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Tillering dynamics in pastures of guinea grass subjected to grazing severities under intermittent stocking

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ABSTRACT - This experiment was carried out to analyze the tillering dynamics of the species *Panicum maximum* cv. Mombaca subjected to three post-grazing heights: residue of 30 cm (30); residue of 50 cm (50); and residue of 50 cm during spring and summer, lowered to 40 cm in the first fall season grazing and to 30 cm in the following grazing cycle, resuming to 50 cm after the first grazing of the following spring season (50-30). Grazings were initiated whenever the swards intercepted 95% of the incident light. The post-grazing heights were allocated in the experimental units in a completely randomized block design with three replications. The density of basal tillers did not vary between the residual heights evaluated. Swards managed with variable residual height (50-30) presented higher rates of appearance and mortality of basal tillers during the summer of 2007, indicating high tiller renovation. Regardless of the post-grazing height evaluated, lower rates of appearance of basal tillers were found in the spring of 2006. The stability index of guinea grass cv. Mombaca was close to 1.0 throughout the experimental period. Swards managed with variable post-grazing present structural changes able to improve the regrowth vigor, which may be important to maximize the use of the forage species in the production system.

Key Words: grazing management, light interception, *Panicum maximum*, stability index, tiller

Introduction

The tiller is the basic unit used in the production of forage grasses, which utilize tillering as a means of growth and mainly of survival (Hodgson, 1990). Species persistence in pasture is associated with the maintenance of plant populations and their production over time (Matthew et al., 2000), which is linked to a dynamic and harmonious balance between mortality and appearance of tillers, in a way that all dead tillers are replaced by new tillers (Da Silva et al., 2008). If the tiller replacement fails or if the use of grasses is incorrect, resulting in consistently higher senescence than the emergence of tillers, the pasture comes into degradation (Marshall, 1987).

The quantity and quality of light incidence, varying between the year seasons, may act on the activation of buds and, therefore, on the production of new tillers (Deregibus et al., 1983; Casal et al., 1985), promoting differences in tiller density in different seasons (Difante et al., 2008; Sbrissia et al., 2010). The intensity of the grazing applied to pastures also alters the quantity and quality of light incidence reaching the interior of the canopy after defoliation, inflicting variations in tiller density. Thus, the management of the defoliation process by adjustments and combinations of frequency and intensity of grazings, among other factors, can generate different responses to the tiller density and patterns of variation (appearance, mortality and survival rates of tillers). Thus, the regrowth rate and forage mass accumulation are dependent on the magnitude of their occurrence. These structural changes promote the maintenance of the dynamic growth of forage plants and represent an adaptation to the grazing system, ensuring productivity through a better use of environmental resources, especially light (Difante et al., 2008).

Studies on tiller density seem to be a good tool to predict these variations and, thus, to determine a managing strategy for the grazing system to maintain an adequate density aimed at optimizing forage production throughout the year (Lemaire & Chapman, 1996). Therefore, this study aimed to evaluate the density patterns of tillering in guinea grass cv. Mombaca subjected to different defoliation intensities under intermittent stocking.

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Material and Methods

The experiment was conducted at Embrapa Gado de Corte (CNPGC) in the municipality of Campo Grande, Mato Grosso do Sul, Brazil (20º27' S; 54º37' W; 530 m) from September 2005 to April 2007 in a pasture of *Panicum maximum* cv. Mombaca, with a total area of 2.25 ha, divided into nine paddocks of 0.25 ha each. The climate (Köppen classification) is tropical rainy, subtype Aw, with irregular distribution of annual precipitation, and with the occurrence of well-defined dry (May-September) and rainy (October to April) seasons (Figure 1).

The climatic conditions data during the experimental period (Figures 1 and 2) were collected at Embrapa Gado de Corte weather station, located about 4,000 m away from the experimental site.

To calculate the rainfall average, values of average temperature and accumulated monthly rainfall were used.

