

## Research Paper

# Height and mowing of pasture at the end of winter modulate the tillering of Marandu palisadegrass in spring

*La altura y el corte de Urochloa brizantha cv. Marandu al final del invierno afectan su capacidad de rebrote en primavera*

BRUNO HUMBERTO REZENDE CARVALHO<sup>1</sup>, LILIAN ELGALISE TECHIO PEREIRA<sup>2</sup>, ANDRÉ FISCHER SBRISSIA<sup>3</sup>, GABRIEL DE OLIVEIRA ROCHA<sup>1</sup> AND MANOEL EDUARDO ROZALINO SANTOS<sup>1</sup>

<sup>1</sup>Faculdade de Medicina Veterinária, Universidade Federal de Uberlândia, Uberlândia, MG, Brazil. [famev.ufu.br](http://famev.ufu.br)

<sup>2</sup>Faculdade de Zootecnia e Engenharia de Alimentos, Universidade de São Paulo, Pirassununga, SP, Brazil. [usp.br/fzea](http://usp.br/fzea)

<sup>3</sup>Centro de Ciências Agroveterinárias, Universidade do Estado de Santa Catarina, Lages, SC, Brazil. [cav.udesc.br](http://cav.udesc.br)

## Abstract

In pastures subjected to stockpiling, the tiller population goes through an intense process of self-thinning, hindering the recruitment of new tillers in the subsequent season. We evaluated different pasture management strategies in late winter in an attempt to modify tiller recruitment during spring. *Urochloa brizantha* cv. Marandu was maintained at 4 different levels (heights) of stockpiled pasture at the end of winter: short (15.1 cm), medium (23.2 cm), tall (31.4 cm) and tall/mown (31.3 cm, mown to 8 cm). In October (early spring), the short and tall/mown pastures had a tiller appearance rate (TAR) and a population stability index (PSI) superior ( $P < 0.05$ ) to that of the tall pasture. During the remainder of the growing season, these characteristics (TAR and PSI) were similar for all pastures. Tiller survival rate (TSR) was also highest ( $P < 0.05$ ) in short pasture in early spring. TAR values were highest in early spring and these tillers persisted throughout the growing season. When stockpiling Marandu palisadegrass pasture during spring it is important to have it short at the end of winter to ensure early and intense tillering in spring. If pasture is tall at the end of winter mowing at this time before spelling is advantageous.

**Keywords:** Population stability index, tiller appearance, tiller survival, *Urochloa brizantha* syn. *Brachiaria brizantha*.

## Resumen

En sistemas de usos diferidos de un pasto, la población de brotes de plantas sufre un intenso proceso de auto-raleo lo que dificulta la regeneración de nuevos brotes en la temporada siguiente. En un estudio conducido en la Universidade Federal de Uberlândia, Minas Gerais, Brasil, se evaluaron diferentes estrategias de manejo del pasto *Urochloa brizantha* cv. Marandu a finales del invierno con el objeto de favorecer la regeneración de brotes durante la primavera. Para el efecto, a finales del invierno, utilizando pastoreo simulado se generaron parcelas de pasto diferido con cuatro niveles de altura diferentes: los tratamientos Corto (15.1 cm), Medio (23.2 cm), Alto (31.4 cm) y Alto/Cortado (31.3 cm, cortado a 8 cm). En octubre (comienzo de la primavera), los pastos en los tratamientos Corto y Alto/Cortado presentaron una tasa de aparición de brotes y un índice de estabilidad poblacional superior ( $P < 0.05$ ) al del pasto en el tratamiento Alto. Durante el resto de la temporada de crecimiento, estas dos características fueron similares para todos los tratamientos. La tasa de supervivencia de brotes también fue más alta ( $P < 0.05$ ) en el pasto del tratamiento Corto a principios de la primavera. La tasa de aparición de brotes fue más alta a principios de la primavera y estos brotes persistieron durante toda la temporada de crecimiento. Al diferir el pasto cv. Marandu durante la primavera, es importante manejarlo a corta altura al final del invierno para asegurar un rebrote temprano y abundante en primavera. Por tanto, si el pasto es alto al final del invierno, se sugiere realizar un corte antes de diferirlo.

**Palabras clave:** Aparición de brotes, índice de estabilidad poblacional, supervivencia de brotes.

Correspondence: M.E.R Santos, Veterinary Medicine School of Federal University of Uberlândia (FAMEV/UFU), Campus Glória, BR-050, km 78, 38410-337, Uberlândia, MG, Brazil.  
Email: [manoel.rozalino@ufu.br](mailto:manoel.rozalino@ufu.br)

## Introduction

Stockpiling of pasture has been widely adopted in many countries such as Canada, USA and Brazil ([Santos et al. 2009](#); [Añez-Osuna et al. 2015](#); [Nave et al. 2016](#); [Silva et al. 2016](#)) as a pasture management strategy in an endeavor to ensure forage is available for fall or winter grazing and to reduce winter feeding costs ([Añez-Osuna et al. 2015](#)). When carried out effectively, stockpiling can improve the environmental impact of winter feeding systems ([Bakelaar et al. 2017](#)), as well as animal health and welfare ([Poore and Drewnoski 2010](#)).

It is important that stockpiled pasture grows rapidly in spring and summer ([Santana et al. 2014](#); [Santos et al. 2020](#)), and the response depends on its ability to emit new tillers ([Colvill and Marshall 1984](#)), as tiller numbers in pasture are a reflection of the balance between birth and survival rates of tillers ([Costa et al. 2016](#); [Pessoa et al. 2016](#); [Duchini et al. 2018](#)).

