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Research paper

Tillering of Marandu palisadegrass maintained at fixed or variable heights throughout the year

Altura de corte y macollamiento de Urochloa brizantha *cv. Marandu*

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Abstract

Satisfactory tillering is the basic attribute to ensure stability and productivity of a grass population. We aimed to develop an understanding of tillering in *Urochloa brizantha* syn. *Brachiaria brizantha* cv. Marandu (Marandu palisadegrass) maintained at constant or variable heights during the various seasons of the year and to identify defoliation strategies that optimize tillering. In an experiment conducted in Uberlândia, Minas Gerais, Brazil, 3 defoliation strategies were studied: sward kept at 30 cm during the whole year (constant height); kept at 15 cm in fall/winter, 30 cm in spring and 45 cm in summer (increasing height); and kept at 45 cm in fall/winter, 30 cm in spring and 15 cm in the summer (decreasing height). The experiment was completely randomized, with 4 replicates. The following variables were evaluated: tiller appearance (TAR), mortality (TMR) and survival (TSR) rates; the balance (BAL) between TAR and TMR; tiller population stability (TPS); and number of tillers/m^2 (NT). In winter and late spring, TAR and BAL were low, while in early spring, the sward with decreasing height showed high TAR, BAL and TPS. The NT was higher when managed with increasing height than with other height strategies. Lowering pasture height from 45 to 30 cm after the winter increased TAR in early spring. Grazing studies seem warranted to assess how these results can be reproduced under grazing and how pasture yield and quality plus animal performance compare with those under the fixed grazing height regimen.

Keywords: Defoliation, grazing management, pasture height, tillers, *Urochloa brizantha.*

Resumen

La capacidad para formar macollas es un atributo básico para garantizar la sostenibilidad y productividad de una población de plantas en una pastura. En Uberlândia, Minas Gerais, Brazil se evaluó el macollamiento de *Urochloa brizantha* (syn. *Brachiaria brizantha*) cv. Marandú manejado a alturas constantes o variables durante las diferentes estaciones del año con el objetivo de identificar las estrategias de defoliación que optimicen el macollamiento de este cultivar. Las estrategias de defoliación consistieron en: pastura a una altura de 30 cm a través del año (altura constante); pastura a 15 cm en otoño/invierno, 30 cm en primavera y 45 cm en verano (altura creciente); y pastura a 45 cm en otoño/invierno, 30 cm en primavera y 15 cm en verano (altura decreciente). El diseño del experimento fue completamente al azar, con 4 repeticiones. Las variables evaluadas fueron: tasas de aparición de rebrotes (TAR), mortalidad de rebrotes (TMR) y supervivencia de rebrotes (TSR); equilibrio (BAL) entre TAR y TMR; estabilidad de la población de rebrotes (TPS); y número de rebrotes/m^2 (NT). En invierno y hacia finales de la primavera, TAR y BAL fueron bajos, mientras que a principios de la primavera, el tratamiento decreciente mostró altos TAR, BAL y TPS. El NT fue mayor en el

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tratamiento creciente que en los demás tratamientos. La reducción de la altura de la pastura de 45 a 30 cm después del invierno aumentó la TAR a principios de la primavera. Se sugieren estudios de pastoreo para investigar cómo estos resultados pueden ser reproducidos en condiciones de pastoreo y cómo la producción y calidad de la pastura más la producción animal se comparan con aquellas bajo un régimen de pastoreo a altura fija.

Palabras clave: Altura de pastura, defoliación, manejo de pastoreo, rebrotes, *Urochloa brizantha*.

Introduction

In Brazil, it is estimated that 85% of pastures belong to the genus *Urochloa* syn. *Brachiaria* (Macedo 2004), and that, of the 190 Mha, 50 Mha are monocultures of *U. brizantha* cv. Marandu (Jank et al. 2014). Despite the widespread adoption of these pastures, adoption of adequate management practices is low, resulting in low livestock production (Ferreira et al. 2013). For Marandu palisadegrass to express its forage production potential, proper defoliation management should be adopted. Defoliation influences light interception and photosynthesis in the sward (Lara and Pedreira 2011), key processes in the development of the forage plant, and consequently in pasture production.

Tillers are the basic units of development of forage grasses (Hodgson 1990), so understanding of plant density and tiller dynamics (appearance, death and survival) are essential to comprehend the effects of defoliation management on pasture production (Giacomini et al. 2009; Fialho et al. 2012).

Continuous stocking of Marandu palisadegrass to maintain pasture at given heights has been recommended (Calvano et al. 2011). However, climatic conditions influence pasture tillering (Santos et al. 2011), such that a particular pasture height may optimize tillering in one season of the year, but not in others (Sbrissia et al. 2010). In view of this scenario, the management of a pasture should be planned seasonally to the extent that the number of stock on the farm allows flexibility.

This study aimed to develop an understanding of the tillering patterns in Marandu palisadegrass kept at constant or variable heights during the various seasons of the year and thus identify defoliation strategies to optimize tillering, and hence stability and productivity of the plant population in the pasture.

