Effects of two post-grazing heights on morphogenic and structural characteristics of guinea grass under rotational grazing

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Abstract

A rotational grazing experiment was carried out to determine the effects of post-grazing height on morphogenic characteristics of guinea grass (*Panicum maximum*) cv. Mombaca between October 2004 and June 2005. The grass was subjected to 2 severities of rotational grazing, represented by post-grazing stubble heights of 30 and 50 cm, and animals were reintroduced when pastures intercepted 95% of incident light. Swards managed with 30 cm post-grazing stubble height had smaller leaf elongation rate (LER) and final leaf length (FLL) and greater tiller population density (TPD), tiller appearance rate (TAR) and tiller mortality rate (TMR) than those grazed to 50 cm. During the second grazing cycle, stem elongation rate (SER) was lower in paddocks grazed to 30 cm stubble height. Grazing cycle had significant effects on plant morphology. Leaf appearance rate (LAR), LER and TAR peaked in the second grazing cycle, while SER, TPD and TMR peaked in cycles 3 and 4. The more intense grazing management (30 cm stubble) resulted in higher levels of tiller renewal and tiller turnover and lower stem elongation. How these changes relate to pasture yields and animal performance is yet to be determined.

Introduction

The cattle industry in Brazil uses pastures for meat and milk production, predominantly under grazing. Guinea grass (*Panicum maximum*) is one of the most popular grasses used to support livestock in Brazil and is normally rotationally grazed.

Proper grazing management of stands to control plant growth and forage quality is critical for successful animal production from pastures. Recent studies carried out in Brazil have consistently shown that the optimum stage to harvest pasture or re-introduce stock is when 95% of the incident light is being intercepted (da Silva *et al*. 2008). Under this management system, forage produced has high nutritive value (younger tillers and leaves). In relation to the residue height, there is still no clear information on the minimum residual leaf area for plants to initiate the regrowth process for a full spring recovery. This experiment aimed to evaluate the effects of 2 post-grazing heights on the morphogenic and structural characteristics of guinea grass under rotational grazing.

Material and methods

The experiment was carried out in the grazing area of the Embrapa Beef Cattle Research Station (CNPGC) (20º 26'S, 54º 43'W; elevation 530 masl) in Campo Grande, MS, from October 2004 to June 2005. The climate, according to Köppen's classification, is a rainy tropical savannah, subtype AW. Rainfall is irregular, with a well defined dry period during the coldest months of the year and a rainy period during the summer months. Climatic data during the experimental period were monitored by the Embrapa-Beef

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Cattle meteorological station, about 4 km from the experimental site. During the experimental period, there were dry spells in the months of February, March and April (Figure 1).

The soil of the experimental area is classified as red dystrophic latosoil (oxisol) (EMBRAPA 1999) and is a clay soil, with acidic pH, low base saturation and high aluminium concentrations. Chemical characteristics of samples taken from depths of 0–10, 0–20 and 20–40 cm are presented in Table 1. Based on this information, lime, phosphorus and potassium fertilisers were used to raise base saturation to 50–70%, phosphorus content to 8–12 mg/dm^3 (Mehlich^{-1} extraction) and potassium content to 80–100 mg/dm^3 (EMBRAPA 1999). In October 2004, we applied 1.0 t/ha dolomitic limestone, 0.8 t/ha agricultural gypsum and 500 kg/ha N:P:K fertiliser (0:20:20 formulation). Urea (200 kg/ha N) was applied as split dressings according to the schedule shown in Table 2.

Guinea grass (*Panicum maximum*) cv. Mombaça had been established in the experimental area in January 1995. The experimental design was a randomised complete block design with 3 replications. The experimental area was 1.5 ha and was subdivided into 3 blocks of 0.5 ha, each consisting of 2 plots of 0.25 ha, totalling 6 paddocks, or experimental units. The treatments consisted of 2 grazing severities characterised by stubble heights post grazing of 30 and 50 cm. Rotational grazing was used, and the intergrazing interval was set as the number of days necessary to achieve 95% interception of incident light (95% LI) by the pasture canopy. This was measured with a Decagon Accupar photoradiometer at 30 random points per paddock. At each point, 2 readings were taken, 1 at the top of the sward and the other at soil level midway between tussocks.