A lower forage mass in stockpiled pasture at the end of winter may allow increased light incidence at the base of plants in early spring, boosting tillering when environmental conditions become more favorable for plant growth. Santana et al. (2014) evaluated the tillering of *Urochloa decumbens* cv. Basilisk during spring, as affected by the management of previously stockpiled pastures. Stockpiled pastures with shorter heights (10 and 20 cm) at the beginning of the stockpiling period produced more new tillers in spring than those stockpiled at a greater height (30 and 40 cm). The authors attributed this response pattern to lower forage mass at the end of winter in the 10 and 20 cm stockpiled pastures compared with those stockpiled at 30 and 40 cm. Santos et al. (2011) had already found that continuously stocked *Urochloa decumbens* cv. Basilisk maintained at 15 cm average height in winter and 25 cm in spring produced more new tillers than pasture managed at constant height (25 cm) throughout the year. According to these authors, pastures kept short in winter senesce less, reducing the amount of dead forage and the degree of shading at the base of the plants, resulting in a microclimate more favorable to tillering in the spring.

On the other hand, when stockpiled pasture has a high forage mass at the end of winter, tillering in the spring can be reduced or delayed ([Santos et al. 2009](#); [Silva et al. 2016](#)). Stockpiled pasture still tall at the end of winter can also contain many dead and old tillers, which remain in the canopy, interspersed with new tillers that appear over the subsequent spring and summer ([Souza et al. 2015](#)). In this situation, mowing of stockpiled pasture with a high forage mass in late winter can improve canopy structure in spring ([Souza et al. 2015](#)), with positive effects on

animal performance, although costs of mowing are an additional expense. In fact, Sousa et al. (2018) found that tall pasture (31.3 cm) of *U. brizantha* cv. Marandu mowed to 8 cm at the end of winter showed a higher percentage of live leaf and a lower percentage of dead stem in the subsequent spring than unmown pasture. Performance of sheep continuously grazing the pastures in spring was 33% higher in the tall/mown pasture than in the unmown pasture.

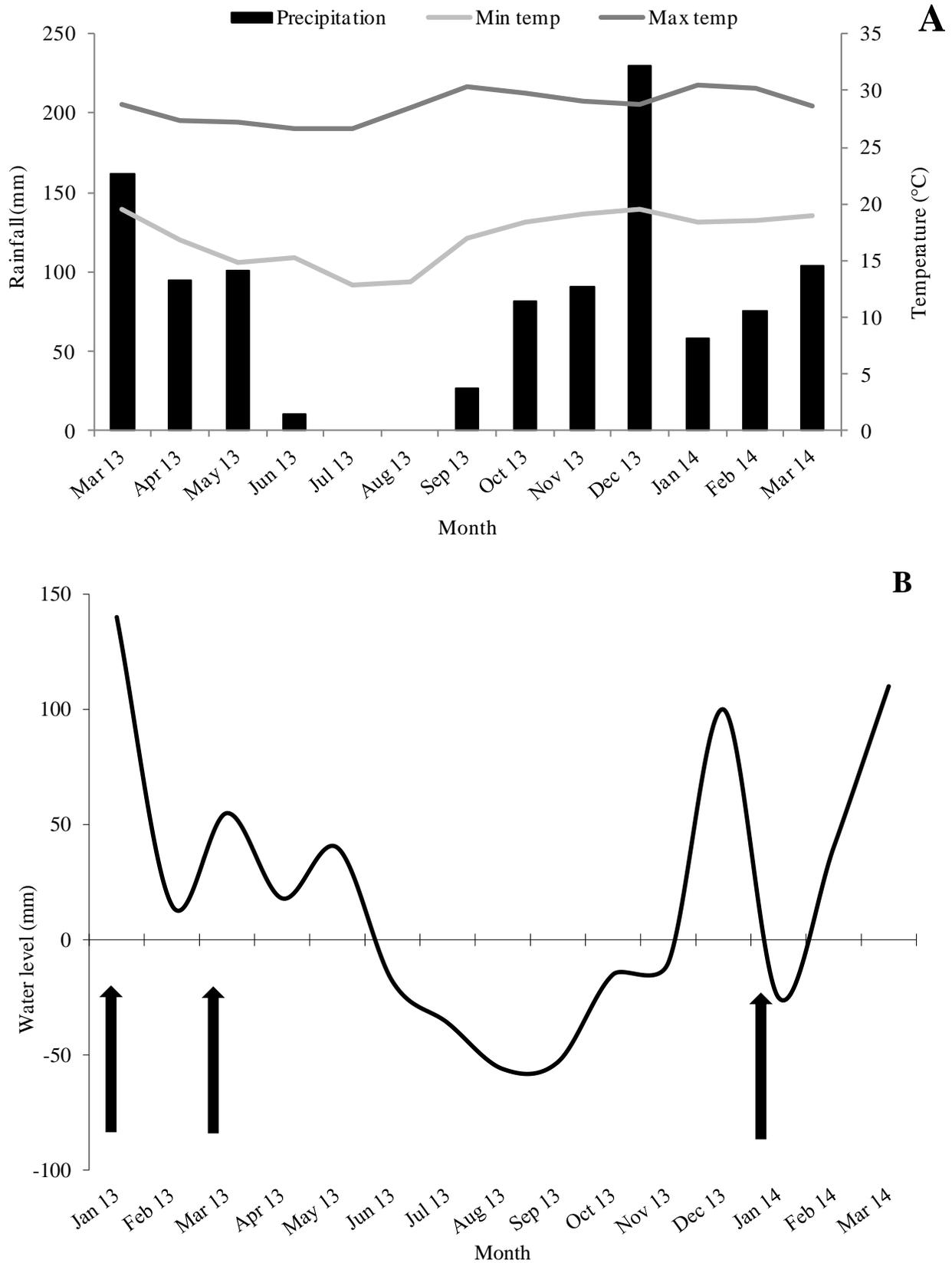
A possible negative consequence of mowing in tall pasture is the large amount of cut plant material over the plants, which could inhibit tillering, owing to: (i) the likely high C:N ratio of the mowed material, which would decrease the N availability for pasture via immobilization by soil microorganisms ([Carneiro et al. 2008](#)); and (ii) greater shading at the base of the pasture, inhibiting tillering. It is worth noting that the effects of mowing at the end of winter on tillering and the stability of the tiller population in spring and summer are still unknown in tropical pastures.