The soil was classified as Dystrophic Red Latosol (Embrapa, 1999) clayey texture, with acidic pH, low base saturation and high concentration of aluminum, and according to results of chemical analysis performed at the start of the experiment, the layer 0 to 20 cm had the following characteristics: pH in H_2O = 5.05; P = 2.03 (Mehlich-1) and K = 150.90 mg/dm^3; Ca^{+2} = 1.95; Mg^{+2} = 1.25; Al^{+3} = 0.03; H+Al = 3.81 and CTC (t) = 3.59 cmol$_c$/dm^3; V = 48.5%.

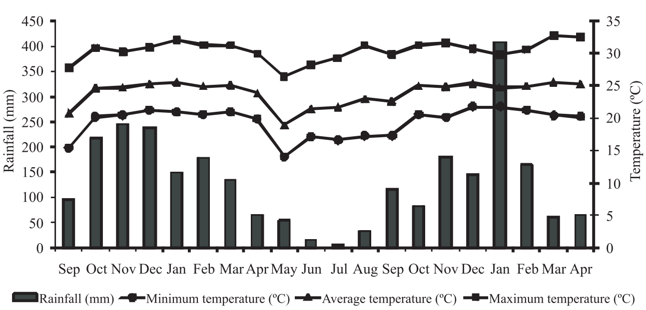


Figure 1 - Accumulated rainfall, and minimum, average and maximum temperatures from September 2005 to April 2007.

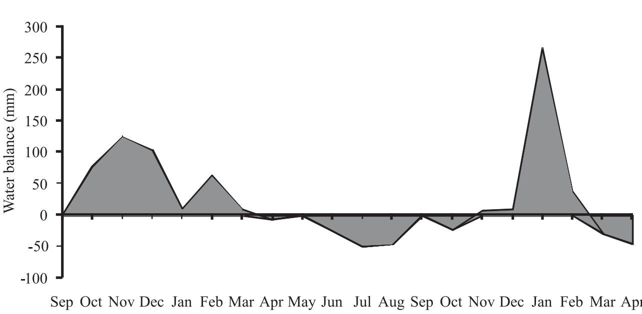


Figure 2 - Monthly water balance during the experimental period from September 2005 to April 2007, in Campo Grande, MS.

Since their establishment in 1994, the pastures were used under a grazing system. In October 2004, 1.0 t/ha of dolomitic limestone (85% PRNT) and 0.8 t/ha of agricultural gypsum were applied. In November 2005 and October 2006, 400 kg/ha of NPK (0-20-20 formulation) and 200 kg/ha of nitrogen as urea were applied. Nitrogen was applied in a parcel manner after grazing in each paddock during the rainy season. During the rainy season of 2006/2007, it was not possible to implement all the doses of urea as planned, since the experiment was terminated after the second grazing cycle on February 14, 2007.

Three post-grazing heights were evaluated: 30 cm and 50 cm of residue throughout the experimental period and 50-30 cm (50 cm of residue in the spring and summer, lowered to 40 cm in the first fall grazing and to 30 cm in the following grazing, returning to 50 cm after the first grazing in the spring), all performed consistently when the plants reached 95% of light interception during regrowth. The post-grazing heights were allocated to experimental units (0.25 ha) in a completely randomized block design with three replications.

The grazing method used was intermittent, using crossbred bulls with an average age of 18 months and average weight of 310 kg. The grazing interval was determined by trapping 95% of light through the canopy during regrowth, which corresponded to the canopy height of 93 cm, regardless of the season, similarly to the results observed at 90 cm by Carnevalli et al. (2006), also for the Mombaça-grass. The monitoring of light interception was carried out with the canopy analyzer *AccuPAR Linear PAR/LAI ceptometer, Model PAR 80* (DECAGON Devices) in 30 reading points per paddock, following trajectories in W-shape. The canopy height in pre and post-grazing was measured using a ruler, with which 40 readings were made in each experimental unit.

The tiller density (tillers/m^2) was determined by counting the total number of tillers (basal and aerial) within three existing metal frames of 1.0 m^2, positioned at points representing the average condition of the paddock at the assessment time. These areas were kept fixed and marked with wooden stakes during the trial period, and were changed only when ceased to represent the average condition of the pasture. Counts were performed consistently after each grazing.

