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Maintaining post-grazing sward height of *Panicum maximum* (cv. Mombaça) at 50 cm led to higher animal performance compared with post-grazing height of 30 cm

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Abstract

In swards of tall, tufted, tropical grasses like Mombaça guinea grass (*Panicum maximum* (Jacq.)), post-grazing heights promote changes in sward structure, which influence animal performance. This study evaluated changes in sward structure in response to grazing management at two post-grazing heights (30 and 50 cm), associated with 90 cm pre-grazing height. Each treatment was allocated to experimental unit (1.5 ha) in three replicated blocks. Pastures were evaluated pre- and post-grazing to estimate herbage mass, percentages of leaf (LP), stem (SP) and dead material (DP), and nutritive value (VN). Stocking rate was adjusted twice a week “using the put-and-take approach,” and animals were weighed every 28 days. Forage accumulation rate was greater for pasture managed at 30 cm (64.8 vs. 55.1 kg ha^{-1} day^{-1}) than 50 cm. A greater number of days were required after grazing 30-cm residual pasture to achieve the pre-grazing target height, resulting in 25% decrease in number of grazing cycles compared with pastures managed at 50 cm. Regardless of post-grazing height targets, SP and DP decreased, whereas LP and NV increased from soil level to top of canopy. Stocking rate was greater in pastures managed to 30 cm than in those managed to 50 cm residual height (4.7 vs. 3.4 AU ha^{-1}). However, average daily gain was greater for 50 cm than for 30 cm post-grazing height (795 vs. 590 g steer^{-1} day^{-1}), resulting in a greater animal production per area (917 vs. 794 kg/ha of live weight). Thus, Mombaça guinea grass subject to intermittent grazing should be managed at 50 cm residual height.

KEYWORDS
guinea grass, intermittent stocking, nutritive value, residual height, stocking rate

1 | INTRODUCTION

Maintaining high rates of forage intake, and consequently high animal performance for tropical forages, requires pastures with adequate canopy structures (Fonseca et al., 2012). Therefore, several researchers (Barbosa et al., 2007; Carnevalli et al., 2006; Zanini, Santos, Padilha, & Sbrissia, 2012) have recommended that when tropical pastures are rotationally grazed, the regrowth should be interrupted when the canopy is intercepting 95% of the incident light. This is because growth beyond this point promotes sward deterioration, which is characterized by higher percentages of stem and dead material, a lower percentage of leaf and a reduced leaf-to-stem ratio, resulting in the accumulation of low-quality forage (Echeverria et al., 2016; Euclides, Montagner, Difante, Barbosa, & Fernandes, 2014). Identifying the correct time to interrupt the grazing period is of utmost importance (Sbrissia et al., 2013; Trindade et al., 2007). In rotational grazing, priority is commonly given to forage harvest efficiency, which ultimately means lower heights of post-grazing residues and few or no leaves. However, when animals are forced to graze in the lower layers of the pasture canopy, significant reductions occur in forage intake by animals (Fonseca et al., 2012; 2013; Mezzalira et al., 2013).

Identifying the optimal time for interruption of the grazing process may ensure higher forage intake rates and consequently better animal performance (Fonseca et al., 2012). In this context, Euclides et al. (2016) observed better animal performance and liveweight gain per unit area when the Mombaça guinea grass pastures were managed at 50 cm of residue compared with those at 30 cm residual height. Nevertheless, the latter findings relate only to a single growing season. This experiment was conducted with the aim of verifying the conclusions from previous experiment which would be confirmed in order to provide farmers with adequate and safe information about post-grazing target height for Mombaça guinea grass subjected to intermittent stocking.

Our hypothesis was that Mombaça guinea grass managed to 50 cm post-grazing height provides a sward structure that favours selecting and prehending of forage by animals, which results in high-quality diet and consequently higher animal performance when compared with swards managed to 30 cm residual height.

2 | MATERIALS AND METHODS

2.1 | Site, treatments and experimental design

The experiment was conducted at the National Beef Cattle Research Centre, Campo Grande, MS, Brazil (latitude 20°27′S, longitude 54°37′W, and altitude 530 m), from October 2011 to June 2012. The climate is rainy tropical savannah, according to Köppen classification, subtype Aw, characterized by seasonal distribution of rainfall and well-defined occurrence of the dry period during the colder months. Monthly rainfall, average relative humidity of the air and minimum, medium and maximum temperatures (Figure 1) were recorded in a meteorological station, located around 3 km, from the experimental area. Water balance in soil (Figure 2) was calculated using Thornthwaite and Mather method with water-holding capacity of 75 mm (Rolim, Sentelhas, & Barbieri, 1998; Thornthwaite & Mather, 1955).

