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Research Paper

Reduction of sward height in the fall and winter as a strategy to improve the structure of marandu palisadegrass (*Urochloa brizantha* syn. *Brachiaria brizantha* cv. Marandu)

Reducción de la altura del pasto en otoño e invierno como estrategia para mejorar la estructura de una pastura de Urochloa *(sin.* Brachiaria*)* brizantha *cv. Marandu*

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Abstract

The objective of this study was to identify defoliation strategies that might improve the structure of *Urochloa brizantha* (syn. *Brachiaria brizantha*) cv. Marandu (marandu palisadegrass). The following 3 defoliation strategies were compared in a plot study: sward kept at 15 cm in fall and winter (W) and 30 cm in spring (Sp) and summer (Su) (15W-30Sp-30Su); sward kept at 30 cm during the entire experimental period (30W-30Sp-30Su); and sward kept at 45 cm in fall and winter and 30 cm in spring and summer (45W-30Sp-30Su). The experimental design was completely randomized, with 4 replicates. Plots were cut with shears to the appropriate height weekly in winter and twice weekly in spring, summer and fall. Tiller density, mean tiller weight, leaf area index, forage mass, percentage of live leaf blades and percentage of stems were measured every 28 days. Forage mass in winter was directly related to pasture height (P<0.05) but differences had disappeared by summer (P>0.05). Mean tiller density was independent of cutting height but was higher in spring and summer than in winter (P<0.05). Mean tiller weight in winter was directly related to cutting height (P<0.05) but differences had disappeared by summer. The percentage of live leaf blades in the swards was affected by season with spring>summer>winter and by cutting height in fall/winter with leaf percentage inversely related to cutting height. Stem percentage in the swards in winter was directly related to cutting height. Grazing studies seem warranted to determine if these plot results are reflected under grazing conditions and what the impacts are on animal performance.

Keywords: Herbage mass, leaf area index, morphological composition, tillering.

Resumen

El objetivo del estudio, conducido en Uberlândia, Minas Gerais, Brasil, fue identificar estrategias de defoliación con el fin de mejorar la estructura de una pastura de *Urochloa brizantha* (sin. *Brachiaria brizantha*) cv. Marandu. Se compararon 3 estrategias: (1) mantener el pasto a una altura de 15 cm en otoño e invierno (W) y de 30 cm en primavera (Sp) y verano (Su) (15W-30Sp-30Su); (2) mantener el pasto a una altura de 30 cm durante todo el período experimental (30W-30Sp-30Su); y (3) mantener el pasto a una altura de 45 cm en otoño e invierno y de 30 cm en primavera y verano (45W-30Sp-30Su). El diseño experimental fue completamente al azar, con 4 repeticiones. Las parcelas se cortaron con tijeras a la altura respectiva semanalmente en invierno y 2 veces por semana en primavera, verano y otoño. Cada 28 días

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se midieron la densidad de brotes, el peso medio de los brotes, el índice de área foliar, la masa de forraje, el porcentaje de hojas vivas y el porcentaje de tallos. La masa forrajera en invierno se relacionó directamente con la altura del pasto (P<0.05), pero las diferencias desaparecieron en verano (P>0.05). La densidad media de los brotes fue independiente de la altura de corte, pero fue mayor en primavera y verano que en invierno (P<0.05). El peso medio de los brotes en invierno estuvo directamente relacionado con la altura de corte (P <0.05), pero las diferencias desaparecieron en verano. El porcentaje de hojas vivas en la pastura se vio afectado por la estación del año, con primavera>verano>invierno y por la altura de corte en otoño/invierno cuando el porcentaje de hojas estuvo inversamente relacionado con la altura de corte. El porcentaje de tallos en invierno estuvo directamente relacionado con la altura de corte. Estudios de pastoreo parecen justificados para determinar si estos resultados, obtenidos a nivel de parcela de corte, se reflejan bajo condiciones de pastoreo, y cuáles son los impactos en la producción animal.

Palabras clave: Composición morfológica, índice de área foliar, masa forrajera, rebrotes.

Introduction

Pasture structure is a function of how the organs of the aerial parts of forage plants are distributed in the pasture, both vertically (Zanini et al. 2012) and horizontally (Barthram et al. 2005). Some parameters used to describe pasture structure are: sward height, forage mass, volume and density (Carvalho et al. 2009).

Pasture height is highly correlated with forage mass and morphological composition (Paula et al. 2012; Nantes et al. 2013), in addition to being a cheap, easy and quick measurement. For this reason, average pasture height has been recommended as a management criterion for when to commence and cease grazing (Silva and Nascimento Júnior 2007). Studies on grazing management strategies, based on pasture height, enable the understanding of variations in pasture structure, as well as the responses of animals and plants to these variations (Trindade et al. 2007; Fonseca et al. 2012, 2013).