We studied Marandu palisadegrass (*Urochloa brizantha* cv. Marandu) to test the following hypotheses: (i) stockpiled but short pasture at the end of winter produces earlier and more intense tillering in spring than tall pasture; and (ii) mowing of pasture with high forage mass at the end of winter inhibits tillering since the mowed forage shades the growing points at the base of the plant and compromises tiller population stability in spring and summer. Thus, our study aimed to identify management conditions at the end of winter for previously stockpiled Marandu palisadegrass that allow a faster renewal of the tiller population in spring and early summer.

## Materials and Methods

### Locality and environmental conditions

The experiment was conducted from January 2013 to February 2014, at Capim Branco Experimental Farm, belonging to the Federal University of Uberlândia, in Uberlândia, MG (18°53' S, 48°20' W; 835 masl). According to Köppen's classification, the climate of the Uberlândia region is Aw-type, i.e. tropical savanna, with mild, dry winters and well-defined dry and rainy seasons ([Alvares et al. 2013](#)). Climatic conditions during the experimental period were monitored at a meteorological station 200 m away from the experimental area (Figure 1A). Temperature and monthly precipitation were used to calculate the soil water balance ([Thorntwaite and Mather 1955](#)), considering soil stored 50 mm water at field capacity (Figure 1B).



**Figure 1.** (A) Monthly weather data during the experimental period; and (B) monthly soil water balance during January 2013 – March 2014. The arrows indicate the months in which fertilizer was applied. Summer: January–March; fall: April–June; winter: July–September; spring: October–December.

The experimental area consisted of a pasture of *Urochloa brizantha* cv. Marandu (Marandu palisade-grass), subdivided into 12 paddocks (experimental units) of 800 m<sup>2</sup> each, in addition to a reserve area, totaling 2 hectares. In January 2013, soil samples were taken from the 0–20 cm layer, and chemical analysis showed the following results: pH (H<sub>2</sub>O): 6.1; P: 4.5 mg/dm<sup>3</sup> (Mehlich D); K<sup>+</sup>: 139 mg/dm<sup>3</sup>; Ca<sup>2+</sup>: 5.5 cmol<sub>c</sub>/dm<sup>3</sup>; Mg<sup>2+</sup>: 1.9 cmol<sub>c</sub>/dm<sup>3</sup>; Al<sup>3+</sup>: 0.0 cmol<sub>c</sub>/dm<sup>3</sup> (KCl 1 mol/L); effective CEC: 7.3 cmol<sub>c</sub>/dm<sup>3</sup>; pH 7.0; CEC: 10.2 cmol<sub>c</sub>/dm<sup>3</sup>; and base saturation: 72.0%.

#### *History of area use, treatments and experimental design*

From January to April 2013, all pastures were continuously stocked with sheep and stocking rates were varied to maintain pastures at 4 average sward heights (15, 25, 35 and 45 cm). Each height was implemented in 3 paddocks. Sward heights were measured weekly from the soil surface to the highest live leaves in the canopy using a graduated rule at 30 random points per paddock and were controlled by adding to or removing from the paddocks sheep with an average body weight of 26 kg.

All pastures were stockpiled, i.e. ungrazed, from 3 April 2013 to 21 June 2013 (79 days). All pastures were then continuously stocked with sheep from 22 June 2013 to 25 September 2013. Initial stocking rate was 4 sheep per paddock, i.e. 2.8 AU (animal units)/ha (1 AU = 450 kg of animal body weight).

At the end of the pasture utilization period on 25 September 2013, sampling revealed that pastures stockpiled at 15, 25 and 35 cm had the following attributes: 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, compared with the 45 cm stockpiled pasture (31.3 cm and 7,200 kg DM/ha). While we aimed to have this final group of pastures at 45 cm, this was not achieved and the pastures were really similar to the 35 cm stockpiled pasture so we decided to mow the pastures to 8 cm on 27 September 2013 to provide a fourth treatment for comparison and this became known as tall/mown.

#### *Management*

From 27 September 2013, the short, medium, tall and tall/mown pastures remained unstocked for 46, 42, 14 and 44 days, respectively, until they reached a target height of 30 cm, when grazing recommenced and continued until 4 February 2014. During this grazing period, all pastures were continuously stocked at variable stocking rates with the aim of maintaining an average height of 25 cm

([Silva et al. 2013](#)), using a similar strategy to that imposed before the stockpiling period. Animals used were crossbred Santa Inês × Dorper sheep (mean body weight 30 kg), which had unrestricted access to water and mineral salt.

Based on the results of the soil analysis, application of lime and potassium fertilizer was not necessary. During the rainy season of 2013, 55 kg P and 50 kg N/ha were applied in January, followed by 70 kg N/ha on 15 March 2013 and a further 70 kg N/ha on 12 January 2014.