The Mombaça guinea grass pastures were established in 2005 and previously had been grazed by steers. The soil of the experimental area is classified as an Oxisol (FAO - Food and Agriculture Organization, 2006) with 35% clay, and chemical analysis showed following soil characteristics: pH 5.8 in $CaCl_2$; 67% base saturation; 1.9% saturation by aluminium; 3.9% organic matter; 6.0 mg/L of P (Mehlich-1); and 15.6 mg/L of K (Mehlich-1). Based on these analyses, in October 2011, pastures were fertilized with 80 kg/ha of P_2O_5 and 80 kg/ha of K_2O. Nitrogen fertilization was performed with 200 kg/ha nitrogen in the form of urea, divided into four applications given in October, December, January and February.

The experimental area comprised 9.0 hectares and was divided into three blocks of 3.0 ha each. Differences in soil fertility were determinant for blocking. Subsequently, each block was subdivided into two pastures of similar size (1.5 ha) and sward characteristics. In turn, each pasture was subdivided into six paddocks of 0.25 ha each. An additional pasture of 6 ha was used for holding extra animals that were used to regulate the grazing intensity on the experimental area, when needed (put-and-take approach, according Mott, 1960).

The experimental design was randomized complete blocks, with two treatments and three repetitions. The treatments corresponded to two grazing intensities characterized by the post-grazing heights of 30 and 50 cm (residues), both of which were associated with a common pre-grazing height of 90 cm. This pre-grazing canopy height was chosen based on findings from previous studies that reported of being associated with a canopy light interception of 95% (Carnevalli et al., 2006; da Silva et al., 2009). Treatments were randomly assigned to the pastures.

Each pasture was rotationally grazed by six ½ Senepol × ½ Caracu tester steers of approximately 12 months of age with a mean initial weight of 245 ± 16 kg. The tester steers were assigned randomly to experimental units. Experimental units did not differ in the live weight of steers at the commencement of the study. Sixty-four grazers (regulator steers) similar to the testers in terms of liveweight, age, background and genetics were kept in 6.0-ha reserve pastures and used when needed to adjust the stocking rate in the experimental pastures (put-and-take approach). The grazers were added or removed as determined by the post-grazing height imposed in each treatment and by the height (pre-grazing target of 90 cm) of the subsequent paddock to be grazed. Paddock to paddock movements of the experimental animals were determined by both the target residual and the pre-grazing heights.

A mineral mixture containing sodium chloride, sulphur, dicalcium phosphate, potassium iodide, sodium selenite, cobalt sulphate, copper sulphate and zinc sulphate (48.75, 7.36, 39.26, 0.015, 0.008, 0.014, 0.69 and 3.89 g 100 g^{-1}, respectively) and drinking water were offered ad libitum to all animals throughout the experiment.

During the dry period preceding the beginning of the experiment, the pastures were grazed to maintain post-grazing heights of 30 or 50 cm. As soon as the rains resumed (Figure 1) and the plants began to recover, grazing was initiated on the first paddock in each experimental unit. Average canopy height of the first paddock was 75 cm when cattle entered. Grazing was initiated at this height so that the last paddock of the rotation would be approximately 90 cm tall when animals entered. This decision was made to avoid the latter paddocks becoming too tall and overly mature by the time they were grazed the first time. Thus, the pre-grazing height was below the target for the first grazing cycle (Table 1).

2.2 | Measures

2.2.1 | Canopy height

Throughout the study, the leaf canopy height was measured twice per week using a 1-m ruler, graduated in centimetres, through