During the experimental period, pasture height and light interception by the canopy were monitored every 7 days during spring and summer and every 14 days in autumn. When the sward intercepted more than 90% of the incident radiation, the monitoring interval was reduced to 2 days until 95% LI was reached, at which time the animals could re-enter the paddocks. Before animals entered the paddocks for grazing, height of the pasture was measured at 40 points per paddock along 5 line transects, each with 8 points, using a yardstick graduated in centimetres. Nelore cattle with an initial average age of 24 months and a body weight of 300 kg were used. The number of animals used per paddock was adjusted so that the post-grazing stubble height was reached within 3 days of animals entering the plots.

Morphogenic and structural characteristics were evaluated on 10 tillers per paddock, selected at random. Length of leaf blades and stems and senescence of leaves were measured every 7 days during spring and summer and every 14 days during autumn. From this information the following variables were calculated: leaf appearance rate (LAR, leaves/tiller/d); leaf elongation rate (LER, cm/tiller/d); stem elongation rate (SER, cm/tiller/d); final leaf length (FLL, cm); number of live leaves per tiller (LLT); leaf lifespan (LLS, d; Lemaire and Chapman 1996);

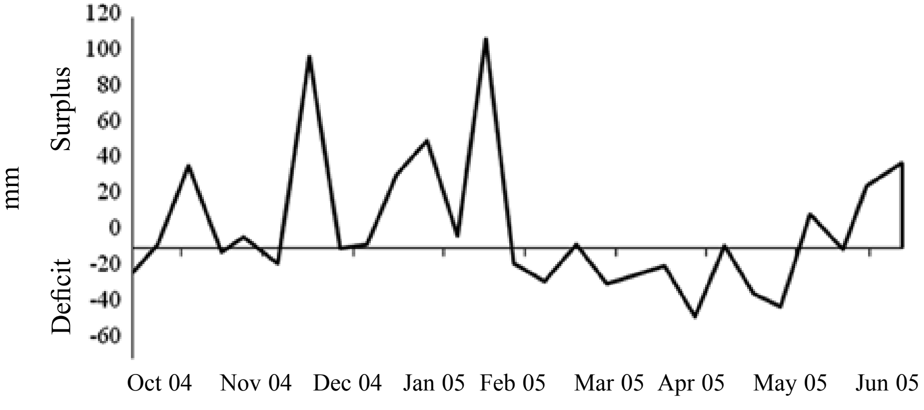

Figure 1. Monthly water balance throughout the experimental period.

Table 1. Soil chemical characteristics of the experimental area at depths of 0–10, 0–20 and 20–40 cm.

Chemical characteristics	Depth (cm)		
	0–10	0–20	20–40
pH ($CaCl_2$)	5.36	5.05	4.66
Ca ($cmol_c/dm^3$)	2.47	1.95	0.85
Mg ($cmol_c/dm^3$)	1.72	1.25	0.41
Al ($cmol_c/dm^3$)	0.00	0.03	0.15
H + Al ($cmol_c/dm^3$)	3.77	3.81	3.21
Sum of bases ($cmol_c/dm^3$)	4.63	3.59	1.37
Effective CEC ($cmol_c/dm^3$)	4.63	3.59	1.53
Base saturation (%)	55.1	48.5	30.1
Al saturation (%)	0.00	0.91	10.87
Organic matter (%)	4.81	4.60	2.94
P – Mehlich^{-1} (mg/dm^3)	3.57	2.03	0.72
K – Mehlich^{-1} (mg/dm^3)	170.6	150.9	44.6

Table 2. Dates and levels of application of N fertiliser to various paddocks during the trial period.

Treat.[1]	Bl.[2]	1		2		3		4	
		Date	kg/ha	Date	kg/ha	Date	kg/ha	Date	kg/ha
30 cm	I	5/11/04	50	31/1/05	75	4/4/05	75	-	-
	II	5/11/04	50	19/1/05	75	4/3/05	75	-	-
	III	5/11/04	50	31/1/05	75	24/3/05	75	-	-
50 cm	I	5/11/04	50	24/1/05	75	4/3/05	75	-	-
	II	5/11/04	50	14/1/05	75	5/2/05	37.5	24/3/05	37.5
	III	5/11/04	50	19/1/05	75	11/2/05	37.5	24/3/05	37.5

[1] Treat. = treatment (residual heights post grazing of 30 and 50 cm).