#### *Measurement of tiller population dynamics*

Basal tillering dynamics was evaluated in 3 areas of 0.07 m<sup>2</sup> per paddock, representative of the average pasture condition. The areas were marked with a PVC ring (30 cm in diameter), fixed to the ground with metal clamps. All basal tillers within the ring were counted and marked on 27 September 2013 and subsequently new basal tillers were counted and marked every 30 days with plastic-coated wire of different colors, to identify each tiller generation until 10 February 2014. Tiller appearance rate (TAR, tillers/100 tillers) represented the number of tillers that appeared between 2 evaluations in relation to the total tiller population at the previous evaluation. Tiller survival rate (TSR, tillers/100 tillers) represented the number of tillers that survived between 2 evaluations in relation to the total tiller population at the previous evaluation. The population stability index 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. Graphs were also generated showing the monthly variation in number of tillers per generation in the pastures.

#### *Measurement of tiller number*

In September, November and December 2013, as well as January 2014, total number of tillers in the pastures was recorded, but outside the rings where tillering dynamics was assessed. In this case, 3 counts were performed per paddock at points that represented the average pasture condition. All live basal tillers contained within a 50 × 25 cm rectangle were counted.

#### *Statistical analysis*

The analysis of variance of the data was performed in a completely randomized design using the MIXED procedure (mixed models) of the SAS<sup>®</sup> (Statistical

Analysis System) statistical package, version 9.2. The covariance matrices were chosen using the Akaike Information Criterion (Wolfinger 1993). The effects of pasture condition at the end of winter, months of grazing and their interaction were considered fixed. Different months of the grazing period were considered repeated measures over time. The means of the factors were compared by the Student Newman Keul's test ( $P < 0.05$ ).

## Results

### *Relative tiller appearance and survival rates*

All response variables were influenced ( $P < 0.05$ ) by an interaction between pasture condition at the end of winter and month of the year (Table 1). In October, tiller appearance rate (TAR) was highest in the tall/mown pasture and lowest in the medium and tall pastures ( $P < 0.05$ ). For the remaining months, TAR was similar for all pastures (Table 1). TAR declined from October to November-December and then rose in January.

In October, the short pasture had the highest tiller survival rate (TSR), while the tall/mown pasture had the lowest ( $P < 0.05$ ; Table 1). In November and January, TSR was similar in all pastures, while tall and tall/mown pastures had higher TSR than medium pasture in December. With the exception of tall/mown pasture, pastures showed a reduction in TSR in December ( $P < 0.05$ ) followed by an increase in January (Table 1).

### *Cohort survival diagrams*

Based on number of tillers in the *Marandu palisadegrass* pastures at successive counts (Figure 2), there was a sharp increase in the number of tillers in the months of October and January. Consequently, tillers generated in October dominated the total tiller population. This phenomenon was most pronounced in short and tall/mown pastures. In addition, total tiller population was higher in short and tall/mown pastures than in medium and tall pastures.

### *Tiller population stability index*

The tiller population stability index (PSI) in October was highest in the short and tall/mown pastures and lowest in the tall pasture. In the remaining months, pasture conditions did not influence PSI. For all pastures, the PSI was highest in October, decreasing in November and December and increasing again in January ( $P < 0.05$ ) (Table 2).

### *Tiller population density*

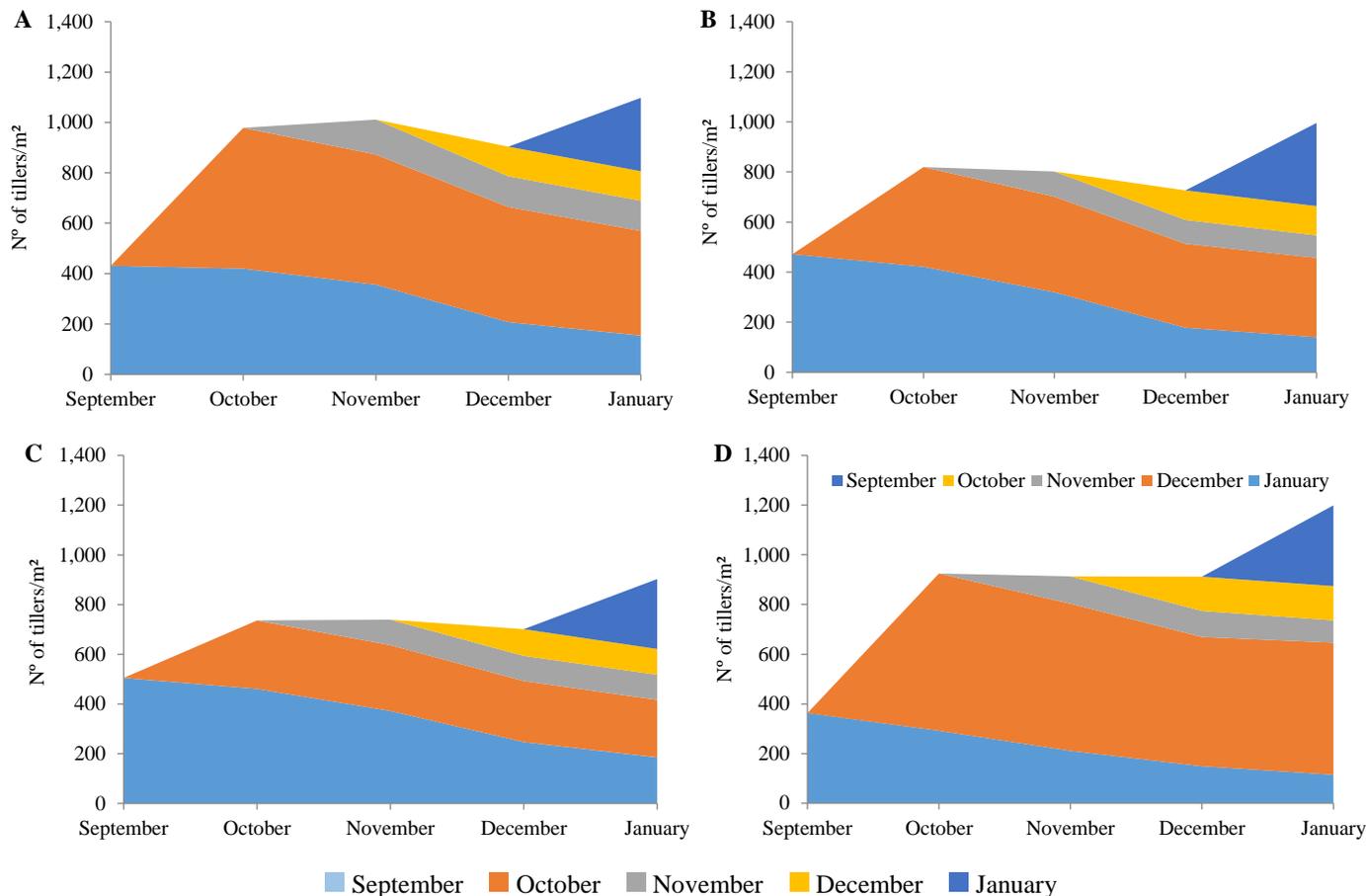
Regardless of the condition of the pasture and the way in which tiller population density was assessed (i.e. inside or outside the tiller dynamics assessment ring), the number of tillers (NT) was lowest in September and highest in January (Table 3). From October to January, NT was generally highest in tall and tall/mown pasture and lowest in tall pasture (Table 3).