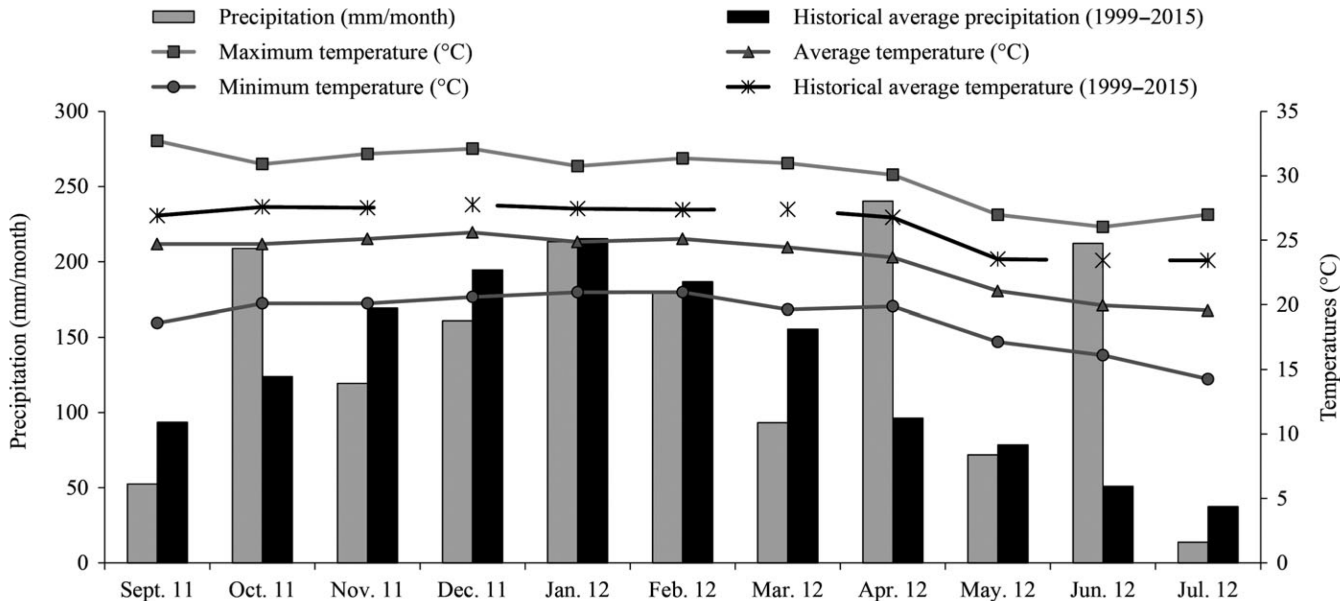

FIGURE 1 Monthly average precipitation and minimum, medium and maximum temperatures from September 2011 to July 2012, and historical 16-year average rainfall

FIGURE 2 Monthly water deficit and surplus in the soil from September 2011 to July 2012, for a soil water-holding capacity of 75 mm

systematic readings performed along five transect lines (eight measurement points per transect) in all paddocks. The readings of sward height were taken from ground level to the "leaf horizon" on the top of the sward as a reference. The post-grazing heights were measured as soon as the cattle left the paddocks.

2.2.2 | Forage mass, morphological composition, nutritive value and forage accumulation

Forage mass pre- and post-grazing, its morphological composition and forage accumulation rate were estimated in one selected randomized paddock of six paddocks in each pasture, at each grazing cycle. The pre- and post-grazing forage masses were estimated by cutting nine randomly selected square samples (1 × 1 m) at the soil level. The cut was performed using a manual mower (KA 85R, Stihl, Campo Grande, Brazil).

The samples were divided into two subsamples: one was weighed and dried in an oven at 65°C until constant weight was achieved, and the other was separated into leaf (leaf blade), stem (sheath and stem) and dead material, and then oven-dried as described above and processed as described above. The herbage accumulation rate was calculated as the difference between the current pre-grazing and the preceding post-grazing herbage mass, considering only the green portion (leaves and stems) divided by the number of days between samples.

In a second paddock per pasture, three stratified samples were collected using a quadrat (1 m × 1 m) with four supports in its base was placed in areas that were representative of the average sward condition. At each point, four samples were collected along the length of the sward (top to bottom), generating samples for the following strata: 0–30, 30–50, 50–70 and 70–90 cm. The cut was performed with scissors. Samples from each stratum were weighed

TABLE 1 Start of grazing cycle (SGC) date, cycle length (CL), grazing days per paddock (GDP), means and standard deviations for steers per paddock (SPP), pre- and post-grazing sward heights (GSH) of *P. maximum* cv. Mombaça pastures subjected to rotational stocking targeting either a 30 or 50 cm post-grazing height, throughout the experiment