[2] Bl. = block.

and leaf:stem ratio (LSR). Tiller population density (TPD, tillers/m^2) was evaluated in 3 fixed areas of 1 m^2 per paddock, which were chosen on each occasion to represent the average condition of the pasture (visual evaluation of height and forage mass). Live tillers that existed immediately before the entry of animals to the paddocks were counted.

To assess the dynamics of tillering, 4 tussocks were selected per paddock at the start of the study. All tillers on these tussocks were marked with coloured plastic wire representing the initial generation. At the end of each grazing, surviving tillers were counted, and new tillers were marked with wire using a different colour from those used previously so that each generation of tillers carried a different colour. Dead tillers and those in the reproductive stage for each generation were also counted. From this information the following variables were calculated: tiller appearance rate (TAR, tillers/100 tillers/d) and tiller mortality rate (TMR, tillers/100 tillers/d).

The data were analysed according to a split-plot design, where treatments constituted the main plots and grazing cycles the subplots, using the GLM procedure of the SAS statistical package (SAS Institute 1996).

Results

The P values related to the analysed variables are shown in Table 3. There were no significant interactions between post-grazing stubble height and grazing cycle, except for SER and TMR, so main effects are presented.

Post-grazing stubble height had no significant effect on LAR, LLS and LLT (Table 4). LER, FLL and SER for a post-grazing stubble height of 50 cm were greater than for 30 cm. TPD, TAR and TMR were all higher in the swards managed at a post-grazing stubble height of 30 cm (Table 4).

Table 3. ANOVA results (P value).

Variable[1]	Grazing management	Grazing cycle	Management × cycle
LAR	0.8857	<0.0001	0.1894
LER	0.0356	<0.0001	0.1346
SER	0.0275	<0.0001	<0.0001
LLS	0.5350	<0.0001	0.5282
FLL	0.0021	<0.0001	0.0502
TPD	0.0120	<0.0001	0.9350
LSR	0.1628	<0.0001	0.1243
LLT	0.1809	<0.0001	0.0630
TAR	0.0145	<0.0001	0.1344
TMR	0.0001	<0.0001	<0.0001

[1] LAR, leaf appearance rate; LER, leaf elongation rate; SER, stem elongation rate; LLS, leaf lifespan; FLL, final leaf length; TPD, tiller population density; LSR, leaf:stem ratio; LLT, live leaves per tiller; TAR, tiller appearance rate; TMR, tiller mortality rate.

Grazing cycle had marked effects on the morphogenic and strutuctural characteristics of the guinea grass (Table 5). LAR, LER and TAR peaked in the second grazing cycle, while LLS, which was relatively constant for most of the study, had lowest values in the second grazing cycle. FLL was high in the first cycle, declining to the second cycle and relatively constant thereafter (Table 5). TPD increased to the third grazing cycle, and then declined. Number of live leaves/tiller (LLT) declined significantly from the first to the second cycle, then showed small non-significant declines for the remainder of the study. TMR increased up to the third grazing cycle and then plateaued.

Significant interactions between grazing treatment and grazing cycle for SER and TMR are presented in Table 6.

Table 4. Morphogenic and structural characteristics of guinea grass cv. Mombaca managed under 2 post-grazing sward heights.

Variable[1]	Residue height (cm)	
	30	50
LAR	0.06 (0.01)[2]	0.07 (0.01)
LER	2.50 B[3] (0.35)	3.70 A (0.35)
SER	0.04 B (0.02)	0.12 A (0.02)
LLS	100 (7.90)	96 (7.90)
FLL	24.60 B (0.92)	29.60 A (0.92)
LLT	1.20 (0.06)	1.20 (0.06)
TPD	559 A (14.00)	508 B (14.00)
TAR	0.011 A (0.01)	0.009 B (0.01)
TMR	0.006 A (0.01)	0.004 B (0.01)

[1] LAR, leaf appearance rate; LER, leaf elongation rate; SER, stem elongation rate; LLS, leaf lifespan; FLL, final leaf length; LLT, live leaves per tiller; TPD, tiller population density; TAR, tiller appearance rate; TMR, tiller mortality rate.