**Table 1.** Rates of appearance and survival of basal tillers in spring and early summer, according to the condition of *Marandu palisadegrass* pasture at the end of winter and after its use under stockpiling.

Month	Pasture condition in late winter <sup>1</sup>				s.e.m.
	Short	Medium	Tall	Tall/Mown	
	Tiller appearance rate (TAR, tillers/100 tillers)				
October	132.9Ab	90.4Abc	55.5Ac	178.3Aa	26.6
November	14.2Ca	12.8Ca	14.1Ba	11.9Ca	0.6
December	11.7Ca	16.2Ca	14.7Ba	16.0Ca	1.0
January	32.1Ba	46.7Ba	39.8Aa	35.8Ba	3.1
	Tiller survival rate (TSR, tillers/100 tillers)				
October	97.5Aa	89.7Ab	91.4Ab	79.9Bc	0.21
November	89.3Ba	85.0Aa	86.6Aa	86.6Ba	0.03
December	77.7Cab	76.2Bb	80.2Ba	84.8Ba	0.02
January	89.2Ba	91.1Aa	88.6 Aa	95.6 Aa	0.03

<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); and Tall/Mown pasture (31.3 cm and 7,200 kg DM/ha, but cut to 8 cm) at end of winter.

For each characteristic, means within columns followed by the same upper-case letter, and within rows followed by the same lower-case letter are not significantly different by the Student Newman Keul's test ( $P > 0.05$ ).



**Figure 2.** Changes in tiller numbers of Marandu palisadegrass pastures for the cohorts generated each month during the experimental period. **A:** Short pasture (15.1 cm and 4,600 kg DM/ha); **B:** Medium pasture (23.2 cm and 5,940 kg DM/ha); **C:** Tall pasture (31.4 cm and 7,640 kg DM/ha); **D:** Tall/Mown pasture (31.3 cm and 7,200 kg DM/ha, but cut to 8 cm) at end of winter.

**Table 2.** Basal tiller population index in spring and early summer, according to the condition of Marandu palisadegrass pasture at the end of winter.

Month	Pasture condition in late winter <sup>1</sup>				s.e.m.
	Short	Medium	Tall	Tall/Mown	
October	2.3Aa	1.7Ab	1.4Ac	2.2Aa	0.21
November	1.0BCa	0.9Ca	1.0Ba	1.0Ca	0.03
December	0.9Ca	0.9Ca	0.9Ba	1.0Ca	0.02
January	1.2Ba	1.3Ba	1.2Aa	1.3Ba	0.03

<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); and Tall/Mown pasture (31.3 cm and 7,200 kg DM/ha, but cut to 8 cm) at end of winter.

For each characteristic, means within columns followed by the same upper-case letter, and within rows followed by the same lower-case letter are not significantly different by the Student Newman Keul’s test (P>0.05).

**Table 3.** Basal tiller numbers in spring and summer according to the condition of *Marandu palisadegrass* pasture at the end of winter and after its use under stockpiling.

Month	Pasture condition in late winter <sup>1</sup>				s.e.m.
	Short	Medium	Tall	Tall/Mown	
	Inside the tiller dynamics ring				
September	431Ca	472Ca	505Ca	363Cb	30.6
October	978Ba	819Bb	736Bc	925Ba	54.1
November	1011Ba	802Bb	686Bc	914Ba	70.2
December	904Ba	727BCb	642Bc	912Ba	66.8
January	1,098Aa	996Aa	945Ab	1,199Aa	56.3
	Outside the tiller dynamics ring				
September	511 Ca	469Ca	451Ca	441Ca	15.5
November	724 Ba	475Cb	631Bab	727Ba	59.1
December	712 Ba	751Ba	647Ba	742Ba	23.5
January	956 Aa	884Aa	956Aa	912Aa	17.7

<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); and Tall/Mown pasture (31.3 cm and 7,200 kg DM/ha, but cut to 8 cm) at end of winter.