50 cm post-grazing height								
SGC date	20/10/11	14/12/11	19/1/12	8/2/12	3/3/12	25/3/12	29/4/12	12/6/12[a]
CL (d)	45	36	30	24	22	35	44	14
GDP (d)	7.5	6.0	5.0	4.0	3.7	5.8	7.3	4.7
SPP (n)	4.1 ± 0.2	7.5 ± 1.2	9.3 ± 1.2	9.6 ± 0.7	8.3 ± 2.0	6.1 ± 1.7	5.0 ± 1.2	4.8 ± 1.7
Pre-GSH (cm)	82.4 ± 5.6	87.4 ± 1.7	88.9 ± 1.1	88.5 ± 2.1	89.2 ± 1.4	87.5 ± 2.1	87.7 ± 2.7	85.6 ± 3.0
Post-GSH (cm)	49.2 ± 0.1	49.6 ± 2.8	48.6 ± 4.7	49.2 ± 1.4	51.7 ± 3.4	49.5 ± 1.7	48.8 ± 2.9	48.5 ± 2.3
30 cm post-grazing height								
CS date	20/10/11	14/12/11	19/1/12	21/2/12	22/3/12	7/5/12	-	-
CL (d)	55	36	33	30	46	37	-	-
GDP (d)	9.2	6.0	5.5	5.0	7.7	6.2	-	-
SPP (n)	6.4 ± 2.6	9.2 ± 2.3	10.0 ± 1.5	10.2 ± 3.1	8.2 ± 1.9	7.2 ± 2.5	-	-
Pre-GSH (cm)	80.2 ± 5.4	88.1 ± 2.1	88.5 ± 1.0	86.6 ± 1.7	88.5 ± 2.4	86.8 ± 2.7	-	-
Post-GSH (cm)	32.0 ± 3.1	33.4 ± 3.2	30.7 ± 2.5	32.5 ± 2.9	32.7 ± 2.8	33.3 ± 3.7	-	-

Grazing cycle involving the grazing of all the paddocks within a pasture.
[a]Only three paddocks were pastured.

and handled in a similar way as described above for herbage mass and its morphological components.

Leaf blade samples from the stratified samples were ground to 1 mm and analysed for content of crude protein (CP), in vitro organic matter digestibility (IVOMD) percentages, neutral detergent fibre (NDF) and acid detergent lignin (ADL) contents using the near-infrared reflectance spectrophotometer (NIRS) system, according to the procedures described by Marten, Shenk, and Barton (1985).

2.2.3 | Animal liveweight gain and stocking rate

All steers were weighed (after being food and water deprived for 16 hr) at 28-day intervals. The average daily gain was calculated as the increase in live weight of the testers divided by the number of days between weighing.

The stocking rate per cycle was calculated according to Petersen and Lucas (1968) as the sum of the animal days (tester and grazer steers) that they remained in each of six paddocks (0.25 ha) divided by the total number of grazing days of a complete cycle, and divided by the pasture area (1.5 ha). It was expressed in animal unit (450 kg live weight) per hectare. The liveweight gain per area (ha) was calculated by multiplying the ADG of the tester steers by the number of steers (testers and grazers) retained per pasture and per grazing cycle (Petersen & Lucas, 1968).

2.3 | Statistical analysis

The data were grouped according to seasons of the year as follows: spring (20 October to 20 December 2011), summer (21 December 2011 to 21 March 2012) and autumn (21 March 21 to 15 June 2012). The experimental unit for both vegetation and animal data was the pasture (1.5 ha and the animals grazed in). The data were subjected to an analysis of variance using the Mixed Procedure in SAS (Statistical Analysis System, version 9.4). The choice of the covariance matrix was made using the Akaike information criterion (AIC) (Wolfinger, 1993) and analysis performed considering post-grazing height and season of the year and their interactions as fixed effects and blocks as a random effect (Littell, Pendergast, & Natarajan, 2000). If appropriate, the means were compared with a Tukey test at a 5% significance level. For the stratified herbage samples, the same model was applied, but the effect of the strata was added and considered fixed. The average daily gain data were analysed via multivariate analysis with repeated measures according to Littell et al. (2000). The GLM procedure in SAS (Statistical Analysis System, version 9.4) was used to analyse the total liveweight gain per area.

3 | RESULTS

Mean air temperature indicated that spring, summer and autumn were relatively cooler, and spring and summer were drier and autumn was wetter than the 16-year average (Figure 1). However, there was soil water deficit just during early spring (Figure 2).

As the pre- and post-grazing sward heights were controlled variables, the sward height data are presented using only descriptive statistics (Table 1). Post-grazing target heights were maintained close to the planned values of 30 and 50 cm. Pre-grazing sward heights remained within the planned range throughout the experiment except for the first grazing cycle (Table 1).

3.1 | Paddock grazing and resting periods

An interaction between the effects of residue canopy height and season of the year (p = .04) was observed for the length of resting period (Table 2). Regardless of the season, less time was necessary to reach the pre-grazing target for the swards grazed to 50 cm of residue than those grazed to 30 cm of residue (Table 2). In both treatments (30 and 50 cm residual heights), resting period in summer was shorter than in the other two seasons. For swards grazed to 50 cm of residue, the resting period was similar during autumn and spring. On the other hand, for those managed at 30 cm of residue, the RP was greater in spring than in autumn (Table 2).