Materials and Methods

The experiment was conducted from January 2013 to March 2014 in the Forage Section, on Capim Branco Farm, at the Faculty of Veterinary Medicine of the Federal University of Uberlândia (UFU), located in Uberlândia, Minas Gerais, Brazil (18º53'19" S, 48°20'57" W; 776 masl). The climate of Uberlândia is a tropical Cwa type, with mild, dry winters and well-defined dry and rainy seasons (Köppen 1948). The average annual temperature is 22.3 ºC, varying between 19.1 and 23.9 ºC. Average annual precipitation is 1,584 mm, varying from 1,260 to 1,680 mm.

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

Before the experiment commenced, soil samples were collected from the 0–10 cm layer and analyzed to reveal the following chemical characteristics: pH (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, 21.8 kg P/ha (as single superphosphate), 60 kg N/ha (as urea) and 41.5 kg K/ha (as KCl) were broadcast on all plots in the first week of January 2013 and again on 1 January 2014.

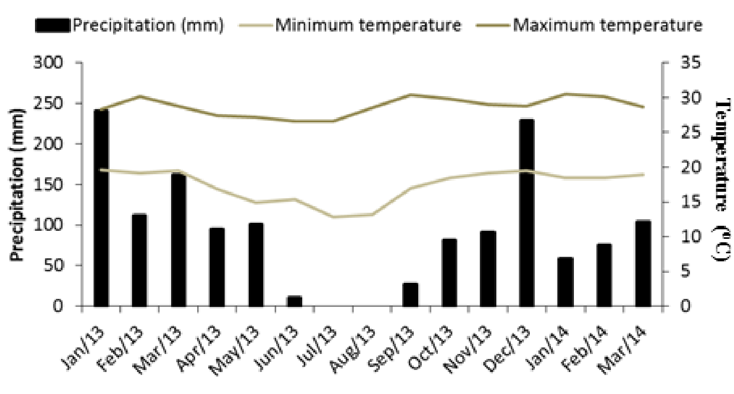

Figure 1. Monthly maximum and minimum mean daily temperatures and precipitation from January 2013 to March 2014. The seasons are: winter, July–September 2013; early spring, October 2013; late spring, November–December 2013; and summer, January–March 2014.

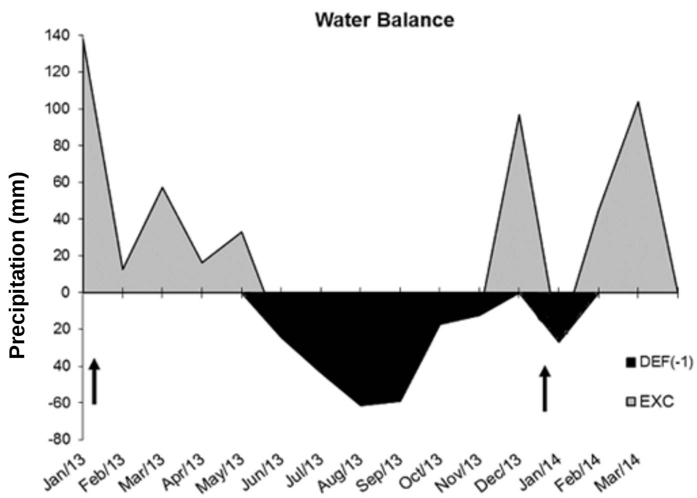

Figure 2. Water balance in the soil from January 2013 to March 2014. Arrows indicate the times when fertilizer was applied. The seasons are: winter, July–September 2013; early spring, October 2013; late spring, November–December 2013; and summer, January–March 2014. DEF (-1) = Deficit; EXC = Excess.

The experimental area consisted of 12 plots (experimental units) of 6 m^2 each, of a healthy Marandu palisadegrass established in 2000.

Three defoliation strategies for Marandu palisadegrass were evaluated: kept at a constant height of 30 cm during the entire experimental period (Sbrissia and Silva 2008); kept at 15 cm in fall and winter, 30 cm in spring and 45 cm in summer (increasing height throughout the year); and kept at 45 cm in fall and winter, 30 cm in spring and 15 cm in summer (decreasing height).

The grass kept at 15 cm in fall and winter took approximately 1 month to reach 30 cm in spring. Likewise, the pasture was not cut for about a month at the end of spring to allow it to reach 45 cm in summer. In contrast, the grass maintained at 45 cm in fall and winter was cut to 30 cm in the beginning of spring (October 2013) and to 15 cm in early summer (January 2014). By contrast, pastures managed at 30 cm in fall and winter continued under the same management until the end of the experiment.

The experimental period in which the evaluations took place was divided, based on the similar patterns of the response variables, into the following subperiods: winter (July−September 2013); early spring (October 2013); late spring (November−December 2013); and summer (January−March 2014). The experimental design was completely randomized, arranged as split plots in time, with 4 replicates.

From January 2013, cuts were made for the desired heights to be implemented in the fall and winter seasons, according to the treatments. The period January−March 2013 was considered the acclimation of the pastures to the various heights. Heights were measured once weekly in fall and winter and twice weekly in spring and summer at 10 points throughout each plot, using a graduated ruler. Excess forage above the desired height was cut and removed manually on each occasion. Thus, in each season of the year, the pastures were maintained at relatively constant heights, through mechanical defoliations.