For each characteristic, means within columns followed by the same upper-case letter, and within rows followed by the same lower-case letter are not significantly different by the Student Newman Keul's test ( $P > 0.05$ ).

## Discussion

The stability of the tiller population can be assessed by the population stability index (PSI), used for the first time by Bahmani et al. (2003) in perennial ryegrass populations. This index is calculated based on an integrated analysis between survival rates (TSR) and appearance (TAR) of tillers and when its value is equal to 1, the tiller population is in balance and remains stable. Values less than 1 mean that pastures show instability in the tiller population (which may be only transitory) and suggest, in general, that the appearance of new tillers is insufficient to compensate for the deaths of tillers from previous generations. On the other hand, values higher than 1 indicate an increase in the tiller population (Bahmani et al. 2003; Caminha et al. 2010). Based on the values of PSI obtained in this study, which were very close to or greater than one unit (Table 2), it is clear that stability of the tiller population was not compromised in any of the pastures.

In general, and in all pastures, the tiller population remained long-lived in the months following the high tiller appearance in October (Table 1). This fact guaranteed the stability of the plant population throughout spring and until the end of summer (Table 2). As previously observed by several authors and under different grazing methods, such as Caminha et al. (2010) in continuously stocked *Marandu palisadegrass*, and Pereira et al. (2018) in intermittently stocked Napier elephantgrass (*Cenchrus purpureus*, syn. *Pennisetum purpureum*), the basal tillers of the first generations produced during the beginning of the rainy season are the main contributors to tiller population density and herbage accumulation up to early summer. Similarly,

in this experiment, tillers which appeared in October made the greatest contribution to the tiller population up to January (Figure 2).

The higher TAR (Table 1) and PSI (Table 2) in October in short pasture, compared with tall pasture, were expected, since the greater amount of incident light reaching basal gems in low canopies stimulates tillering (Matthew et al. 2000; Sbrissia et al. 2010). Santana et al. (2014) also found an increase in TAR of *U. decumbens* in early spring, following a decrease in sward height at the beginning of the previous stockpiling period. In addition, higher TAR in October than in the other months (Table 1) was promoted by the improvement in climatic conditions (Figure 1), resulting in elevated values of PSI in this month (Table 2). In contrast with the short and tall/mown pastures, the tall pasture produced significantly fewer new tillers in October, probably because of reduced light incidence at the base (Figure 2). The lower PSI value in October (Table 2) in the tall pasture is consistent with its lower tiller population density within the tiller dynamics assessment ring (Table 3).

In October, the highest PSI value observed in short and tall/mown pastures (Table 2) was due to the more intense production of new tillers in these forage canopies, when compared with the medium and tall pastures (Figure 2). This may have compensated for the lower TSR of the tall/mown pasture, causing this pasture to present a high PSI in October (Table 1). The lower TSR of tall/mown pasture in October (Table 1) may have been caused by the elimination of the apical meristem (Matthew et al. 2000) of many tillers during the mowing carried out at the end of September. However, this lower TSR did not compromise tiller population stability of the tall/mown pasture, which

contradicted our hypothesis. It is possible that removal of the apical meristem from tillers during mowing may have reduced apical dominance and stimulated tillering (Santos et al. 2010). In addition, the stock of reserve compounds may have been sufficient to allow high tillering of tall/mown pasture in early spring. It is likely that stockpiled pastures have accumulated a high amount of reserve compounds during stockpiling in autumn, which may have been little used in winter, due to the low growth of the pasture (Silva et al. 2014). These reserve compounds accumulated in autumn and winter may, therefore, be important for the spring tillering of previously stockpiled pastures. However, this hypothesis has yet to be proven.

Considering that the short pasture at the end of the winter was made up of younger tillers, they may have stayed alive longer, which would justify their high TSR in October (Table 1).

The highest TAR in October, compared with the other months (Table 1), would have been a response to the improved climatic conditions (Figure 1), causing PSI values to peak during this month (Table 2). In November and December, the increasing number of tillers in the pastures (Table 3) probably increased the volumetric forage density, which may have intensified the level of shading within the canopies and, thus, decreased the TAR in those months (Table 1). This resulted in a small increase in tiller population density in November and December (Table 3; Figure 2), which promoted a decrease in PSI values in these months (Table 2). In January, nitrogen fertilizer application to the experimental area may have been the main determinant of increases in TAR values (Table 1), since this element is recognized for promoting the activation of dormant gems (Matthew et al. 2000), provided that the leaf area index of the pasture is low. In addition, the soil water deficit that occurred in January (Figure 1) may have been the cause of an unexpected increase in TSR this month, compared with the previous 2 months (Table 1). In this sense, Santos et al. (2011) also observed that, in winter (time of soil water deficit), tillers of *U. decumbens* cv. Basilisk continuously stocked with cattle survived longer than in spring and summer.

The greater tiller survival in times of water deficit may be an ecological strategy by Marandu palisadegrass for nutrient conservation (Santos et al. 2011). This strategy is interesting, since the absorption of nutrients by plants, via mass flow and/or diffusion, is hampered in conditions of water deficit in the soil (Novaes and Smyth 1999). Furthermore, in the months when there is a reduction in the rate of appearance, the tillers survive for a longer time, in order to stabilize the tiller population and, thus, guarantee their persistence in the area under different environmental conditions (Santos et al. 2011). In the present study, a high

TSR, combined with the increase in TAR, contributed to the increase in PSI in January (Table 2).