There was no post-grazing height × season of the year interaction (p = .18) for the paddock grazing period. However, paddocks with pastures managed to 30 cm residual height had longer grazing days than those managed to 50 cm residual height (6.6 ± 0.3 vs. 5.2 ± 0.2; $p < .01$).

3.2 | Herbage accumulation rate, stocking rate and steers liveweight gain

No interaction ($p > .05$) was observed between the effects of post-grazing height and season of the year for the herbage accumulation rate (HAR), stocking rate (SR), average daily gain (ADG) and liveweight gain per area (LGA). However, HAR and SR were higher for the pastures managed at 30 cm residual height compared with those managed at 50 cm residual height (Table 3). On the other hand, the ADG and LGA were higher for the pastures managed at 50 cm compared with those managed at 30 cm post-grazing (Table 3).

TABLE 2 Resting period in *P. maximum* cv. Mombaça pastures subjected to rotational stocking targeting either a 30 or 50 cm post-grazing height, according to the seasons of the year

	Resting period (day)					
	Spring		Summer		Autumn	
Residue height (cm)	Mean	*SEM*	Mean	*SEM*	Mean	*SEM*
30	55.8Aa	1.9	33.8Ac	0.9	46.7Ab	1.1
50	44.4Ba	1.5	27.6Bb	0.8	40.2Ba	1.0

SEM, standard error of the mean. Values followed by different letters, lower case in row and upper case in column, differ significantly at $p < .05$ according to Tukey's test.

TABLE 3 Herbage accumulation rate (HAR), stocking rate, average daily gain and liveweight gain per area, in *P. maximum* cv. Mombaça pastures subjected to rotational stocking targeting either a 30 or 50 cm post-grazing height

	Residual heights				
	30 cm		50 cm		*p*
	Mean	*SEM*	Mean	*SEM*	
HAR (kg/ha/day)	64.8	2.5	55.1	2.0	**
Stocking rate (AU[a]/ha)	4.7	0.1	3.4	0.1	**
Average daily gain (g/animal/day)	590	10	795	11	**
Liveweight gain per area (kg/ha)	794	12.3	917	12.3	*

SEM, standard error of the mean. *p*, significance between treatments. *$p < .05$ and **$p < .01$.
[a]AU, animal units, with 1 AU = 450 kg LW.

3.3 | Herbage mass and structural morphological distribution

Pre-grazing herbage mass (HM) averaged 5.8 ± 0.1 t/ha of dry matter and was not affected by post-grazing height (p = .37). Also, no effect of the residual height was found for pre-grazing percentages of leaf (LP; p = .19), stem (SP; p = .33) and dead material (DP; p = .54) or leaf:stem ratio (LSR; p = .13). The mean (± standard error) values for the above variables were as follows: 68.2 ± 0.6%, 19.1 ± 0.5%, 12.7 ± 0.7% and 3.7 ± 0.2 respectively. There was no residual height × season interaction effect on these variables ($p > .05$).

No effects of residual height treatments were observed on HM (p = .35), LP (p = .24), SP (p = .28), DP (p = .29) and LSR (p = .60) in the vertical profile of the canopy. However, the HM, SP and DP decreased, and the LP and LSR increased from the base to the top of the canopy (Table 4). No effects ($p > .05$) of stratum × season, or residual height × season or stratum × residual height × season interactions on variables associated with sward structure were observed.

3.4 | Nutritive value

Residual height treatments did not differ in their effects on crude protein (CP; p = .72), in vitro organic matter digestibility (IVOMD; p = .28), neutral detergent fibre (NDF; p = .10) or acid detergent lignin (ADL; p = .73) in the leaves at pre-grazing. Moreover, no effects of residual height × season, stratum × season or residual height × stratum × season interactions ($p > .05$) on variables associated with nutritive value were observed. Nevertheless, there were significant effects ($p < .05$) of residual height × stratum interaction on CP and NDF contents and IVOMD. At the stratum 30–50 cm, grazing management to 30 cm residual height yielded higher CP and IVOMD but lower NDF contents than grazing managed to 50 cm residual height (Table 5).

Regardless of residue height, CP and IVOMD increased and NDF and ADL contents decreased from the base to the top of the canopy (Table 5). Contents of ADL in the leaf did not change with post-

TABLE 4 Herbage mass, percentages of leaf, stem, and dead material and leaf:stem ratio (LSR) of herbage in the vertical strata of *P. maximum* cv. Mombaça pastures subjected to rotational grazing

	0–30	30–50	50–70	70–90	*SEM*	*p*
Herbage mass (t/ha)	5.2a	1.7b	0.9c	0.6c	0.1	**
Leaf (%)	12.2c	68.7b	91.1a	94.5a	3.2	**
Stem (%)	23.8a	15.5a	5.2b	4.2b	2.7	**
Dead material (%)	73.6a	21.5b	4.6c	0.2c	3.2	**
Leaf:stem ratio	0.5b	4.4b	17.5a	22.0a	3.8	**

SEM, standard error of the mean. ***p*, significance between treatments. Values followed by different letters in row differ significantly at $p < .05$ according to Tukey's test.