To assess the tiller density, four clumps were marked randomly in each experimental unit. In a first assessment (spring 2005), all tillers in each clump of wires were marked with a single color, identifying the generation of reference tillers. With every new assessment, carried out consistently in the post-grazing period, all marked tillers were recounted, new tillers were marked with a different color and the strands of senescent tillers were collected.

In each procedure of counting and marking tillers, they were differentiated as for the location of their point of origin in the basal or aerial tillers. The strands lost in each generation were disregarded in the total value of tillers per clump. Based on the scores, the number of basal and aerial tillers was obtained in each measurement. Rates of appearance (emerged tillers/total tillers alive in the previous marking) and mortality (senescent tillers/total tillers alive in the previous marking) of basal tillers and aerial tillers were calculated. The stability index [(1-mortality rate of tillers) × (1+appearance rate of tillers)] of the population of tillers was calculated according to methodology described by Bahmani et al. (2003).

Due to the number of cycles of variable grazing systems (5 grazing sections in pastures lowered to 30 cm, and 6, in those lowered to 50 and 30-50cm throughout the trial period) and the variable grazing interval between paddocks and post-grazing heights evaluated, the data were grouped (weighted average) into four seasons: summer 2006 (January-March 2006); fall 2006 (April-June 2006), winter/spring 2006 (July-December 2006); and summer 2007 (January-March 2007). The data, therefore processed, were analyzed by split plot in time, in which the post-grazing height constituted the plots and, the seasons, the subplots. The variance analyses of the weighted average per season showed no heterogeneity. Thus, the data were analyzed by a mathematical model containing the random block effect and fixed effects of post-grazing height, seasons and interactions between them. For that purpose, the GLM procedure of the SAS statistical package (Statistical Analysis System, version 6) was used. The comparison of means was performed using the Tukey test at 5% probability. In the case of significant interactions, the comparison of means was performed by the probability of difference and by the Tukey test at 5% probability.

Results and Discussion

The density of basal tillers was not affected (P>0.05) by post-grazing heights, seasons or interaction between height and seasons. Thus, pastures grazed at 30 cm had an average of 374 tillers/m^2, while pastures maintained at 50 cm and 50-30 cm, had 356 and 386 tillers/m^2 (standard error of the mean = 19.2), respectively.

Throughout the regrowth, the intraspecific competition for light increases gradually, reducing the quantity and quality of light reaching the interior of the canopy, causing morphophysiological changes in plants. This process occurs through a compensation mechanism of size/population density of tillers (Matthew et al. 1995; Sbrissia et al., 2001, 2003; Sbrissia & Da Silva, 2008), in which tillers die basically because of competition for light in the canopy. However, when the forage is harvested at 95% of light interception, the intense competition for light is avoided. Given that the criterion for termination of regrowth was the same (95% of light interception), the density of basal tillers did not vary between the post-grazing heights or seasons with an average of 374, 356 and 386 of tillers/m^2 for the post-grazing heights of 30, 50 and 50-30 cm, respectively. Sousa et al. (2010), evaluating the Andropogon grass and Sousa et al. (2011), evaluating the Xaraes palisade grass subjected to different cutting heights, all performed when the canopy reached 95% of light interception, also reported no changes in density of basal tillers, corroborating, thus, the results obtained in this study.

Although there was variation in the density of basal tillers, it is known that it continually adjusts and is determined by a dynamic balance between the rates of emergence and senescence of tillers. Therefore, there was variation in the pattern of tiller density due to post-grazing heights and seasons.

For the appearance rate of basal tillers, there was an interaction (P<0.05) between post-grazing heights and seasons, except for the summer of 2007, when the appearance rate of basal tillers was similar within the seasons. The increase in the leaf area index causes changes in the quality of the light ambience inside the canopy and contributes to altering the emergence rate of new tillers (Deregibus et al., 1983). Thus, on pastures managed with reduction in residue height during the fall (50-30 cm), the stubble accumulation at the base of the canopy was possibly lower, allowing greater light penetration into the canopy, which caused the appearance rate of basal tillers higher in the summer of 2007, when the weather conditions became predisposing for plant growth. On the other hand, on the pastures managed with less intensity (50 cm post-grazing height) there may have been a greater accumulation of forage grass at the base of the canopy, affecting light penetration and, therefore, the appearance rate of basal tillers in the summer of 2007. The amount of forage mass affects tillering (Langer, 1956), in a way that after severe defoliation occurs after inhibition of tillering due to low availability of organic reserves in the plant (Matthew, 1992). Thus, in pastures managed with greater intensity (30 cm post-grazing height) there may have been less accumulation of forage mass, which compromised the appearance rate of basal tillers in the summer of 2007.