In early July 2013, evaluation of tillering dynamics commenced in 2 areas, which were delineated with a PVC ring of 30 cm diameter (0.07 m^2) that was fixed in the soil using metal clasps. Initially, all tillers were marked with strings of the same color, and identified as the base generation (BG). Thirty days afterwards, live tillers inside the BG rings were counted and dead ones were calculated by difference. New tillers that appeared were marked with strings of a different color, counted and identified as first generation (G1), and this procedure was repeated every 30 days. From these data, tiller appearance (TAR), tiller mortality (TMR) and tiller survival (TSR) rates were calculated on a percentage basis every 30 days. TAR corresponded to the number of new tillers, multiplied by 100 and divided by the total number of existing tillers at the beginning of that period; TMR consisted of the total number of dead tillers from the previous marking, multiplied by 100 and divided by the total number of tillers in the previous generations. TSR was obtained by subtracting TMR from 100%. The balance between TAR and TMR in each period of the year was calculated by subtracting TMR from TAR. Based on the original tiller count data from the base generation, the monthly variation curves of the number of tiller generations were generated monthly, and the total number of tillers/m^2 present in the area of evaluation of tillering dynamics was also calculated.

Tiller population stability was calculated by the equation proposed by Bahmani et al. (2003):

$$FP/IP = TSR\ (1 + TAR)$$

in which FP/IP represents the current or final tiller population (FP), expressed as a percentage of the original or initial tiller population (IP) in a given period of evaluation.

For analysis of the data, the results were grouped according to the seasons of the year (winter, early spring, late spring and summer). Initially, the dataset was analyzed to check if it met the assumptions of variance analysis (normality and homogeneity). For the statistical assumptions to be met, data for the response variable 'tiller mortality rate' were transformed using the square root. The data were analyzed using the MIXED (mixed models) procedure of the SAS® (Statistical Analysis System) version 9.2 program. The variance and co-variance matrix was chosen using Akaike's Information Criterion (Wolfinger 1993). Treatment means were estimated using the LSMEANS option and compared by Student's t test at 5% probability.

Results

Tiller appearance rate (TAR) was influenced by an interaction between sward height and time of year (P=0.0021). In winter and late spring, TAR was lower than at other times of the year, and was independent of sward height. In early spring and summer, swards with decreasing height showed a higher TAR than those with constant or increasing heights (Figure 3) and within heights TAR was higher in early spring than summer.

Tiller mortality rate (TMR) was influenced by an interaction between sward height and time of year (P=0.0002). In winter and late spring, no difference was detected in TMR between defoliation strategies, but in summer, the sward with decreasing height showed a higher TMR and in early spring the sward with constant height had lower TMR (Figure 4).

Tiller survival rate (TSR) was influenced by an interaction between sward height and time of year (P<0.0002). While in winter and early and late spring, TSR did not vary between defoliation management strategies, in summer, TSR in the sward with decreasing height was lower than in those with constant and increasing heights (Figure 5).

The balance between tiller appearance and mortality rates (BAL) was influenced by an interaction between sward height and time of year (P<0.0001). In winter and late spring, BAL was lower than for other seasons and negative for all studied heights. In early spring, the sward with decreasing height achieved a higher BAL than others, while in summer, sward height did not affect BAL (Figure 6).

Tiller population stability (TPS) also was influenced by an interaction between sward height and time of year (P<0.0001). Although no difference in TPS was found between sward heights during winter and late spring, in early spring, TPS was higher in the sward with decreasing height than in those with constant and increasing heights. In summer, TPS was lower in the sward with decreasing height than in that with constant height (Figure 7). Overall, TPS was better in early spring than in other seasons.

Sward height influenced (P=0.0039) the number of tillers in Marandu palisadegrass, which showed higher values when managed with increasing height than with other height strategies (Figure 8).