Sbrissia et al. (2010) suggested that the optimal height range for management of marandu palisadegrass (*Urochloa brizantha* syn. *Brachiaria brizantha* cv. Marandu) under continuous grazing during the rainy season was 20–40 cm. However, Santos et al. (2013) suggested that pasture height should be adjusted according to the season of the year to optimize the productivity of the pasture. Other studies, e.g. Sbrissia and Silva (2008) and Giacomini et al. (2009), indicated that plant development is often affected by interactions between defoliation management strategies and season of the year, which suggests that the success of a particular management strategy might differ between seasons. On the basis of these findings, we conclude that grazing management strategies should be flexible over the year and vary with seasonal conditions.

Maintaining the sward shorter during winter, the season with adverse climate and in which the plant has the lowest rate of photosynthesis (Lara and Pedreira 2011a), could result in lower maintenance respiration by the plants, which would provide greater energy and carbon balance in the sward (Taiz and Zeiger 2012). In contrast, keeping pasture tall in winter would increase the energy needs for survival of individual plants, precisely when photosynthesis is at its lowest point.

Moreover, Santana et al. (2014) suggested that the greater shading at the plant base, inherent in taller pastures, would lead to greater leaf senescence at the lower canopy stratum, which might inhibit tillering in early spring. On the other hand, pasture grazed short in winter would permit greater incidence of light at the base of the sward in spring, which should stimulate the appearance of young tillers (Paiva et al. 2012) with better structural traits (Barbosa et al. 2012).

We therefore hypothesize that, by varying sward height during fall and winter, it may be possible to modify physiological processes such as photosynthesis and respiration as well as plant development, e.g. tillering and leaf senescence. All these processes, in turn, may change sward structure not only in fall and winter, the seasons in which plant height is changed, but also in subsequent ones.

This study was conducted to characterize the structural changes of a marandu palisadegrass sward maintained at various sward heights in fall and winter, and kept at a constant height in spring and summer. This knowledge should prove beneficial in formulating recommendations regarding defoliation strategies for this forage plant throughout the year.

Materials and Methods

The experiment was conducted from March 2013 to March 2014, on the Capim Branco farm, belonging to the Faculty of Veterinary Medicine of the Federal University of Uberlândia, in Uberlândia, MG, Brazil (18º53’19” S, 48°20’57” W; 776 masl). The climate in the region of

Uberlândia, according to the Köppen (1948) classification, is a Cwa altitude tropical type, with mild and dry winters and well defined dry and rainy seasons. The average annual temperature is 22.3 ºC, with mean maximum and minimum values of 23.9 and 19.3 ºC, respectively. Average annual precipitation is 1,584 mm.

The experiment was developed on a pasture of *Urochloa brizantha* syn. *Brachiaria brizantha* cv. Marandu (palisadegrass), established in the year 2000, and well managed with cattle. Twelve plots (experimental units) with an area of 12 m^2 each were used. A border area of 0.25 m wide was discarded leaving a usable area of 8.75 m^2 on each plot for data collection.

Climatic conditions during the experimental period were monitored at the meteorological station, located approximately 200 m from the experimental area (Figures 1 and 2).

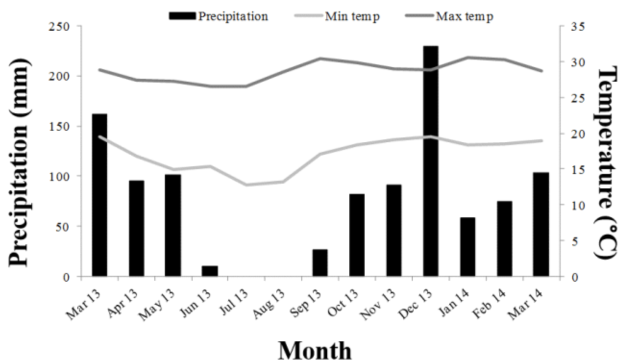

Figure 1. Monthly mean minimum and maximum temperatures and precipitation from March 2013 to March 2014. The seasons are: winter, July–September 2013; spring, October–December 2013; and summer, January–March 2014.