TABLE 5 Percentages of crude protein, in vitro organic matter digestibility, neutral detergent fibre and acid detergent lignin of leaves in the vertical strata of *P. maximum* cv. Mombaça pastures subjected to rotational stocking targeting either a 30 or 50 cm post-grazing height

	Stratum (cm)				
Residue heights (cm)	0–30	30–50	50–70	70–90	*SEM*
Crude protein (%)					
30	6.6Ac	8.7Ab	11.9Aa	12.8Aa	0.4
50	6.8Ac	7.1Bb	12.3Aa	13.5Aa	0.4
In vitro organic matter digestibility (%)					
30	48.3Ac	55.5Ab	59.2Aa	60.9Aa	0.8
50	48.2Ac	50.1Bb	58.7Aa	61.2Aa	0.7
Neutral detergent fibre (%)					
30	77.3Aa	74.1Bb	73.3Ab	72.0Ab	0.4
50	77.8Aa	77.5Aa	72.7Ab	71.1Ab	0.4
Acid detergent lignin (%)[†]					
Mean (30 and 50)	4.2a	4.0a	3.4b	3.3b	0.1

SEM, standard error of the mean. Values followed by different letters, upper case in column and lower case in row, differ significantly at $p < .05$ according to Tukey's test.
[†] There was no interaction ($p = .45$) between residue height and stratum.

grazing treatments, but contents decreased from the bottom to the top of the sward (Table 5).

3.5 | Season

There were no season effects ($p > .05$) on DP, CP, IVOMD, NDF or ADL contents in the pre-grazing condition of the pastures. However, HAR and SR were higher in summer, intermediate in autumn and lowest in spring (Table 6). The inverse pattern was observed in the paddock grazing occupation (Table 6). During spring, the HM was smaller compared with that in the other seasons (Table 6). On the other hand, lower LP and LSR and higher SP were observed during autumn than during other seasons (Table 6). The ADG in spring was higher than in summer and autumn (Table 6).

3.6 | Post-grazing height

In the post-grazing condition, no interaction ($p > .05$) was observed between the post-grazing height × season for the HM, LP, SP and DP. Residual height did not affect SP ($p > .05$). However, pastures managed at 50 cm post-grazing showed higher values of HM and LP, and smaller values of DP, compared with pastures managed at 30 cm post-grazing (Table 7).

4 | DISCUSSION

We tested the hypothesis that *P. maximum* (cv. Mombaça) managed at 50 cm post-grazing height provides a sward structure that favours selecting and prehending of forage by animals, which results in high-quality diet and consequently higher animal performance when compared with swards lowered to 30 cm of residue. We found evidence to support our hypothesis, which will be presented below.

The live weight of the experimental animals increased throughout the experiment, regardless of the post-grazing heights. However, steers grazing pastures managed to 30 cm residual height had lower average daily gain than their counterparts grazing pastures managed to 50 cm residual height, a fact also observed by Euclides et al. (2016) for steers managed at similar experimental grazing conditions to those in the present study. The lower average daily gain of animals grazed to 30 cm residual height most likely reflected the imposed grazing conditions, i.e., the need for the animals to graze the 30- to 50-cm stratum, which is characterized by smaller leaf percentage and lower leaf:stem ratio but greater percentages of stem and dead material than strata above 50 cm. Animals prefer leaf to stem and the presence of stem in the "grazing horizon" limits depth, area and mass of the bites, consequently affecting negatively the instantaneous intake rate (Benvenutti, Gordon, & Poppi, 2006). Although to maintain the daily forage intake, the animals may compensate the low instantaneous intake rate by increasing the grazing time (Difante et al., 2009), this ability seems limited and the low instantaneous intake rate may in many circumstances limit the daily

TABLE 6 Herbage accumulation rate (HAR), herbage mass, leaf and stem percentages and leaf:stem ratio at pre-grazing condition, grazing period, stocking rate and average daily gain (ADG) in *P. maximum* cv. Mombaça pastures subjected to rotational stocking targeting either a 30 or 50 cm post-grazing height, according to the season of the year

