to the high amount of forage cut and deposited on the base of the plants, which would prevent sunlight from acting as a trigger for the development of basal tiller buds (Matthew et al. 2000; Sousa et al. 2013; Costa et al. 2016; Pessoa et al. 2016). However, if this effect occurred, it was restricted to the beginning of the grazing period, since by the middle of this period tiller numbers in the tall/mowed pasture were similar to those in the short pasture (Table 3). Probably, mowing of the tall pasture removed apical meristems from many tillers, reducing the production of hormones responsible for

apical dominance, which may have stimulated tillering (Santos et al. 2010). Another factor that may have contributed to tillering of the pastures at the beginning of the grazing period may be the stock of reserve compounds. During winter, low growth of tropical grasses results in low demand for reserve compounds (Da Silva et al. 2015a), which are thus available for tillering in the spring.

At the end of the grazing period, there was no difference in tiller number between swards (Table 3), possibly because all pastures were maintained at the same average sward surface height of 25 cm, as recommended by Sbrissia et al. (2010) and Da Silva et al. (2013) for Marandu palisade grass under continuous stocking. The similar numbers of tillers at the end of the grazing period indicate that all pastures had recovered their tiller population. However, the highest percentage increase was observed in the tall pasture (Figure 4).



**Figure 4.** Percentage increase in tiller number, from the beginning to the end of the growing-season grazing period (spring and summer), according to sward condition in late winter.

With the exception of mass and bulk density of live stem (Table 3), all structural characteristics of Marandu palisade grass presented patterns of responses (Tables 2 and 3) that indicated improvement of sward structure during the grazing period. In fact, mass and bulk density of live leaf lamina increased from the beginning to the end of the grazing period. Live leaf lamina is the principal organ responsible for canopy photosynthesis (Peri et al. 2003), has a higher nutritive value (Nave et al. 2010) and is preferentially consumed by grazing animals (Benvenuti et al. 2006). On the other hand, mass and bulk density of dead material decreased from the beginning to the end of the grazing period (Table 2). Dead material can shade the basal buds and delay tillering (Santana et al. 2014), has lower nutritive value (Santos et al. 2008) and is avoided by grazing animals (Sousa et al. 2018). These results are a consequence of the natural pattern of tiller renewal during spring (Sbrissia et al. 2010; Da Silva et al.

2015b), due to the improvement of climatic conditions (Figures 1 and 2). This improvement in climatic conditions from spring was also responsible for the increase in tiller numbers during the grazing period in all swards (Table 3). In line with our results, Pereira et al. (2010) found an increase in live leaf bulk density and a decrease in dead material bulk density from early spring to summer in continuously stocked Marandu palisade grass fertilized with nitrogen.

The results presented in our study (Tables 1, 2 and 3) showed that sward structure of tall pasture in late winter limits plant growth in spring, since its low LAI values can compromise light interception by the canopy and limit photosynthesis and forage production (Peri et al. 2003). Greater values of mass and bulk density of dead material in tall pasture can also increase the shading at the base of the canopy and delay tillering (Santana et al. 2014). In addition, greater mass and bulk density of dead material can adversely affect the selection of live leaf lamina by grazing animals, with probable negative effects on animal performance (Sousa et al. 2018).

Mowing of tall pasture appears to be a technically feasible option for improving sward structure during spring and summer. However, cost of labor and fuel during the mowing operation should be considered in deciding whether or not to use this technique as a pasture management strategy. In this sense, keeping pasture short in late winter appears to be a more appropriate option, when the objective is the improvement of sward structure in spring. With short pasture it is unnecessary to increase costs by mowing and additionally tiller numbers in early spring are not reduced.

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## References

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- Alvares CA; Stape JL; Sentelhas PC; Gonçalves JLM; Sparovek G. 2013. Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift* 22:711–728. doi: [10.1127/0941-2948/2013/0507](https://doi.org/10.1127/0941-2948/2013/0507)
- Benvenuti MA; Gordon IJ; Poppi DP. 2006. The effect of the density and physical properties of grass stems on the foraging behaviour and instantaneous intake rate by cattle