Sbrissia et al. (2010) and Santos et al. (2011) suggest that monthly manipulation of tillers during counting may have an impact on tiller regeneration. In the tall/mown pasture, the possible negative effect on tiller generation of the plant residue deposited on the base of the mown plants could have been minimized or even annulled by the monthly manipulation of tillers within the evaluation rings, and may even have stimulated tillering. However, the numbers of live tillers recorded at points outside the evaluation rings confirmed the data obtained within the rings for tall/mown pasture (Table 3).

The results of our work indicate that the high TAR observed in October was extremely important to maintain the stability of Marandu palisadegrass pastures. Despite this, even in October, TSR values were high (>0.75) and remained high over the following months, while the magnitude of TAR decreased (Table 1).

At the end of the experiment (January), on average, 14.2% of the total tillers were made up of the base generation (first marked generation) of tillers, which probably appeared during the previous autumn, since in winter climatic conditions were restrictive to plant growth. In contrast, 85.8% of all existing tillers had emerged from the end of October. Thus, most tillers present in pastures at the end of summer (late January) can be considered relatively young, less than 90 days old (Paiva et al. 2011). These facts indicate that the Marandu palisadegrass presented a population of young tillers that survived from the end of October until January. The lack of application of nitrogen fertilizer during the spring, added to a single low dose (70 kg N/ha) only in January, would have generated a condition of low N availability and, in effect, contributed to the longevity of the tiller population. This same pattern of response had already been reported by Costa et al. (2016) and Pessoa et al. (2016), who evaluated the tiller dynamics of Marandu palisadegrass under conditions of low nitrogen fertilizer application (50 and 60 kg N/ha during the entire rainy season, respectively) and observed TSR values above 80% from winter to summer. However, despite the relevance of TSR for the persistence of Marandu palisadegrass, it is important that management practices ensure high TAR in early spring (October), a time when this forage plant regains its tiller population density (Costa et al. 2016; Pessoa et al. 2016).

Based on our results, it is also possible to state that the effects of sward height and mowing at the end of winter on tillering occurred only in the 3 months of spring. Stockpiled pastures maintained at lower heights or those maintained at higher heights and then mown at the end of winter, showed the highest TAR and PSI, allowing the maintenance of

higher tiller population density during the spring. During summer all pastures, which were under the same management, showed similar tillering patterns (Table 1) and number of tillers (Table 3).

Our results demonstrate that short or tall/mown pastures have a faster tiller renewal, early in the growing season, compared with medium and tall pastures. In the latter ones, tillers still alive at the end of winter and early spring died off and were replaced by new ones, but with a lag in relation to short or tall/mown pastures. Therefore, the dynamics was the same, with a delay in the taller pastures, caused by the treatments imposed. In other words, pasture tillering patterns responded strongly to variations in availability of climatic growth factors, but these responses were modulated by experimental treatments. It is obvious that mismanagement during the transition from winter to spring may seriously impair the pasture's ability to rebuild tiller population and may compromise production for the entire next pasture growing season.

The importance of tillering dynamics for persistence and high yield of pastures in grazing systems is widely recognized (Colvill and Marshall 1984). The knowledge of seasonal patterns of tiller birth and death has allowed an understanding of how pasture management strategies affect tillering dynamics and has helped to define better grazing practices. This study has shown that the same rationale applies to stockpiled pastures, as both sward height and mowing at the end of winter grazing affect tiller population density and tillering dynamics early in the grazing season, i.e. in spring.

This study has revealed that, when stockpiling *Urochloa brizantha* cv. Marandu for providing winter feed, it is important to keep sward height low at the end of winter or alternatively mow the sward at the end of winter. Both strategies will ensure early and intense tillering in early spring. This strategy will ensure population stability of tillers in the Marandu palisadegrass pasture, as tillers generated in early spring are long-lived and therefore contribute significantly to the total population of tillers in the pasture during the growth season.

## Acknowledgments

The authors thank the National Council for Scientific and Technological Development (CNPq) for funding (Grant no 476869/2012-9). They also thank the members of TESTHFOR (Hypothesis Testing Group in Forage) of Federal University of Uberlândia for their contributions during the field trial setup. The first author thanks Minas Gerais Research Foundation (FAPEMIG) for their scholarship (Grant n° CVZ - PPM - 00144-13).

## References

(Note of the editors: All hyperlinks were verified 12 January 2020.)