	Spring		Summer		Autumn		
	Mean	*SEM*	Mean	*SEM*	Mean	*SEM*	*p*
HAR (kg/ha/day)	39.7c	3.3	79.5a	3.9	60.8b	2.8	**
Herbage mass (t/ha)	5.0b	0.16	6.3a	0.13	6.1a	0.15	**
Leaf (%)	70.0a	0.8	68.9a	0.7	62.3b	0.8	**
Stem (%)	17.6b	0.6	18.0b	0.5	21.2a	0.6	**
Leaf:stem ratio	4.0a	0.3	3.8a	0.2	2.9b	0.2	**
Grazing period (day)	8.2a	0.3	4.8c	0.1	7.0b	0.2	**
Stocking rate (UA[a]/ha)	2.7c	0.14	5.4a	0.13	4.0b	0.13	**
ADG (g/animal/day)	721a	0.02	697ab	0.01	660b	0.01	*

SEM, standard error of the mean. *p*, significance between treatments, $^*p < .05$ and $^{**}p < .01$. Values followed by different letters in row differ significantly according to Tukey's test.
[a]AU, animal units, with 1 AU = 450 kg LW.

TABLE 7 Herbage mass, percentages of leaf and dead material, in post-grazing, of *P. maximum* cv. Mombaça pastures subjected to rotational stocking targeting either a 30 or 50 cm post-grazing height

	Residual heights				
	30 cm		50 cm		
	Mean	*SEM*	Mean	*SEM*	*p*
Herbage mass (t/ha)	3.5	0.1	4.8	0.1	**
Leaf (%)	23.9	1.4	29.6	2.1	**
Dead material (%)	58.0	3.5	47.4	2.7	*

SEM, standard error of the mean. *p*, significance between treatments, $^{*}p < .05$ and $^{**}p < .01$.

forage intake (Pérez-Prieto, Peyraud, & Delagarde, 2011). Thus, it is plausible that the sward structure influences the quality and quantity of forage harvested by the animal. In fact, Euclides et al. (2016) observed lower feed intakes by steers grazing Mombaça pastures to 30 cm of residual height than those managed to 50 cm residual height. In this context, Baumont, Cohen-Salmon, Prache, and Sauvant (2004) concluded that during the process of lowering of the sward height during grazing, there is a strong decrease in forage intake rate and in the daily forage intake. In addition to the difficulties in selecting and prehending forage by animals that explored the 30- to 50-cm stratum, the low nutritive value of this stratum was observed.

On the other hand, the higher herbage accumulation rate for pastures managed at 30 cm of residue was probably due to the higher number of new tillers. Barbosa et al. (2007) observed an increase in the number of new tillers for Tanzania guinea grass (*P. maximum*, cv. Tanzania) pastures managed with more intense defoliation (25 cm of residue) compared with the lenient defoliation pastures (50 cm of residue). Furthermore, young tillers presented higher leaf appearance and elongation rates and consequently increased growth vigour compared with both mature and old ones (Barbosa et al., 2012). Despite the larger herbage accumulation rate for pastures managed to 30 cm residual height, these pastures needed more days to reach the pre-grazing target height, resulting in fewer (by 0.25%) grazing cycles compared with pastures managed at 50 cm residual height. This observation confirms previous findings (Carnevalli et al., 2006; Euclides et al., 2016) involving similar target residual heights.

As a consequence of the larger herbage accumulation rate in summer, a fact resulting from favourable weather conditions, and nitrogen fertilizer, the resting period of pasture during this season was shorter than spring and autumn. Consequently, a higher stocking rate was required in the summer in order to achieve the pre- and post-grazing sward height targets. On the other hand, in spring, the water levels in the soil were not restored until October, resulting in low accumulation of herbage and hence a reduced stocking rate. However, when no water deficit was present in autumn, the reduced herbage accumulation observed in this season may have been due to the decrease in the minimum temperature, hence affecting the stocking rate. During the eighth cycle of pasture managed to 50 cm residual height, only three paddocks were grazed, as in June the average canopy height in the other three paddocks was approximately 75 cm, far below the pre-grazing target height of 90 cm. The same criterion was adopted for the pastures managed at 30 cm residual height; in that case there were six complete cycles. For this reason, we decided to end the experiment, as there is a drastic decrease in herbage accumulation during the winter for Mombaça guinea grass (da Silva, et al., 2009).