- grazing an artificial reproductive tropical sward. *Grass and Forage Science* 61:272–281. doi: [10.1111/j.1365-2494.2006.00531.x](https://doi.org/10.1111/j.1365-2494.2006.00531.x)
- Costa LKP; Santos MER; Silva GP; Carvalho BHR; Pessoa DD; Galzerano L; Silva NAM. 2016. Reduction of sward height in the fall/winter as strategy to optimize tillering in *Urochloa brizantha* syn. *Brachiaria brizantha*. *Archivos de Zootecnia* 65:499–506. [bit.ly/2EXYOvn](https://doi.org/bit.ly/2EXYOvn)
- Da Silva SC; Carvalho PCF. 2005. Foraging behaviour and intake in the favourable tropics/sub-tropics. In: McGilloway DA, ed. *Grassland: A global resource*. Wageningen Academic Publishers, The Netherlands. p. 81–95. doi: [10.3920/978-90-8686-551-2](https://doi.org/10.3920/978-90-8686-551-2)
- Da Silva SC; Gimenes FMA; Sarmento DOL; Sbrissia AF; Oliveira DE; Hernandez-Garay A; Pires AV. 2013. Grazing behaviour, herbage intake and animal performance of beef cattle heifers on marandu palisade grass subjected to intensities of continuous stocking management. *The Journal of Agricultural Science* 151:727–739. doi: [10.1017/S0021859612000858](https://doi.org/10.1017/S0021859612000858)
- Da Silva SC; Pereira LET; Sbrissia AF; Hernandez-Garay A. 2015a. Carbon and nitrogen reserves in marandu palisade grass subjected to intensities of continuous stocking management. *The Journal of Agricultural Science* 153:1449–1463. doi: [10.1017/S0021859614001130](https://doi.org/10.1017/S0021859614001130)
- Da Silva SC; Sbrissia AF; Pereira LET. 2015b. Ecophysiology of C<sub>4</sub> forage grasses: Understanding plant growth for optimising their use and management. *Agriculture* 5:598–625. doi: [10.3390/agriculture5030598](https://doi.org/10.3390/agriculture5030598)
- Fonseca L; Carvalho PCF; Mezzalira JC; Bremm C; Galli JR; Gregorini P. 2013. Effect of sward surface height and level of herbage depletion on bite features of cattle grazing *Sorghum bicolor* swards. *Journal of Animal Science* 91:4357–4365. doi: [10.2527/jas.2012-5602](https://doi.org/10.2527/jas.2012-5602)
- Matthew C; Assuero SG; Black CK; Hamilton NRS. 2000. Tiller dynamics of grazed swards. In: Lemaire G; Hodgson J; Moraes A de; Nabinger C; Carvalho PCF, eds. *Grassland ecophysiology and grazing ecology*. CABI Publishing, Wallingford, UK. p. 127–150. doi: [10.1079/9780851994529.0127](https://doi.org/10.1079/9780851994529.0127)
- Mezzalira JC; Carvalho PCF; Fonseca L; Bremm C; Cangiano C; Gonda HL; Laca EA. 2014. Behavioural mechanisms of intake rate by heifers grazing swards of contrasting structures. *Applied Animal Behaviour Science* 153:1–9. doi: [10.1016/j.applanim.2013.12.014](https://doi.org/10.1016/j.applanim.2013.12.014)
- Mott GO; Lucas HL. 1952. The design, conduct, and interpretation of grazing trials on cultivated and improved pastures. *Proceedings of the 6th International Grassland Congress, State College, Pennsylvania, 17-23 August 1952. Volume 2*. State College Press, PA, USA. p. 1380–1385.
- Nave RLG; Pedreira CGS; Pedreira BC. 2010. Nutritive value and physical characteristics of Xaraes palisadegrass as affected by grazing strategy. *South African Journal of Animal Science* 40:285–293. doi: [10.4314/sajas.v40i4.65236](https://doi.org/10.4314/sajas.v40i4.65236)
- Paiva AJ; Da Silva SC; Pereira LET; Guarda VDA; Pereira PM; Caminha FO. 2012. Structural characteristics of tiller age categories of continuously stocked marandu palisade grass swards fertilized with nitrogen. *Revista Brasileira de Zootecnia* 41:24–29. doi: [10.1590/S1516-35982012000100004](https://doi.org/10.1590/S1516-35982012000100004)
- Pereira LET; Paiva AJ; Da Silva SC; Caminha FO; Guarda VD; Mesquita P. 2010. Sward structure of marandu palisadegrass subjected to continuous stocking and nitrogen-induced rhythms of growth. *Scientia Agrícola* 67:531–539. doi: [10.1590/S0103-90162010000500006](https://doi.org/10.1590/S0103-90162010000500006)
- Peri PL; Moot DJ; McNeil DL; Lucas RJ. 2003. Modelling net photosynthetic rate of field-grown cocksfoot leaves to account for regrowth duration. *New Zealand Journal of Agricultural Research* 46:105–115. doi: [10.1080/00288233.2003.9513536](https://doi.org/10.1080/00288233.2003.9513536)
- Pessoa DD; Cardoso RC; Santos MER; Carvalho BHR; Silva GP; Silva NAM. 2016. Tillering of Marandu palisadegrass maintained at fixed or variable heights throughout the year. *Tropical Grasslands-Forrajes Tropicales* 4:101–111. doi: [10.17138/TGFT\(4\)101-111](https://doi.org/10.17138/TGFT(4)101-111)
- Santana SS; Fonseca DM da; Santos MER; Sousa BML; Gomes VM; Nascimento Júnior D do. 2014. Initial height of pasture deferred and utilized in winter and tillering dynamics of signal grass during the following spring. *Acta Scientiarum: Animal Sciences* 36:17–23. doi: [10.4025/actascianimsci.v36i1.20463](https://doi.org/10.4025/actascianimsci.v36i1.20463)
- Santos MER; Fonseca DM da; Euclides VPB; Ribeiro Júnior JI; Balbino EM; Casagrande DR. 2008. Forage nutritional value and its morphological components on *Brachiaria decumbens* stockpiled forage. *Boletim da Indústria Animal* 65:303–311. (In Portuguese). [bit.ly/35236NI](https://doi.org/bit.ly/35236NI)
- Santos MER; Fonseca DM da; Gomes VM; Silva SP da; Pimentel RM. 2010. Basal and aerial tillers morphology in *Brachiaria decumbens* pastures managed under continuous stocking. *Enciclopédia Biosfera* 6:1–13. (In Portuguese). [bit.ly/2QC7IB8](https://doi.org/bit.ly/2QC7IB8)
- Santos MER; Fonseca DM da; Gomes VM. 2013. Forage accumulation in brachiaria grass under continuous grazing with single or variable height during the seasons of the year. *Revista Brasileira de Zootecnia* 42:312–318. doi: [10.1590/S1516-35982013000500002](https://doi.org/10.1590/S1516-35982013000500002)
- Santos MER; Avila AB; Carvalho AN de; Rocha GO; van Cleef FOS; Segatto BN; Vasconcelos KA; Pereira RS. 2018. Marandu palisade grass management strategies at the beginning of the deferment period and effects on tillering. *Semina: Ciências Agrárias* 39:1617–1626. doi: [10.5433/1679-0359.2018v39n4p1617](https://doi.org/10.5433/1679-0359.2018v39n4p1617)
- Sbrissia AF; Da Silva SC. 2008. Tiller size/density compensation in Marandu palisadegrass swards. *Revista Brasileira de Zootecnia* 37:35–47. (In Portuguese). doi: [10.1590/S1516-35982008000100005](https://doi.org/10.1590/S1516-35982008000100005)
- Sbrissia AF; Da Silva SC; Sarmento DOL; Molan LK; Andrade FME; Gonçalves AC; Lupinacci AV. 2010. Tillering dynamics in palisadegrass swards continuously stocked by cattle. *Plant Ecology* 206:349–359. doi: [10.1007/s11258-009-9647-7](https://doi.org/10.1007/s11258-009-9647-7)
- Silva CS; Montagner DB; Euclides VPB; Queiroz CA; Andrade RAS. 2016. Steer performance on deferred pastures of *Brachiaria brizantha* and *Brachiaria decumbens*. *Ciência Rural* 46:1998–2004. doi: [10.1590/0103-8478cr20151525](https://doi.org/10.1590/0103-8478cr20151525)