Pastures managed with 30 cm of residue had higher appearance rate of basal tillers in the summer of 2006 and the fall of 2006 and lower in the winter/spring of 2006, while on pastures managed with 50 cm of residue, the appearance rate of basal tillers was higher in the fall of 2006 and lower in the other seasons. Pastures managed with variable amounts of forage mass during the year showed lower appearance rate of basal tillers in the winter/spring of 2006 (Table 1).

Regardless of the post-grazing height, the appearance rate of basal tillers were high in the summer of 2006 and fall of 2006, decreasing in the winter/spring of 2006 and increasing again in the summer of 2007 (Table 1). This variation coincides with changes in environmental conditions throughout the year (Difante et al., 2008; Pena et al., 2009; Sbrissia et al., 2010), since, in the processes of formation, development, growth and senescence of tillers are influenced by weather conditions (Mazzanti et al., 1994). It is also worth noting that the adoption of a variable post-grazing height throughout the year (50-30 cm) resulted in higher appearance rate of basal tillers in the summer of 2007 (Table 1). Certainly, this management system decreased the amount of dead forage in the winter/spring of 2006, allowing greater light penetration in the following spring, a fact known to promote differentiation of buds that originate new tillers (Matthew et al., 2000), mainly basal tillers. This shows an important response to the reduction of forage mass, which occurred in the fall and may promote tillering and ensure a quicker resumption of the grass production cycle in the following growing season (Da Silva et al., 2008).

The mortality rate of basal tiller was influenced ($P<0.05$) by the interaction between post-grazing heights and seasons. Pastures managed with post-grazing heights of 30 and 50-30 cm had higher mortality rate of basal tiller in the summer of 2007 (Table 2). Thus, the high tiller appearance was offset by high tiller mortality. This shows a dynamic and balanced mechanism between the processes of appearance and mortality of tillers in order to keep the population of tillers stable (Da Silva et al., 2008). Additionally, high tiller appearance and mortality rates during periods characterized by better growth and development (temperature, precipitation) (Figures 1 and 2) show reduced longevity and increased renewal of tillers, resulting in a younger population. The age of the tillers may influence their morphogenesis and structure, resulting in progressive loss of strength as tillers age (Barbosa, 2004; Paivaet al., 2011, 2012). Therefore, management practices that favor a rapid turnover of tillers are desirable, since new tillers grow at rates higher than the older ones (Barbosa, 2004).

The density of aerial tillers varied ($P<0.05$) only according to the seasons. An increased number of aerial tillers ($P<0.05$) was observed in the summer of 2007 (5.1tillers/m^2), followed by the winter/spring of 2006 (1.3 tillers/m^2). In the summer of 2006 and fall of 2006, aerial tillers were not observed (Figure 3). In general, the guinea grass cv. Mombaca has low aerial tillering and even during the summer of 2007, when the highest density of aerial tillers was observed, the number of aerial tillers was very small. Moreover, in the summer of 2006, the density of aerial tillers was practically zero (Figure 3), which indicated that no aerial tillers were found in this season.

Certainly, the greatest number of aerial tillers in the summer of 2007 is a consequence of greater appearance rate of aerial tillers in this season (Figure 4). Although the aerial tillers represent an important contribution to the total tiller density of some forage grasses, such as the Marandu palisade grass (Difante et al., 2008), in the guinea grass cv. Mombaca these tillers seem to have a minor importance, since they account for a small proportion of the total density of tillers (1.4%).