The above-described variation in herbage accumulation rate seems typical of tropical pastures, which may be due to variation in weather, principally rainfall. The largest HAR is known to occur in summer, whereas the smallest is in winter, with intermediate levels in spring and autumn (da Silva et al., 2009; 2013). In the current study, rainfall in spring and autumn was below and above, respectively, the historical average, and accordingly, herbage accumulation rate was significantly larger in autumn than in spring. These observations were in contrast with those of Euclides et al. (2015) who was working with Mombaça guinea grass pastures managed with the same residual (30 and 50 cm) and canopy (90 cm) sward heights of pre- and post-grazing. Those authors observed a water deficit throughout autumn, and consequently a smaller HAR than in spring. Thus, differences between studies in herbage accumulation rate during spring and autumn seem to be due to variations in rainfall across years (Euclides et al., 2016).

As expected, variations in herbage accumulation rate, decisions in stocking rate adjustments to achieve the post-grazing heights and the need for the herds to remain in their current paddock until the desired pre-grazing height in the next paddock was reached all resulted in variation in the duration of grazing of the paddock. Consequently, the stocking rate was greater in the pastures grazed to 30 cm residual height than in those grazed to 50 cm, a fact determining treatment differences in post-grazing herbage mass and leaf percentage (lower in pastures managed at 30 cm residual).

As expected, a decrease in the percentage of stem and dead material, and an increase in the percentage of leaf from the soil level to the top of the canopy were observed. This was associated with an increase in the contents of CP and IVOMD and a decrease in the NDF and ADL contents. The greater quantity of old and senescent leaves rejected by the grazing animals found in the lower stratum (0–30 cm) most likely contributed to the lower value of this stratum. In turn, the higher nutritive value in the 30- to 50-cm stratum for pastures managed to 30 cm of residue could be due to the frequent removal of this stratum as well as the renewal of leaves.

In this study, the number of extra animals (1.3 AU/ha) used in the pastures managed to a 30 cm did not compensate for the lower individual average daily gain, resulting in a lower liveweight gain per area compared with those managed to 50 cm residual height. The latter corroborates the observations reported by Euclides et al. (2016). In addition, Fonseca et al. (2013) suggested that to maintain high rates of forage intake during intermittent grazing, the sward canopy should be lowered until 40% of the optimal pre-grazing target height is achieved, which in the case of Mombaça guinea grass pastures would be approximately 50 cm.

In this study, the pre-grazing canopy height was common (90 cm) for both the experimental treatments (30 and 50 cm residual height) and treatments did not differ in herbage mass or canopy structure. However, during autumn, when the Mombaça guinea grass flowered, lower leaf:stem ratio was observed in the pre-grazing condition, whereas ADG decreased regardless of the residual height. In this context, Drescher, Heitkönig, Raats, and Prins (2006) demonstrated that for the same forage mass density (which in this experiment was 71.7 and 72.8 kg/ha/cm, for summer and autumn, respectively), the decrease in leaf quantity and increase in stem quantity reduced the bite size, biting rate and consequently the herbage intake rate. The aforementioned authors also observed that changes in grazing behaviour were not only a consequence of leaf quantity decrease, but were also caused by the interference of stem in the diet selection by the animals. According to Prache, Roguet, and Petit (1998), animals interact with the sward structure by adjusting bite dimensions and this allows them to select the most nutritious parts of the sward and improve diet quality. However, in certain circumstance, the animals may take small bites and spend more time searching for bites, leading to a low forage intake (Laca, Shipley, & Reid, 2001). As the rate of nutrient intake is one of the main determinants of animal performance in pastures, these considerations could explain the lower ADG of the animals during the autumn.

The results of the current work confirm the conclusions of Euclides et al. (2016) stating that Mombaça guinea grass subjected to intermittent stocking resulted in higher weight gain per animal and per area, when managed at the post-grazing target height of 50 cm, which is consistent with the findings of Fonseca et al. (2013), who suggested that the pasture sward height should be lowered to the point when changes in canopy structure are at a minimum, as the sward structure directly influences the rate of forage intake, and consequently animal production. In this regard, it was noted that there was deterioration in the sward structure below 50 cm, as was also reported by Euclides et al. (2016).

5 | CONCLUSION

It is concluded that in pastures of *Panicum maximum* Mombaça, the canopy structure, nutritive value and animal performance are determined by the post-grazing residue height.

The lower liveweight gain of animals grazing the pasture managed to 30 cm sward height compared with 50 cm is fundamentally a consequence of the need of the grazing animals to graze the 30- to 50-cm stratum, which is characterized by lower leaf:stem ratio and nutritive value relative to strata above 50 cm.

Therefore, in order to achieve higher liveweight gains per animal and per unit area, Mombaça guinea grass pastures subjected to intermittent stocking should be managed to a post-grazing sward height of 50 cm associated with pre-grazing sward height of 90 cm.

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