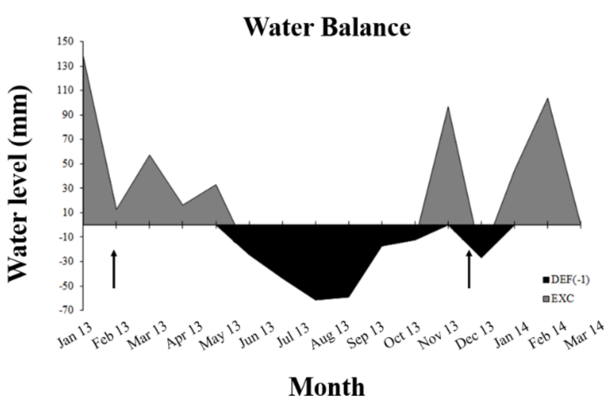

Figure 2. Summary of the water balance in the soil from January 2013 to April 2014. Arrows indicate the time when fertilizer was applied. The seasons are: winter, July–September 2013; spring, October–December 2013; and summer, January–March 2014. DEF (-1) = Deficit; EXC = Excess.

Before the experiment commenced, soil samples from the 0–10 cm layer were collected and analyzed, revealing the following chemical properties: pH in H_2O - 6.1; P - 9.4 mg/dm^3 (Mehlich-1); K^+ - 156 mg/dm^3; Ca^{2+} - 5.5 cmol$_c$/dm^3; Mg^{2+} - 1.7 cmol$_c$/dm^3; Al^{3+} - 0.0 cmol$_c$/dm^3 (KCl 1 mol/L); effective CEC - 7.6; CEC at pH 7.0 - 10.3; and base saturation - 74%. Based on these results, 35.5 kg P/ha as single superphosphate, 50 kg N/ha as urea and 41.5 kg K/ha as KCl were broadcast on the plots in February 2013. These same amounts were applied again in January 2014.

Three defoliation strategies were evaluated, characterized by the heights at which the marandu palisadegrass sward was maintained during fall and winter (15, 30 and 45 cm), with a standard height of 30 cm during spring and summer. To maintain the grass at these heights, the swards were cut with pruning shears once a week in winter and twice a week during spring, summer and fall. This approach aimed to ensure that the actual heights of the canopies remained within 100–110% of the desired values. The first strategy, with marandu palisadegrass maintained at 15 cm in fall and winter and 30 cm in spring and summer, equated with heavy defoliation during winter and moderate defoliation subsequently. For the second strategy the pasture was maintained at 30 cm during the entire experimental period, according to the recommendations of Sbrissia and Silva (2008), i.e. moderate defoliation throughout. The third strategy consisted of maintaining the grass at 45 cm in fall and winter, i.e. only light defoliation, and at 30 cm in spring and summer.

The experimental period during which pasture measurements occurred was divided into winter (July–September 2013), spring (October–December 2013) and summer (January–March 2014). The experimental design was completely randomized, with 4 replicates.

The fall (March–June 2013) was considered the period of acclimation of the plants to the particular sward heights. From June 2013, at 28-day intervals, tiller density was evaluated by counting the live tillers within two 50 × 25 cm metal frames randomly located in each experimental unit. The data were grouped according to season.

Monthly, in each season of the year and on each plot, a sample of 50 tillers with average length similar to the sward height was chosen. These tillers were harvested at ground level and divided into live leaf blade, dead leaf blade and live stem (stem + leaf sheath). Parts of the leaf blade that did not show signs of senescence (green organ) were incorporated into the live leaf blade fraction. Any part of the leaf blade with a yellowish tone and or necrosis was considered dead leaf blade. Each sub-sample (live leaf blade, dead leaf blade and live stem) from the 50 tillers was collected in a single paper bag, dried in an oven at 65 ºC for 72 h and then weighed together, in order to obtain the masses of the morphological components, and the mean weight of tillers was calculated. The masses of the sward morphological components were obtained by the following formula: FM = NT × TM, in which FM is the forage mass or the mass of the plant morphological component (kg DM/ha); NT is the number of tillers/10,000 m^2; and TM is the mass of the morphological component of the tiller (kg DM/tiller). The masses of the plant morphological components were expressed as percentages of the total forage mass.

After harvesting the tillers in each plot, 50 live leaf blades were also collected at random and placed in plastic bags. A small portion of the extremities of the leaf blades (apex and base) was cut and discarded, so as to generate an approximately rectangular leaf blade segment. The width and length of each segment were measured, and the leaf area of the leaf blade segments was calculated as the product of these dimensions. These segments were placed in a forced-ventilation oven at 65 ºC for 72 h and then weighed. With these data, the specific leaf area (cm^2 leaf blade/g dry leaf blade) was calculated. The leaf area index of each tiller was calculated as the product of the specific leaf area and the live leaf blade mass of the tiller. The pasture leaf area index, however, was obtained by multiplying the leaf area of the tiller by the number of tillers per ha.

For the data analysis, the results were grouped according to the season of the year (winter, spring and summer). Initially, the dataset was analyzed to check if it met the assumptions of the analysis of variance (normality and homogeneity). The data were then analyzed using the MIXED procedure (mixed models) of the SAS® (Statistical Analysis System) statistical package, version 9.2. The variance and covariance matrix was chosen using Akaike's Information Criterion (Wolfinger 1993). The treatment means were estimated using the "LSMEANS" option, and compared with each other by Student's t test at 5% probability.