There was no interaction ($P>0.05$) between the heights and seasons or difference between post-grazing heights in relation to the appearance rate of aerial tillers. Greater appearance rate of aerial tillers was observed in the summer of 2007 (0.016 tillers/tillers.day) while the lowest ones were found in the summer of 2006 (0 tillers/tillers.day) in the fall (0.005 tillers/tillers.day) and winter/spring of 2006 (0.003 tillers/tillers.day) (Figure 4).

Table 1 - Appearance rate of basal tillers (tillers/tillers.day) in pastures of guinea grass cv. Mombaca subjected to grazing intensities in a rotational system

Seasons	Post-grazing heights		
	30	50	50-30
Summer 2006	0.010aA	0.007aB	0.009aB
Fall 2006	0.011aA	0.012aA	0.010aAB
Winter/Spring 2006	0.003aB	0.003aB	0.004aC
Summer 2007	0.007bAB	0.006bB	0.012aA

Standard error of the mean - 0.0008.
Distinct lowercase letters in the same line differ ($P<0.05$) by the Tukey test.
Distinct uppercase letters in the same column differ ($P<0.05$) by the Tukey test.

Table 2 - Mortality rate of basal tillers (tillers/tillers.day) in pastures of guinea grass cv. Mombaca subjected to grazing intensities in a rotational system

Seasons	Post-grazing heights		
	30	50	50-30
Summer 2006	0.006aBC	0.004aAB	0.003aB
Fall 2006	0.007aB	0.005aA	0.006aB
Winter/Spring 2006	0.003aC	0.003aAB	0.003aB
Summer 2007	0.013aA	0.002bB	0.014aA

Standard error of the mean - 0.0005.
Distinct lowercase letters in the same line differ ($P<0.05$) by the Tukey test.
Distinct uppercase letters in the same column differ ($P<0.05$) by the Tukey test.

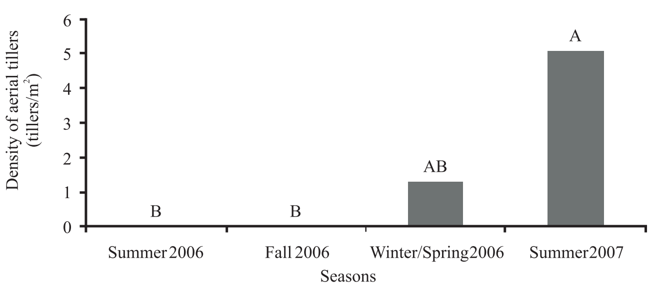
There was interaction (P<0.05) between the post-grazing heights and seasons for the mortality rate of aerial tillers. Within the season, except for the summer of 2007, the mortality rate of aerial tillers was similar between the post-grazing heights evaluated. Pastures kept at 30 and 50 cm had similar mortality rate of aerial tillers (P>0.05) between seasons. Pastures managed with variable residue had higher mortality of aerial tillers (P<0.05) in the summer of 2007 (Table 3), certainly in response to the increased renewal of tillers, as discussed earlier.

To better analyze the effect of significant variations on the mortality and appearance rates of tillers, it is important to assess the combined effect of both (Difante et al., 2008). This can be done through the stability index of the population (Bahmani et al., 2003). Overall, values below 1.0 indicate that the survival and emergence of new tillers are not sufficient to compensate for mortality rates and, therefore, the population tends to decrease. Values greater than 1.0 suggest the reverse situation, while values near 1.0 indicate a stable population of tillers, in which the number of tillers hardly varies, despite being a result of a dynamic balance (Bahmani et al., 2003).

The stability index of the basal tillers for the guinea grass cv. Mombaca remained near 1.0 throughout the experimental period, regardless of the post-grazing height (Figure 5).

The values had a little variation, with a tendency to a slight rise in the fall of 2006, a reduction in the winter/spring of 2006 and stabilization at 1.0 in the summer of 2007. The only exception was the post-grazing height of 50 cm in the summer of 2007, which tended to increase. These results are consistent with the density of basal tillers and show that the post-grazing height did not affect the stability of the population of basal tillers of the guinea grass cv. Mombaca.

The stability of aerial tillers (Figure 6) shows an increase in the density of tillers in the summer of 2007 for post-grazing heights of 50 and 50-30 cm, and a decrease for post-grazing height of 30 cm. Certainly, a more severe grazing (30 cm) promotes greater removal of forage and, therefore, of aerial tillers, which are located mainly in the upper parts of the plants.