Sousa BML; Santos MER; Vilela HH; Silveira MCT da; Rocha GO; Freitas CAS; Silva NAM da; Nascimento Júnior D do. 2013. Piata palisade grass deferred with two distinct initial heights: Luminous environment and tillering dynamics. *Revista Brasileira de Zootecnia* 42:36–43. doi: [10.1590/S1516-35982013000100006](https://doi.org/10.1590/S1516-35982013000100006)

Sousa DOC de; Santos MER; Fonseca DM; Macedo Junior GL; Silva SP. 2018. Sheep production during the rainy season in marandu palisadegrass swards previously utilized under deferred grazing. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia* 70:554–562. doi: [10.1590/1678-4162-9414](https://doi.org/10.1590/1678-4162-9414)

Souza DOC de; Fernandes WB; Silva GF; Santos MER; Silva SP da. 2015. The cut of high marandu palisade grass in late winter better the pasture structure in early summer. *Enciclopédia Biosfera* 11:12–22. (In Portuguese). [bit.ly/3hWK3Hu](https://bit.ly/3hWK3Hu)

Thornthwaite CW; Mather JR. 1955. The water balance. *Publications in Climatology* 8. Drexel Institute of Technology, Centerton, NJ, USA. [bit.ly/3hKQNIp](https://bit.ly/3hKQNIp)

Wolfinger R. 1993. Covariance structure selection in general mixed models. *Communications in Statistics - Simulation and Computation* 22:1079–1106. doi: [10.1080/03610919308813143](https://doi.org/10.1080/03610919308813143)

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