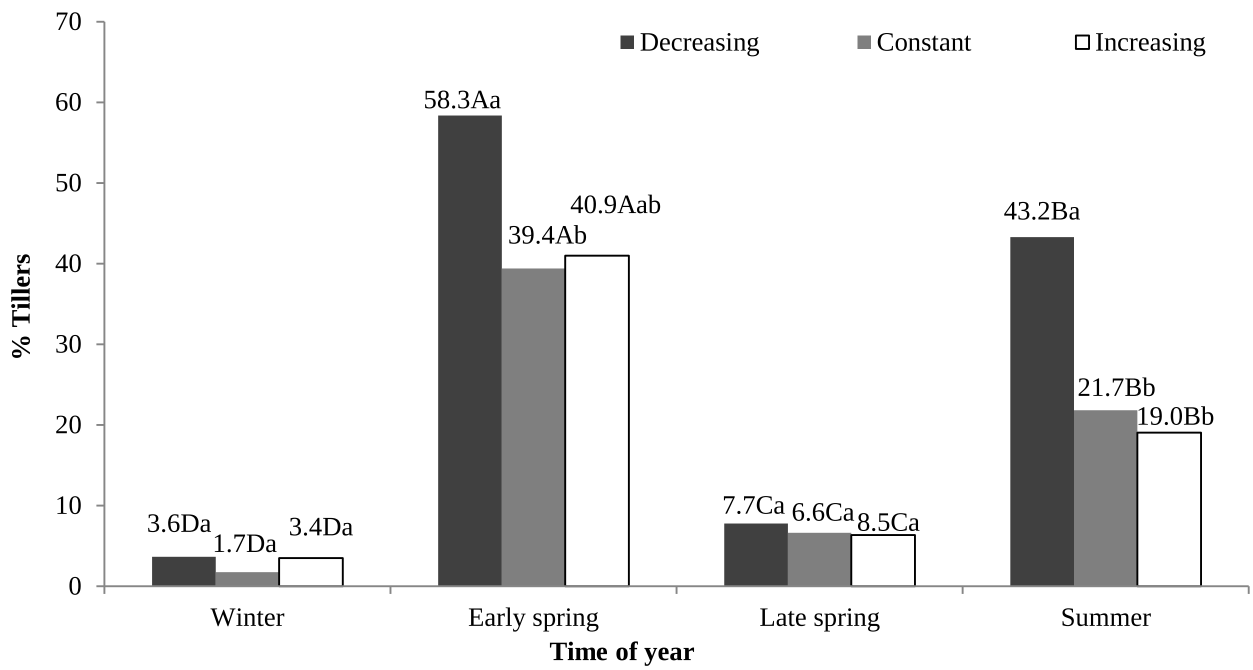

Figure 3. Effects of time of year and sward height on monthly tiller appearance rate (TAR) in Marandu palisadegrass.
Decreasing: sward at 45 cm in fall and winter, 30 cm in spring and 15 cm in summer; Constant: sward at 30 cm during the entire experimental period; Increasing: sward at 15 cm in fall and winter, 30 cm in spring and 45 cm in summer. Lower-case letters compare heights within times of the year and upper-case letters compare times of the year within heights. Where letters are different, means differ (P<0.05).

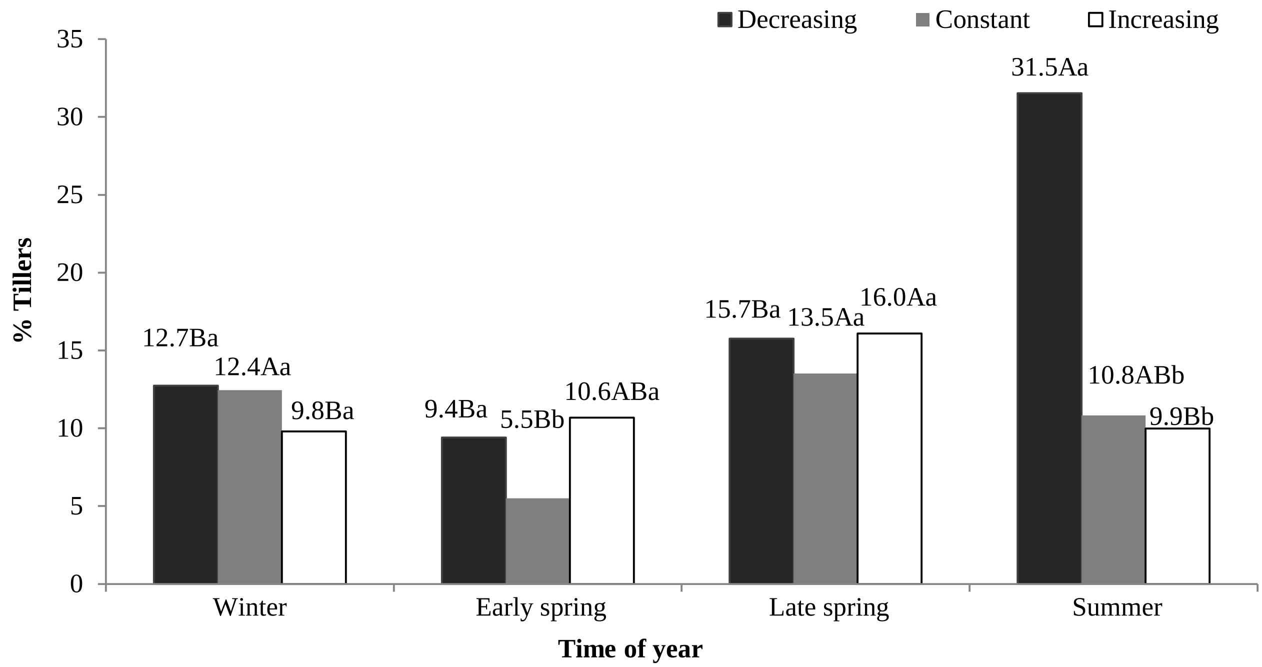

Figure 4. Effects of time of year and sward height on monthly tiller mortality rate (TMR) in Marandu palisadegrass.
Decreasing: swards at 45 cm in fall and winter, 30 cm in spring and 15 cm in summer; Constant: swards at 30 cm during the entire experimental period; Increasing: swards at 15 cm in fall and winter, 30 cm in spring and 45 cm in summer. Lower-case letters compare heights within times of year and upper-case letters compare times of year within heights. Where letters are different, means differ (P<0.05).