Results

Tiller density in the palisadegrass was influenced only by season of the year (P = 0.035), with fewer tillers in winter than in spring and summer (Figure 3).

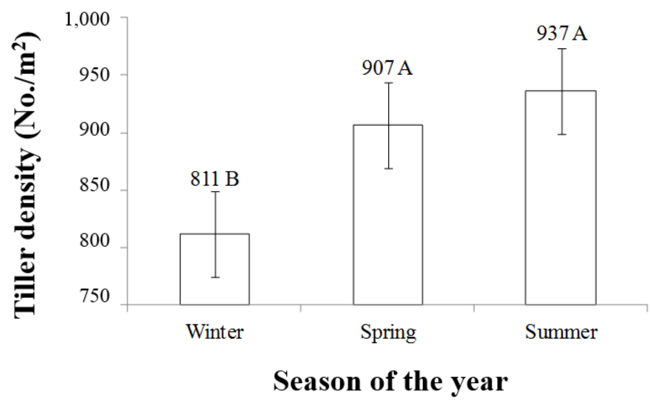

Figure 3. Effects of time of year on mean tiller density in palisadegrass swards.
Means followed by the same letter do not differ (P>0.05).

Mean tiller weight was influenced by defoliation strategy (P = 0.016) and by the interaction between this factor and season of the year (P = 0.024). In winter, tiller weight was greater in the sward maintained at 45 cm in fall/winter than in that at 15 cm, while in spring, the sward kept at 45 cm in fall/winter produced heavier tillers than that at 30 cm in fall/winter. However, by summer, mean tiller weight was similar for all defoliation strategies in fall/winter (Figure 4). The sward maintained at 45 cm in fall/winter produced similar sized tillers throughout (P>0.05), while the 30 cm sward in winter produced its smallest tillers in spring (P<0.05) and the 15 cm sward in winter produced progressively bigger tillers from winter to summer (P<0.05).

Forage mass in the marandu palisadegrass was influenced by season of the year (P = 0.013) and by the interaction between this factor and defoliation strategy (P = 0.009). In winter, forage mass was greatest in the sward maintained at 45 cm, intermediate in the sward maintained at 30 cm, and lowest in the sward maintained at 15 cm in fall/winter. In spring, forage mass in the sward maintained at 45 cm in fall/winter was greater than in that kept at 30 cm in fall/winter. However, forage mass in summer was independent of defoliation strategy in fall/winter (Figure 5).

The percentage of live leaf blades (PLLB) in the forage mass was influenced by both season of the year (P<0.0001) and defoliation strategy (P = 0.010). Overall PLLB followed the order: spring>summer>winter (Figure 6A), and was inversely related to height in winter (Figure 6B).