[2] Numbers in parentheses correspond to standard error of the mean.

[3] Within rows, values followed by different letters differ ($P<0.05$).

Discussion

The results of this study provide some understanding of the dynamics of pasture growth when grazed rotationally to given stubble heights, which should prove useful in determining grazing management of a pasture. In this study, the criterion for introducing animals after the regrowth phase was the level of light interception by the canopy.

In recent studies of tropical grasses, a strong relationship has been found between canopy height and light interception by the pasture, and hence the dynamics of accumulation of dry matter (Carnevalli *et al.* 2006; Barbosa *et al.* 2007; Difante *et al*. 2009), suggesting that sward height can be a reliable criterion for determining

Table 5. Effects of grazing cycle on morphogenic and structural characteristics of guinea grass cv. Mombaca.

Variable[1]	Grazing cycle			
	1	2	3	4
LAR (leaves/tiller/d)	0.05 B[2] (0.01)[3]	0.09 A (0.01)	0.05 B (0.01)	0.05 B (0.01)
LER (cm/tiller/d)	2.8 B (0.50)	5.2 A (0.50)	2.3 B (0.50)	2.1 B (0.60)
SER (cm/tiller/d)	0.02 B (0.03)	0.13 A (0.03)	-0.03 B (0.03)	0.19 A (0.04)
LLS (d)	124 A (10.00)	68 C (10.00)	102 AB (10.00)	99 BC (12.00)
FLL (cm)	32.6 A (1.20)	27.5 B (1.20)	24.3 B (1.20)	24.0 B (1.40)
LLT	1.4 A (0.08)	1.2 B (0.08)	1.0 AB (0.08)	0.9 B (0.09)
TPD (tillers/m^2)	348 D (19.5)	447 C (19.5)	700 A (19.5)	638 B (19.5)
TAR (tillers/100 tillers/d)	0.007 B (0.001)	0.016 A (0.001)	0.008 B (0.001)	0.008 B (0.001)
TMR (tillers/100 tillers/d)	0.002 C (0.001)	0.004 B (0.001)	0.007 A (0.001)	0.007 A (0.001)

[1] LAR, leaf appearance rate; LER, leaf elongation rate; SER, stem elongation rate; LLS, leaf lifespan; FLL, final leaf length; LLT, live leaves per tiller; TPD, tiller population density; TAR, tiller appearance rate; TMR, tiller mortality rate.

[2] Within rows, values followed by different letters differ ($P<0.05$).

[3] Numbers in parentheses correspond to standard error of the mean.

Table 6. Interaction between grazing cycle and post-grazing height for stem elongation rate and tiller mortality rate of guinea grass cv. Mombaca, under 2 severities of rotational grazing.

Variable[1]	Post-grazing height (cm)	Grazing cycle			
		1	2	3	4
SER (cm/tiller/d)	30	-0.01 Ba[2] (0.04)[3]	-0.05 Bb (0.04)	0.02 Ba (0.04)	0.17 Aa (0.06)
	50	0.06 Ba (0.04)	0.33 Aa (0.04)	-0.08 Ca (0.04)	0.22 Ba (0.04)
TMR (tillers/100 tillers/d)	30	0.003 Ca (0.04)	0.006 Ba (0.04)	0.008 Aa (0.04)	0.009 Aa (0.04)
	50	0.001 Cb (0.04)	0.003 Bb (0.04)	0.006 Aa (0.04)	0.004 Bb (0.04)

[1] SER, stem elongation rate; TMR, tiller mortality rate.

[2] Means within rows followed by the same upper case letter and within parameters and columns followed by the same lower case letter are not different ($P>0.05$).

[3] Numbers in parentheses correspond to standard error of the mean.

when to reintroduce animals in a rotational grazing system. Carnevalli *et al.* (2006) reported that Mombaça guinea grass trapped 95% of incident light at a sward height of about 90 cm.