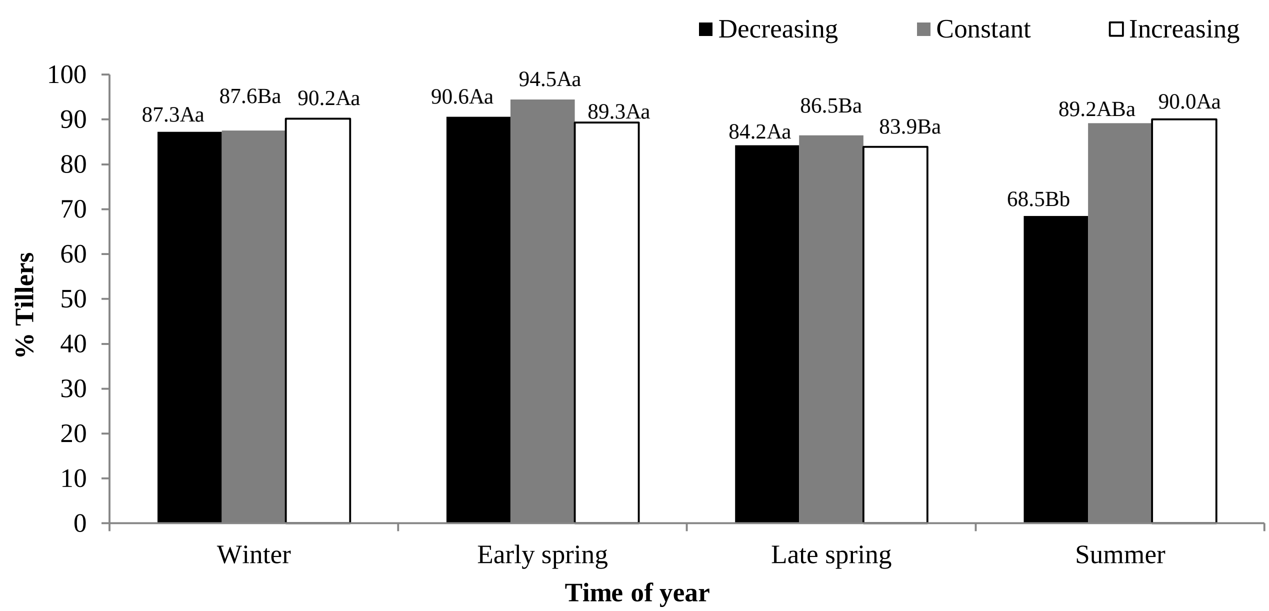

Figure 5. Effects of time of year and sward height on monthly tiller survival rate (TSR) of Marandu palisadegrass.
Decreasing: swards at 45 cm in fall and winter, 30 cm in spring and 15 cm in summer; Constant: swards at 30 cm during the entire experimental period; Increasing: swards at 15 cm in fall and winter, 30 cm in spring and 45 cm in summer. Lower-case letters compare heights within times of year and upper-case letters compare times of year within heights. Where letters are different, means differ (P<0.05).

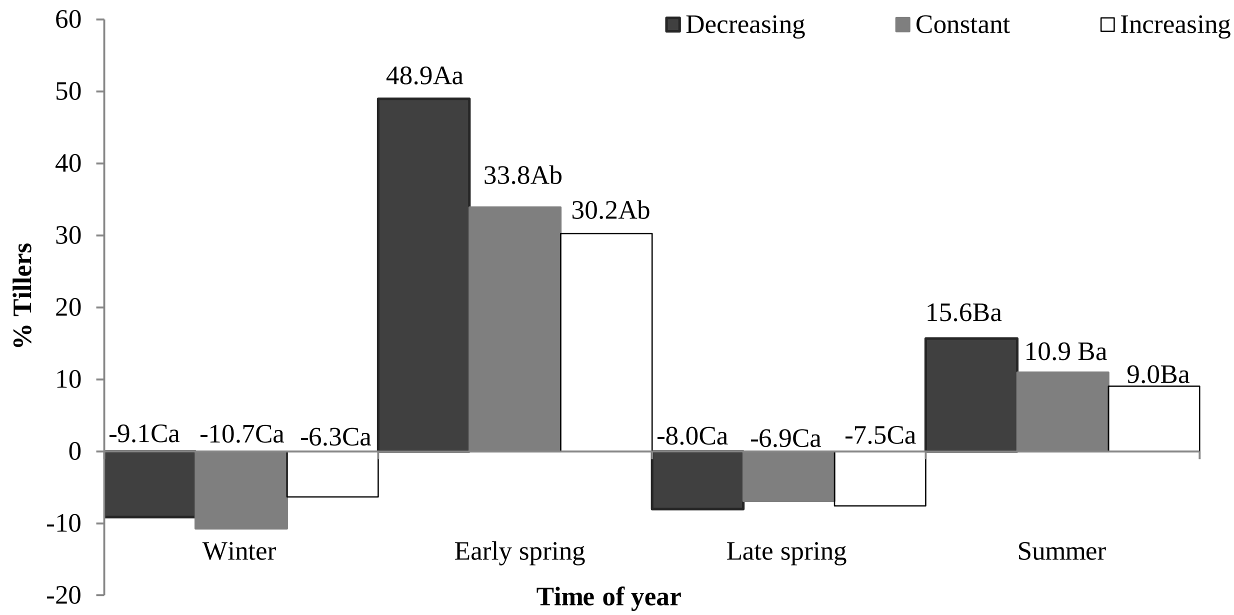

Figure 6. Effects of time of year and sward height on balance (BAL) between monthly tiller appearance and mortality in Marandu palisadegrass.

Decreasing: swards at 45 cm in fall and winter, 30 cm in spring and 15 cm in summer; Constant: swards at 30 cm during the entire experimental period; Increasing: swards at 15 cm in fall and winter, 30 cm in spring and 45 cm in summer. Lower-case letters compare heights within times of year and upper-case letters compare times of year within heights. Where letters are different, means differ (P<0.05).