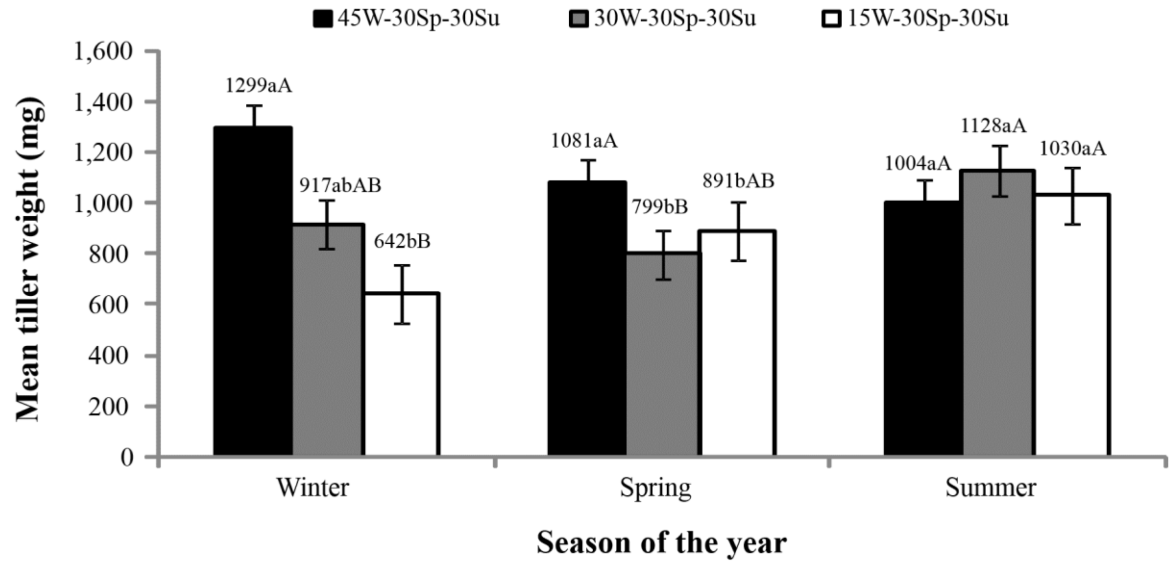

Figure 4. Effects of time of year and defoliation management on mean tiller weight in palisadegrass swards.
45W-30Sp-30Su: sward kept at 45 cm in winter and 30 cm in spring and summer; 30W-30Sp-30Su: sward kept at 30 cm in winter, spring and summer; and 15W-30Sp-30Su: sward kept at 15 cm in winter and 30 cm in spring and summer. Lowercase letters compare defoliation strategies within seasons of the year, and uppercase letters compare seasons of the year within each defoliation strategy. Means followed by the same letter do not differ (P>0.05).

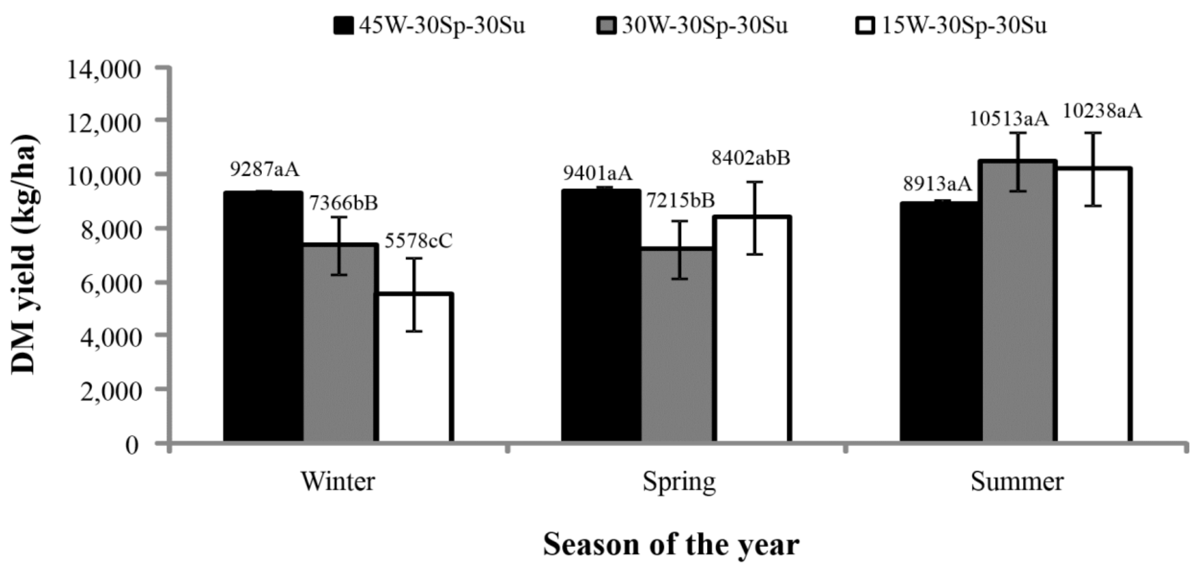

Figure 5. Effects of time of year and defoliation strategy on forage mass in palisadegrass swards.
45W-30Sp-30Su: sward kept at 45 cm in winter and 30 cm in spring and summer; 30W-30Sp-30Su: sward kept at 30 cm in winter, spring and summer; 15W-30Sp-30Su: sward kept at 15 cm in winter and 30 cm in spring and summer. Lowercase letters compare defoliation strategies within each season of the year, and uppercase letters compare seasons of the year within each defoliation strategy. Means followed by the same letter do not differ (P>0.05).