Dry matter production by a pasture is a complex process, with the rates of appearance and death of tillers plus the rates of leaf appearance and extension interacting. LER is an important variable in this process and is positively correlated with dry matter accumulation (Horst *et al.* 1978). While the higher values for LER in swards managed at 50 cm stubble height are indicative of greater leaf accumulation in this sward, this advantage is balanced by the higher TAR and TPD in the 30 cm sward. The greater tiller mortality rates in swards managed at 30 cm stubble height indicate a younger profile in the tiller population on this pasture. Morais *et al.* (2006), in studying basal tiller demography in swards of *Brachiaria decumbens,* observed high TAR and TMR, indicating a high turnover in the tiller population, as was observed in this experiment .

The differences in SER between the two pastures (Tables 4 and 6) could possibly reflect differences in competition for light. The plants grazed to a height of 30 cm experienced limited competition for light, so stem elongation was not stimulated, while plants grazed to 50 cm were already competing for light, which would stimulate stem elongation and exposure of young leaves at the top of the sward (Woledge 1978).

Environmental factors, especially moisture availability, seemed to play a significant role in morphological development of the pastures. The peaks in LAR, LER, TAR and TPD during the first regrowth period (Table 5) coincided with a period of high moisture availability, high temperatures and long hours of sunlight and N fertiliser had been applied. Since N affects both the rate of expansion of cells and cellular division, which operate simultaneously in tiller generation and leaf elongation (van Keulen *et al.* 1989), application of N might have contributed to the changes in morphology and forage canopy structure.

A practical implication of this finding would be that, as length of regrowth periods is based on plant development, lower LAR could increase the time for the plants to reach the pre-determined stage for recommencement of grazing (Bircham and Hodgson 1983; Parsons *et al.* 1988; Carnevalli *et al.* 2006; Barbosa *et al.* 2007). Duru and Ducrocq (2000a; 2000b) reported a direct relationship between LAR and LER, with differences in LAR basically reflecting variations in LER. In the present experiment, the slightly lower LAR and significantly lower LER in the 30 cm pasture combined to extend the inter-grazing intervals, so that there were 4 grazing cycles at 30 cm and 5 cycles at 50 cm.

Compared with the morphogenic characteristics, structural characteristics were more stable. The structural variations followed a constant pattern throughout the experimental period, with an increase in TPD and a small reduction in FLL and LLT initially, followed by relative stability.

Lemaire and Chapman (1996) suggested that LLT is genetically determined and relatively constant and is independent of the applied management or environmental conditions. In this study, the values recorded for LLT were 1.4–0.9 leaves/tiller during the course of the study. This compares with reports in the literature ranging from 3 to 5 green leaves/tiller (Gomide and Gomide 1996; Carvalho 2002; Marcelino *et al.* 2006; Carnevalli *et al.* 2006). This variation in a structural characteristic that is genetically determined probably is a function of the differences in methodology used to define what constitutes a live leaf. While some authors define a live leaf as showing no senescence, others require a leaf to show less than 50% senescence and others consider a leaf to be live so long as there is not complete senescence of the leaf.

The marked increase in TPD in the second cycle resulted from a high tiller appearance rate and low mortality. As conditions were ideal for growth (favourable light and temperatures), the plants continued to generate new tillers (Figure 1). Tillering is related to both temperature change (Mitchell 1953a, 1953b; Gillet *et al.* 1984) and light regimes, which control LAR (Davies and Thomas 1983). Throughout the remaining cycles, TAR declined as plants moved into the reproductive phase, which might also affect the TMR. Carvalho (2002) suggested that guinea grass quickly eliminates weak or old tillers.

Conclusion

The results show that there was great variability in the structure of the swards, with the lower grazing height resulting in higher levels of tiller renewal and reduced stem elongation. While these are desirable characteristics in a grazed sward, this study was of short duration and the impacts on pasture production and animal performance over longer periods need to be demonstrated before any recommendations on pasture management could be made.

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(*Received for publication February 10, 2010; accepted July 29, 2010*)