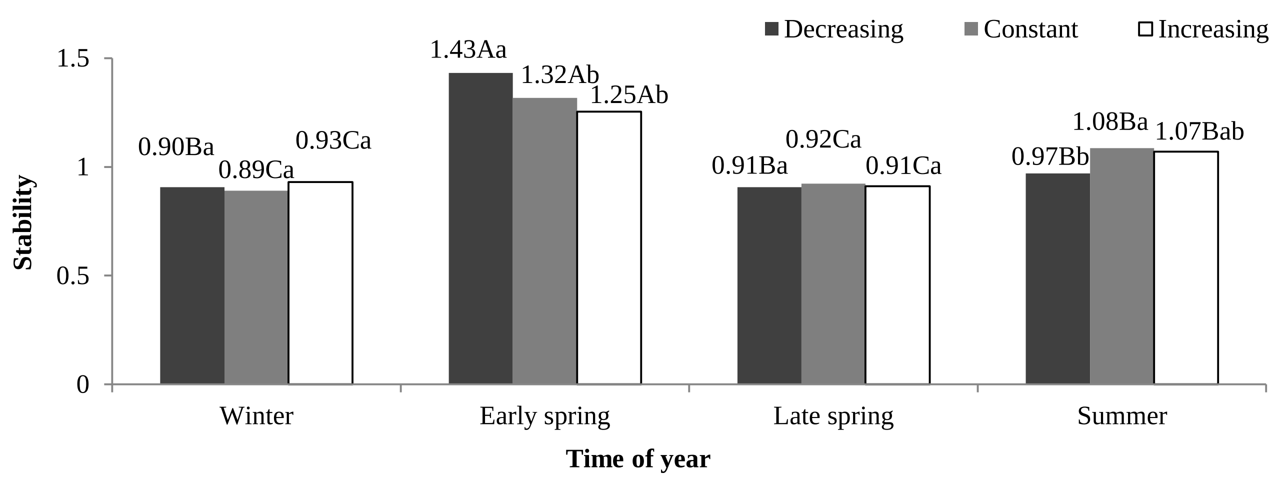

Figure 7. Effects of time of year and sward height on monthly tiller population stability (TPS) in Marandu palisadegrass.

Decreasing: sward at 45 cm in fall and winter, 30 cm in spring and 15 cm in summer; Constant: sward at 30 cm during the entire experimental period; Increasing: sward at 15 cm in fall and winter, 30 cm in spring and 45 cm in summer. Lower-case letters compare heights within times of year and upper-case letters compare times of year within heights. Where letters are different, means differ (P<0.05).

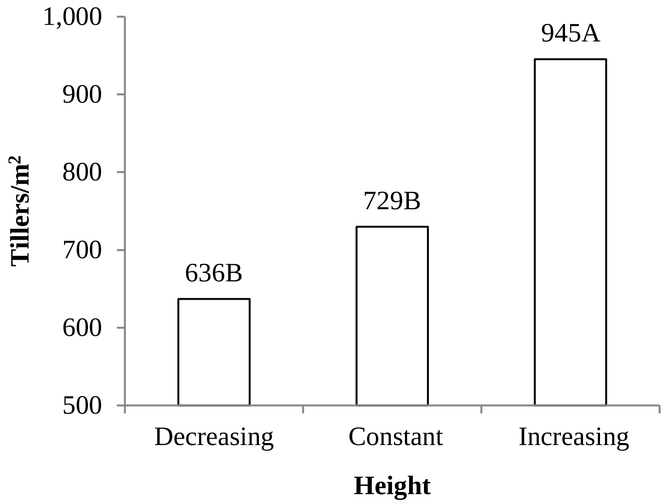

Figure 8. Effects of height management on number of tillers in Marandu palisadegrass.
Decreasing: sward at 45 cm in fall and winter, 30 cm in spring and 15 cm in summer; Constant: sward at 30 cm during the entire experimental period; Increasing: sward at 15 cm in fall and winter, 30 cm in spring and 45 cm in summer. Means followed by different upper-case letters differ (P<0.05).

Discussion

This study has shown the important interactions between height management of a Marandu palisadegrass pasture and season of year on degree of tillering in the pasture.

Climatic conditions were unfavorable for growth of the sward during winter, which explains the low TAR in this period, when low temperature, precipitation and incident radiation were experienced (Figures 1 and 2). In July and August, minimum temperatures were below 15 ºC and there was no rain (Figure 1). These environmental conditions inhibit the development of buds located at the base or lateral portions of the plant (Matthew et al. 2000). According to McWilliam (1978), the ideal temperature for growth of tropical grasses ranges from 30 to 35 ºC, while growth is severely impaired from 10 to 15 ºC.

A high TSR in winter (Figure 3) failed to offset the low TAR in this period, resulting in a negative BAL, as well as a TPS lower than 1.0. When TPS is lower than 1.0, the tiller population decreases, because the appearance of tillers is insufficient to offset their poor survival (Bahmani et al. 2003).

In early spring, the change in climatic conditions, which became more favorable for plant growth (Figures 1 and 2), stimulated the development of basal buds on new tillers, so TAR values (Figure 3) exceeded TMR levels (Figure 4). As a consequence, in early spring, BAL (Figure 6) and TPS were the highest recorded during the study.