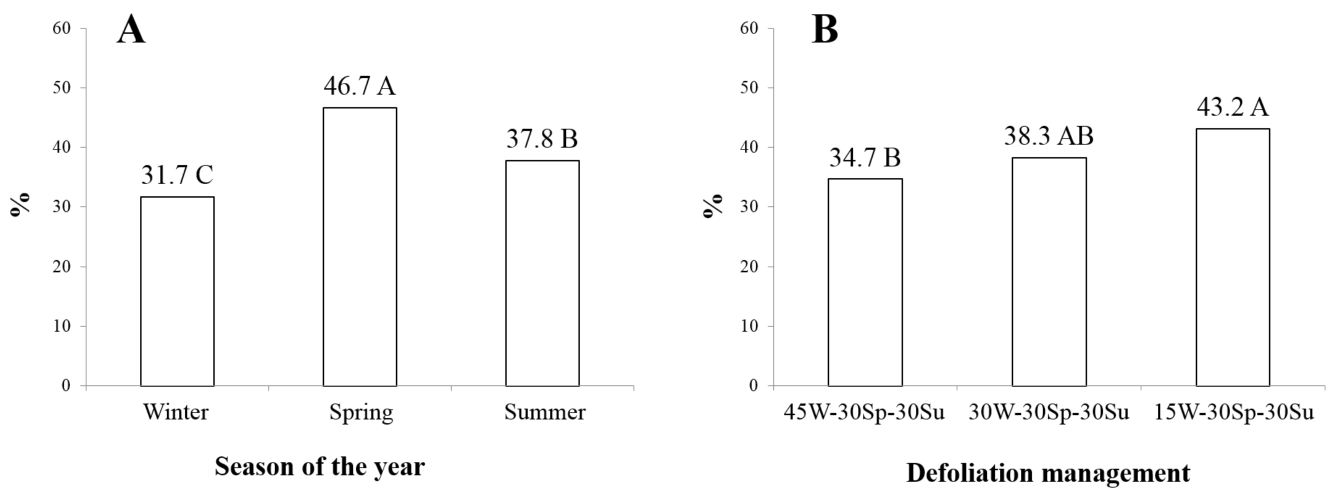

Figure 6. Percentage of live leaf blades in the forage mass of palisadegrass according to season of the year (A) and defoliation management strategy (B).
45W-30Sp-30Su: sward kept at 45 cm in winter and 30 cm in spring and summer; 30W-30Sp-30Su: sward kept at 30 cm in winter, spring and summer; and 15W-30Sp-30Su: sward kept at 15 cm in winter and 30 cm in spring and summer. In each graph, means followed by the same letter do not differ (P>0.05).

The percentage of stems (PS) was influenced by season of the year (P<0.0001), defoliation strategy (P = 0.0002) and the interaction of these factors (P = 0.007). In winter, the sward kept at 15 cm in fall and winter displayed a lower PS than those kept at 45 and 30 cm. During spring and summer, PS was independent of the sward height during the fall/winter period (Figure 7).

The percentage of dead material was not influenced by season of the year (P = 0.191), defoliation strategy (P = 0.575) or by the interaction of these factors (P = 0.305), averaging 23%.

Season of the year affected leaf area index (LAI) (P<0.0001), with a lower value in winter than in spring and summer (Figure 8).

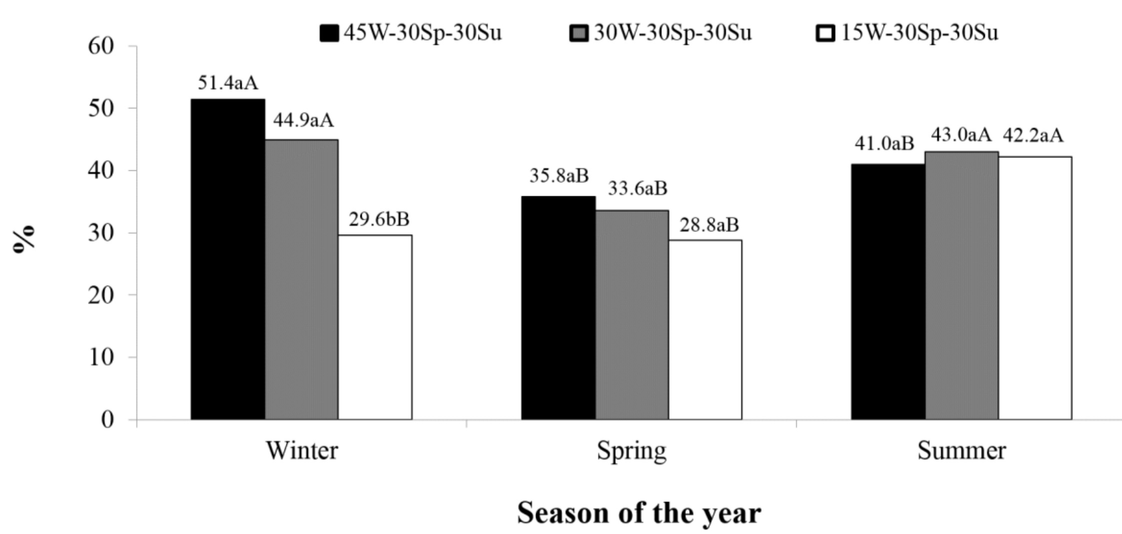

Figure 7. Percentage of live stems in the forage mass of palisadegrass according to time of year and defoliation strategy.
45W-30Sp-30Su: sward kept at 45 cm in winter and 30 cm in spring and summer; 30W-30Sp-30Su: sward kept at 30 cm in winter, spring and summer; 15W-30Sp-30Su: sward kept at 15 cm in winter and 30 cm in spring and summer. Lowercase letters compare defoliation strategies within each season of the year, and uppercase letters compare seasons of the year within each defoliation strategy. Means followed by the same letter do not differ (P>0.05).