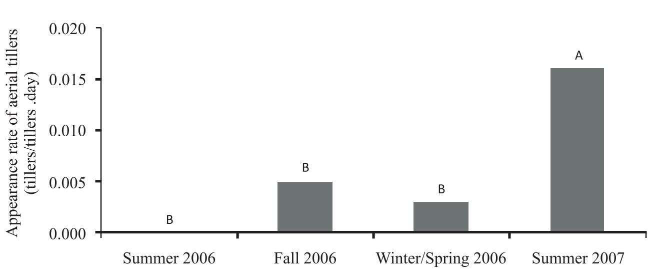
Distinct uppercase letters differ (P<0.05) by the Tukey test.

Figure 3 - Density of aerial tillers (tillers/m^2) in pastures of guinea grass cv. Mombaca subjected to grazing intensities in a rotational system.

Table 3 - Mortality rate of aerial tillers (tillers/tillers.day) in pastures of guinea grass cv. Mombaca subjected to grazing intensities under rotational system

Seasons	Post-grazing heights		
	30	50	50-30
Summer 2006	0.000aA	0.000aA	0.000aB
Fall 2006	0.000aA	0.000aA	0.000aB
Winter/Spring 2006	0.003aA	0.000aA	0.001aB
Summer 2007	0.011bA	0.001cA	0.016aA

Standard error of the mean = 0.0005.
Distinct lowercase letters in the same line differ (P<0.05) by the Tukey test
Distinct uppercase letters in the same column differ (P<0.05) by the Tukey test.



Distinct uppercase letters differ (P<0.05) by the Tukey test.

Figure 4 - Appearance rate of aerial tillers (tillers/tillers.day) in pastures of guinea grass cv. Mombaca subjected to grazing intensities in a rotational system.

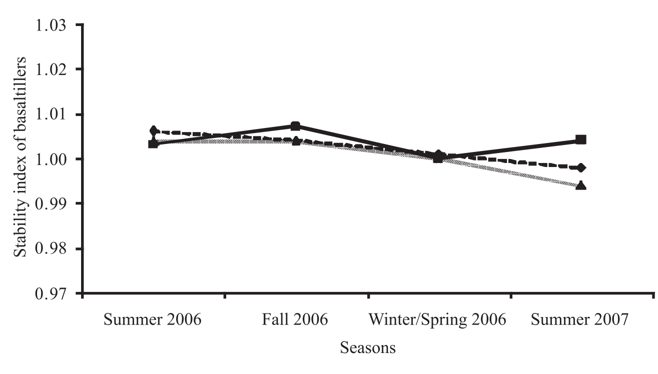


Figure 5 - Stability index of basal tillers in pastures of guinea grass cv. Mombaca subjected to grazing intensities in a rotational system.

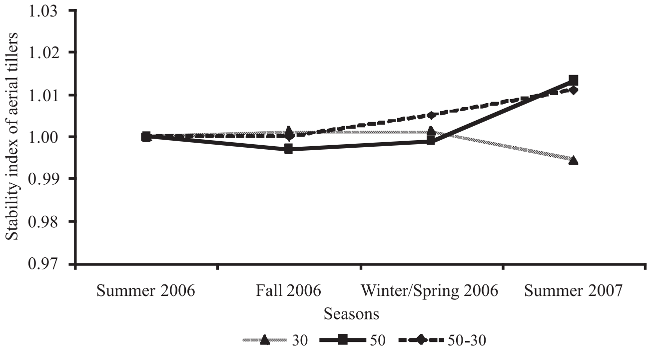


Figure 6 - Stability index of aerial tillers in pastures of guinea grass cv. Mombaca subjected to intensities grazing in a rotational system.

Conclusions

The post-grazing heights evaluated are appropriate for the guinea grass cv. Mombaca, since they did not affect the stability of the tiller density. The lowering of the post-grazing height from 50 cm to 30 cm in the fall, returning to 50 cm after the first grazing in the spring seems promising, allowing greater emergence and renewal of tillers in the following summer.

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