However, tillering rates declined in late spring (Figure 3). The intense tillering in early spring increased the number of tillers in the sward, probably causing shading at the base of the plants, which possibly inhibited the development of basal buds on new tillers in late spring. As a result, BAL became negative again (Figure 6), and TPS was lower than 1.0, typical of swards with unstable tiller populations (Caminha et al. 2010).

Despite the soil water deficit (Figure 2), tillering increased from late spring to summer (Figure 3). This might be a response to the application of NPK fertilizer in January 2014, which stimulated the Marandu palisadegrass and increased the percentage of buds that developed on new tillers (Morais et al. 2006).

The higher TAR values in early spring and summer compared with winter (Figure 3) support the results of Santos et al. (2011), who obtained low TAR in winter and high TAR in spring and summer in a *Brachiaria decumbens* cv. Basilisk pasture managed under continuous grazing by cattle.

The high TAR in early spring indicates renewal of tillers, which demonstrates an increased percentage of younger tillers in the sward. These tillers have higher leaf appearance and elongation rates (Paiva et al. 2011), in addition to having better morphological composition and nutritive value (Santos et al. 2010). In addition, they are more responsive to nitrogen fertilization, which is appropriate for improving the performance of a grazing animal.

The response pattern of TPS observed in this study (Figure 7) corroborates that obtained by Sbrissia et al. (2010), who found TPS values slightly lower than 1.0 in Marandu palisadegrass pastures kept at 30 cm at times when environmental conditions were least favorable for growth. As environmental conditions improved in spring, the TPS values increased.

Since it showed lower forage mass, the sward kept at a lower height in fall and winter (increasing height) was expected to have a lower demand for growth factors like light and water, which would improve the water and carbon balance in plants at times when these resources were limited (Taiz and Zeiger 2012). Thus, the sward with increasing height would have low senescence and reduced dead tissue at the base of plants, thereby allowing light to penetrate to basal buds, a predisposing factor for tillering (Martuscello et al. 2009). However, this hypothesis was not confirmed in this study, possibly due to the increased shading within the sward with the increasing height in early spring from 15 to 30 cm.

Moreover, the increased shading within the sward as height increased in early spring might have elevated the allocation of nutrients and photoassimilates to older tillers as opposed to formation of new tillers, which would mean higher energy requirements by the plant (Langer 1963; Briske et al. 1996).

In contrast, the greater tillering in early spring in the sward with decreasing height might have been stimulated by its rapid lowering from 45 to 30 cm. This could have resulted in sudden increased incidence of light at the base of the sward, and consequently stimulated tillering (Figure 3). As a result BAL (Figure 6) and TPS (Figure 7) were higher in the sward with decreasing height than in swards with constant and increasing heights in early spring.

The same physiological response might explain the higher TAR in summer in the sward with decreasing height compared with the other defoliation strategies (Figure 3), as this pasture was lowered in late spring from 30 to 15 cm, which broke apical dominance by removing apical meristems of existing tillers.

The higher TMR in summer, with consequent reduction of TSR in the sward with decreasing height, may be a function of the reduction in height of pasture eliminating the apical meristem of many tillers, which resulted in their deaths (Matthew et al. 2000). The decreasing height strategy obviously produced a higher tiller turnover rate with a more positive balance (BAL) than other sward management strategies in times of active growth (early spring and summer, Figure 6).

For swards with constant and increasing heights, the highest TAR occurred in early spring (Figure 3), whereas the highest TMR was found in late spring (Figure 4). This response pattern demonstrates that, when climatic conditions are again favorable for grass growth, i.e. in spring, the plant primarily supports the emergence of new tillers, which then triggers the death of old tillers. This can be a strategy of Marandu palisadegrass to ensure the stability of the tiller population during transition periods between seasons.

The number, i.e. density, of tillers was higher in the sward with increasing height than in those with constant and decreasing heights (Figure 8). Lowering the sward to 15 cm from the summer of 2013 (acclimation period) and during the fall and winter, i.e. 6 months before the commencement of observations, probably promoted the emergence of tillers, as the summer is a period with favorable climatic conditions and the weather in the fall is still not completely restrictive to plant growth (Figures 1 and 2). When pasture is kept short, there is a higher incidence of light at the base of the plant, and apical dominance of existing tillers is broken, which results in the activation of a higher number of buds, which in turn produce tillers (Difante et al. 2008; Giacomini et al. 2009; Portela et al. 2011). As a result, at the beginning of the evaluation in winter, the sward already had a large number of tillers, which remained high during the subsequent periods (Figure 9). To what extent the differences in tiller density in the various treatments at the start of the observations (approximately 700 tillers/m^2 for decreasing, 800 tillers/m^2 for constant and 1,000 tillers/m^2 for increasing) affected the outcome of the study and subsequent tiller performance we do not know.

High numbers of tillers are important for productivity, provided that their growth is not compromised, and also for the perenniality of forage plants (Matthew et al. 2000). A high tiller density also results in dense pasture, which may lead to high bite mass of grazing animals (Fonseca et al. 2013), which is desirable for increasing daily forage intake and, consequently, the performance of grazing animals.