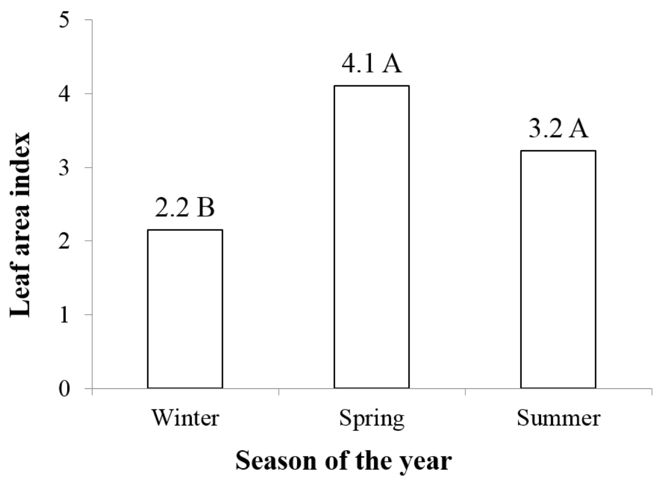

Figure 8. Leaf area index of palisadegrass according to season of the year.
Means followed by the same letter do not differ (P>0.05).

Discussion

This study has provided further valuable information on how the height, at which a marandu palisadegrass pasture is maintained in winter, spring and summer, affects the structure and composition of the pasture. This will be of use in explaining why pastures behave differently and have different levels of production under differing grazing strategies, especially in winter.

We hypothesized that keeping pasture short in winter would allow greater light penetration to the base of the sward, which might stimulate greater tiller development in spring as reported by Matthew et al. (2000) and Sbrissia et al. (2010). However, the defoliation strategy in fall/winter did not influence the number of tillers in the sward in spring and summer, which demonstrates the flexibility of marandu palisadegrass to variations in height in the fall and winter. During fall/winter tiller density was similar on all pastures regardless of sward height and increased following the onset of better conditions for growth in spring. Climatic conditions seemed to be the overriding factor. There was very little precipitation in June and no rain in July and August, with mean minimum temperature below 15 ºC (Figure 1). When the temperature is below 15 ºC, the lower threshold temperature for marandu palisadegrass (Mendonça and Rassini 2006), the rate of photosynthesis is impaired, which compromises tillering in the pasture. Sbrissia and Silva (2008), in a study with marandu palisadegrass under continuous stocking, also observed lower tiller density in winter than in spring and summer.

The adverse climatic conditions for plant growth in winter (Figure 1) might also have resulted in a lower percentage of live leaf in the forage mass in this season as compared with spring and summer (Figure 6A). Low temperatures and water deficit, typical of winter conditions, decrease leaf appearance and elongation rates (Lara and Pedreira 2011b), which would reduce the percentage of live leaves in the forage mass. A similar lower percentage of live leaves during winter was observed by Paula et al. (2012) in palisadegrass pastures continuously grazed at 15, 30 and 45 cm throughout the year.

The low tiller density in winter (Figure 3) was partially responsible for the low forage mass in swards maintained at 15 and 30 cm in fall/winter (Figure 5), as well as for the lower leaf area index (LAI) in all swards (Figure 8) in winter. Three structural traits could potentially change the sward LAI: tiller density, number of leaves per tiller and leaf blade size. Of these, tiller density has the greatest potential to change the LAI (Matthew et al. 2000). According to Fagundes et al. (2005), the low LAI of the pastures in winter would be a result of the lower number of live leaves per tiller and the shorter final length of the leaves at that time.

On the other hand, in spring and summer, the increase in temperature and occurrence of rainfall (Figure 1) provided favorable conditions for tillering, resulting in increased numbers of tillers (Figure 3), a typical response pattern observed in other research studies with forage grasses of the genus *Brachiaria* (Sbrissia and Silva 2008; Calvano et al. 2011). Lara and Pedreira (2011b) recorded twice as many tillers in summer as in winter in cvv. Marandu, Xaraés, Arapoty and Capiporã of *Urochloa brizantha* (syn. *Brachiaria brizantha*) and cv. Basilisk of *U. decumbens* (syn. *B. decumbens*).

The greater number of tillers in spring and summer (Figure 3) resulted in a higher LAI of the swards in these seasons (Figure 8). Since increased LAI increases interception of light by the sward (Pedreira et al. 2007), which is a premise for the occurrence of photosynthesis (Taiz and Zeiger 2012), this results in increased growth rate of the pasture.