- 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)
- Añez-Osuna F; Penner GB; Larson K; Jefferson PG; Lardner HA; McKinnon JJ. 2015. Effect of rumen degradable energy supplementation on forage utilization and performance of steers grazing stockpiled cool season perennial grass pastures. *Canadian Journal of Animal Science* 95:255–265. doi: [10.4141/cjas-2014-148](https://doi.org/10.4141/cjas-2014-148)
- Bakelaar J; Neher DA; Gilker R. 2017. Minimal soil quality impact by cold season pasture management in Vermont. *Canadian Journal of Soil Science* 97:215–225. doi: [10.1139/cjss-2014-0005](https://doi.org/10.1139/cjss-2014-0005)
- Bahmani I; Thom ER; Matthew C; Hooper RJ; Lemaire G. 2003. Tiller dynamics of perennial ryegrass cultivars derived from different New Zealand ecotypes: Effects of cultivar, season, nitrogen fertilizer, and irrigation. *Australian Journal of Agricultural Research* 54:803–817. doi: [10.1071/AR02135](https://doi.org/10.1071/AR02135)
- Caminha FO; Silva SC da; Paiva AJ; Pereira LET; Mesquita P de; Guarda VA. 2010. Stability of tiller population of continuously stocked marandu palisade grass fertilized with nitrogen. *Pesquisa Agropecuária Brasileira* 45:213–220. (In Portuguese). doi: [10.1590/S0100-204X2010000200013](https://doi.org/10.1590/S0100-204X2010000200013)
- Carneiro MAC; Cordeiro MAS; Assis PCR; Moraes ES; Pereira HS; Paulino HB; Souza ED. 2008. Phytomass yield of different cover crops and alterations in the microbial activity in a cerrado soil in Brazil. *Bragantia* 67:455–462. (In Portuguese). doi: [10.1590/S0006-87052008000200021](https://doi.org/10.1590/S0006-87052008000200021)
- 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/2LbQ14z](https://bit.ly/2LbQ14z)
- Colvill KE; Marshall C. 1984. Tiller dynamics and assimilate partitioning in *Lolium perenne* with particular reference to flowering. *Annals of Applied Biology* 104:534–537. doi: [10.1111/j.1744-7348.1984.tb03038.x](https://doi.org/10.1111/j.1744-7348.1984.tb03038.x)
- Duchini PG; Guzzatti GC; Echeverria JR; Américo LF; Sbrissia AF. 2018. Experimental evidence that the perennial grass persistence pathway is linked to plant growth strategy. *PLoS ONE* 13:e0207360. doi: [10.1371/journal.pone.0207360](https://doi.org/10.1371/journal.pone.0207360)
- Matthew C; Assuero SG; Black CK; Hamilton NRS. 2000. Tiller dynamics of grazed swards. In: Lemaire G; Hodgson J; Morales A de; Nabinger C; Carvalho PCF, eds. *Grassland ecophysiology and grazing ecology*. CABI, Wallingford, UK. p. 127–150. doi: [10.1079/9780851994529.0127](https://doi.org/10.1079/9780851994529.0127)
- Nave RL; Barbero RP; Boyer CN; Corbin MD; Bates GE. 2016. Nitrogen rate and initiation date effects on stockpiled tall fescue during fall grazing in Tennessee. *Crop, Forage & Turfgrass Management* 2:1–8. doi: [10.2134/cftm2015.0174](https://doi.org/10.2134/cftm2015.0174)

- Novaes RF; Smyth TJ. 1999. Fósforo em solo e planta em condições tropicais. UFV, Viçosa, MG, Brazil.
- Paiva AJ; Silva SC da; Pereira LET; Caminha FO; Pereira PM; Guarda VA. 2011. Morphogenesis on age categories of tillers in marandu palisadegrass. *Scientia Agricola* 68:626–631. doi: [10.1590/S0103-90162011000600003](https://doi.org/10.1590/S0103-90162011000600003)
- Pereira LET; Paiva AJ; Geremia EV; Silva SC da. 2018. Contribution of basal and aerial tillers to sward growth in intermittently stocked elephant grass. *Grassland Science* 64:108–117. doi: [10.1111/grs.12194](https://doi.org/10.1111/grs.12194)
- 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)
- Poore MH; Drewnoski ME. 2010. Utilization of stockpiled tall fescue in winter grazing systems for beef cattle. *The Professional Animal Scientist* 26:142–149. doi: [10.15232/S1080-7446\(15\)30573-8](https://doi.org/10.15232/S1080-7446(15)30573-8)
- Santana SS; Fonseca DM da; Santos MER; Sousa BML; Gomes VM; Nascimento Jr D. 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; Balbino EM; Monnerat JPIS; Silva SP da. 2009. Tiller characteristics in nitrogen fertilized and deferred signalgrass pastures. *Revista Brasileira de Zootecnia* 38:643–649. doi: [10.1590/S1516-35982009000400008](https://doi.org/10.1590/S1516-35982009000400008)
- 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](http://bit.ly/2QC7IB8)
- Santos MER; Fonseca DM da; Gomes VM; Nascimento Jr D do; Gomide CAM; Sbrissia AF. 2011. Signalgrass under continuous stocking and with fixed or variable height during the seasons: Tillering dynamics. *Revista Brasileira de Zootecnia* 40:2332–2339. doi: [10.1590/S1516-35982011001100008](https://doi.org/10.1590/S1516-35982011001100008)
- Santos MER; Carvalho BHR; Carvalho AN de; Rocha GO; Van Cleef FOS; Queiroz GJS; Moraes LS; Carmo LLS do. 2020. Number and morphology of tiller age groups during summer in Marandu palisadegrass pastures previously used under deferred grazing. *Bioscience Journal* 36:173–182. doi: [10.14393/BJ-v36n1a2020-42215](https://doi.org/10.14393/BJ-v36n1a2020-42215)
- Sbrissia AF; Silva SC da; Sarmiento 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 SC da; Gimenes FMA; Sarmiento 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)
- Silva SC da; Pereira LET; Sbrissia AF; Hernandez-Garay A. 2014. 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)
- Silva CS; Montagner DB; Euclides VPB; Queiroz CA; Andrade AS. 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 DOC de; Santos MER; Fonseca DM; Macedo Jr 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* 70:1–8. 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 betters the pasture structure in early summer. *Enciclopédia Biosfera* 11:12–22. (In Portuguese). [bit.ly/3hWK3Hu](http://bit.ly/3hWK3Hu)
- Thorntwaite CW; Mather JR. 1955. The water balance. Drexel Institute of Technology, Centerton, NJ, USA.
- 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)

(Received for publication 17 August 2020; accepted 31 December 2020; published 31 January 2021)

© 2021



*Tropical Grasslands-Forrajes Tropicales* is an open-access journal published by *International Center for Tropical Agriculture (CIAT)*, in association with *Chinese Academy of Tropical Agricultural Sciences (CATAS)*. This work is licensed under the Creative Commons Attribution 4.0 International ([CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)) license.