Tillers marked in early July contributed significantly to total tiller population in the sward during winter, but this participation decreased sharply after early spring (Figure 9). Fewer tillers were produced in winter than in spring and summer. In early spring and summer, the new generations of tillers contributed most to total tiller density, which is a reflection of high tiller renewal. However, it should be noted that, even with the renewal of tillers in early spring and summer, some old tillers remained until the end of the experiment, less though at decreasing than at constant or increasing height.

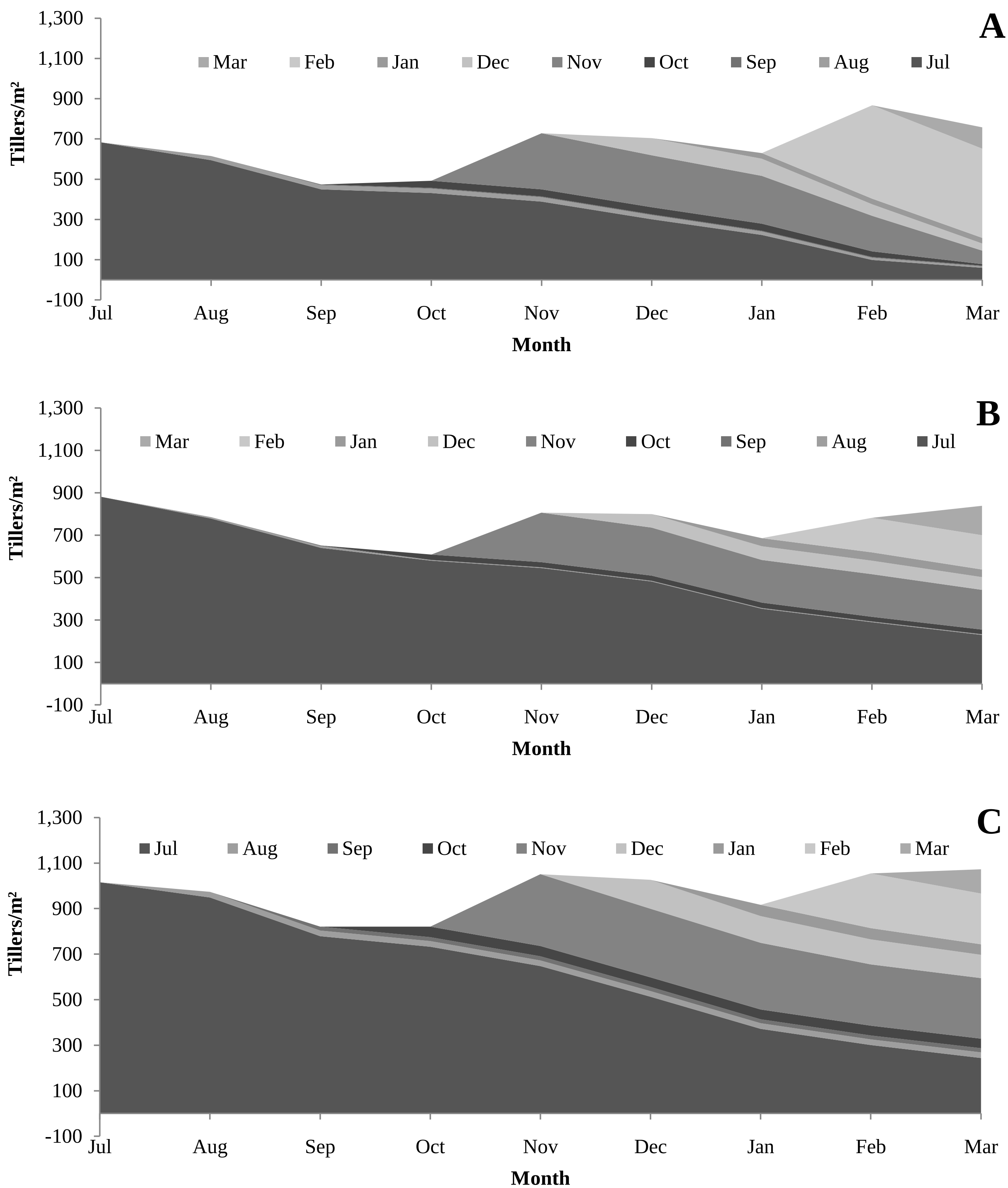

Figure 9. Tiller demographic pattern in Marandu palisadegrass kept at decreasing (A), constant (B) or increasing (C) heights during the various seasons of the year.

Decreasing: plants at 45 cm in winter, 30 cm in spring and 15 in summer; Constant: plants at 30 cm in winter, spring and summer; Increasing: sward at 15 cm in winter, 30 cm in spring and 45 cm in summer.

Conclusions

This study has shown that both grazing height of pasture and season affect tiller dynamics of *Urochloa brizantha* (syn. *Brachiaria brizantha*) cv. Marandu. Tiller appearance and stability rates were higher in early spring than in other seasons of the year and lower grazing heights stimulated appearance of new tillers.

This suggests that, for grazing management, farmers should adjust canopy height throughout the year rather than grazing at a fixed height as has been recommended in the past.

Further grazing studies seem warranted to determine whether the effects demonstrated in this experiment hold under grazing and how they compare with a fixed grazing height. How the different pasture dynamics affect pasture yield and quality and translate into animal performance should be monitored before recommendations should be made.

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