As a consequence of the accumulated effects of rainfall, temperature and solar radiation as the seasons progressed, a larger number of tillers was expected in summer than in spring. This response pattern did not occur, possibly due to the lower than normal rainfall experienced in January and February 2014 (Figure 2). Additionally, the similar LAI in spring and summer (Figure 8) might also have contributed to tiller density remaining stable in these seasons (Figure 3). The LAI controls, in part, the amount of solar radiation that reaches the soil surface, such that a larger LAI is associated with higher light interception by the sward (Giacomini et al. 2009) and in fact, with lower penetration of light to the soil. Since the amount of light received at the base of plants has a significant influence on degree of tillering (Martuscello et al. 2009), the constancy of LAI in spring and summer might have provided similar levels of luminosity close to the soil surface, resulting in similar numbers of basal buds developing into new tillers. The maintenance of marandu palisadegrass at a constant height in spring and summer also resulted in similar tiller weight in these seasons to the swards managed at 15 and 45 cm in fall/winter (Figure 4).

On swards maintained at 15 and 30 cm in fall/winter, the greater forage mass in summer than in the other seasons of the year (Figure 5) might have been a consequence of the onset of flowering of the palisadegrass in this season (Calvano et al. 2011). With flowering, the leaf:stem ratio in the plant is reduced (Santos et al. 2009), which explains the lower percentage of live leaves in the forage mass in summer as compared with spring (Figure 6A). Since stem is a denser organ than leaf (Pereira et al. 2010), its greater proportion in the sward should result in a larger forage mass. Furthermore, with flowering, compounds from root reserves are translocated to the aerial parts of the forage plant (Silva et al. 2015), which also contributes to increasing the sward forage mass.

It should be noted that we might have overestimated the forage mass values (Figure 5) in this study. To obtain this response variable, we multiplied average tiller weight by the number of tillers. It is possible that some young tillers, shorter than the average sward height, were counted along with the taller ones. However, to determine mean tiller weight, we harvested only those with height similar to the sward height, so the average tiller weight would have been overestimated, with an equal effect on forage mass.

Considering that the tiller is the basic growth unit of forage grasses (Hodgson 1990), the stability of tiller density in the swards subjected to variable defoliation regimes in fall and winter indicates that their perenniality was not compromised and that the growth potential of the pasture was probably not impaired.

In winter, variations in mean weight of tillers (Figure 4) and forage mass (Figure 5) were a consequence of the modification of the sward height in this season. When the sward heights were similar (30 cm) in all swards, differences in tiller weight and forage mass between the swards declined and had disappeared by summer (Figure 4). Moreover, in the sward kept at 45 cm in fall and winter, there might have been more competition for light among the tillers (Sbrissia et al. 2010), which can lead to greater stem elongation and consequently a greater tiller weight (Figure 4), as well as a higher percentage of live stems in the forage mass (Figure 7). This high relative contribution of live stem in winter resulted in a reduction in the percentage of live leaves during the entire experimental period in the sward kept at 45 cm in fall/winter as compared with that kept at 15 cm (Figure 6B). Nevertheless, in spring, when all swards were kept at the same height (30 cm), the highest one (45 cm) in fall and winter continued to present a greater tiller weight. Thus, a residual effect of the management employed in fall and winter was detected in the subsequent season. Contrastingly, maintaining the sward lower (15 cm) in fall and winter resulted in lower tiller weight in winter (Figure 4), as well as a lower percentage of live stems in the forage mass during winter (Figure 7). These results allow us to infer that the structure of the marandu palisadegrass kept shorter in winter would be more favorable for forage intake by grazing animals.

The effect of a particular defoliation strategy in a particular season of the year on tiller growth in the following season is partially due to the phenotypic plasticity of the forage plant, i.e. to the change in the morphogenetic and structural traits of the plant in response to environmental variations, including the defoliation environment (Silva and Nascimento Júnior 2007). This is a gradual process, and, therefore, does not occur in the short term; when the defoliation management in a sward is changed, there is a carry-over effect and effects of the previous management are displayed in the subsequent periods.

Conclusions

This study has shown that: 1) *Urochloa brizantha* (syn. *Brachiaria brizantha*) cv. Marandu (marandu palisadegrass) shows limiting structural traits in winter as compared with spring and summer; 2) both pasture height and season affect pasture structure of Marandu; and 3) managing Marandu at 15 cm in fall and winter and 30 cm in spring and summer will result in a leafier pasture with lower percentage stems than keeping it at 30 or 45 cm in winter.

Grazing studies seem warranted to determine whether the effects demonstrated in this experiment hold under grazing and how varying pasture height in different seasons compares with maintaining a fixed grazing height. Furthermore, how the sward height variation affects pasture yield and quality and translates into animal performance should be monitored before recommendations should be made.

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