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Forage mass and canopy structure of Zuri and Quênia guineagrasses pasture under rotational stocking

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ABSTRACT - This work evaluated the productive and structural characteristics of the BRS Zuri and BRS Quênia cultivars under rotational stocking management. The evaluations were divided into five periods according to rainfall regime (high, medium, and low rainfall) during 16 months of the years 2016-2018. Pastures were grazed when canopies intercepted 95% of incident light to stubbles corresponding to 50% of the pre-grazing height. The pre- and post-grazing heights varied as a function of cultivar, with higher values for BRS Zuri (89 and 49 cm) than for BRS Quênia (78 and 45 cm). No differences in canopy lowering percentage, forage mass, and stem and dead material dry masses between cultivars were observed, with averages of 41.3%, 5,856, 1,835, and 841 kg ha^{-1}, respectively. The post-grazing canopy height was lower in the second year, which resulted in higher values of canopy lowering percentage (51%). The highest value for leaf:stem ratio for both cultivars was observed in the high rainfall period of the second year. Higher average tiller population density was observed for BRS Quênia (477 tillers m^{-2}) than for BRS Zuri (260 tillers m^{-2}) for all the rainfall periods. Forage bulk density was similar between cultivars and varied according to the periods evaluated, with the highest value observed during the dry period of the year. Forage mass, as well as its component fractions, did not vary between cultivars, but was influenced by the studied periods. The cultivars showed high leaf mass in the pre-grazing forage mass with an average value of 3,174 kg ha^{-1}. The cultivars are similar in morphological composition and offer high yield potential when managed under a rotational grazing system.

Keywords: canopy height, leaf:stem ratio, light interception, morphological composition, rest period

1. Introduction

The intensification of livestock production in the tropics can guarantee sustainable protein production for a growing world population. The search for intensification in Brazilian livestock can be perceived, among other factors, by the replacement of native pastures by cultivated ones observed in recent decades (IBGE, 2017). In this context, guineagrass (*Megathyrsus maximus* sin. *Panicum maximum* Jacq.) is one of the most important tropical grasses species for intensifying pasture-livestock systems due to its high forage production and good nutritive value (Paciullo and Gomide, 2016).

Despite the high productive capacity of *Megathyrsus maximus*, a difficulty encountered in their management is the control of stem elongation (Santos et al., 1999) that deteriorates the canopy structure and, consequently, the forage harvesting (Benvenutti et al., 2008). Management guidelines based on morphophysiological criteria (Carnevalli et al., 2006; Barbosa et al., 2007; Gomide et al., 2007) help to overcome this trait. Among them, we highlight the reduction in the regrowth period (Gomide et al., 2007) and the greater lowering of the canopy (Carnevalli et al., 2006; Barbosa et al., 2007). In the management of tropical grasses, to decrease stem elongation and the accumulation of senescent forage, the paddocks rest period has been based on reaching a 95% of canopy light interception (LI) (Carnevalli et al., 2006; Barbosa et al., 2007). Also, the 50% lowering of the canopy, in relation to pre-grazing height, seeks to reconcile the necessary control of post-grazing residue (Barbosa et al., 2007) without compromising the forage intake by grazing animals (Carvalho et al., 2013; Schmitt et al., 2019). However, many producers still report difficulties in managing guineagrass pastures. In this sense, breeding programs for this species seek to release cultivars that are more productive and easier to be managed (Jank et al., 2010).

In 2014 and 2017, Embrapa launched, respectively, cultivars BRS Zuri and BRS Quênia (Jank et al., 2017). These cultivars present higher forage yield potential and better structural traits, such as lower canopy height and higher leaf:stem ratio, than the traditional cultivars Mombaça and Tanzânia. However, few studies have assessed canopy characteristics and forage yield potential of these released cultivars under grazing.

Within this proposal, it would be ideal if cultivars can be launched and be accompanied by management guidelines. To accomplish this, detailed studies about the new cultivars are required to define the choice of cultivars and the better pasture management for intensive pasture-livestock systems.

We hypothesize that there are differences in their canopy structure and forage production, as BRS Zuri is taller than BRS Quênia, even subjected to the same criteria for rotational stocking management (95% of LI and 50% intensity defoliation). The objective of this study was to investigate these variables to understand their behavior over the seasons when managed under intensive grazing.

2. Material and Methods

The experiment was carried out in an experimental farm located in Coronel Pacheco, Minas Gerais, Brazil (21°33' S, 43°16' W, 435 m altitude). The climate, according to the Köppen classification, is Cwa (mesothermal), with a tropical rainy summer and a dry winter from June to September. The monthly accumulated precipitation, average monthly temperature and water balance data during the experimental period (Figures 1 and 2) were obtained from the INMET automatic station, located 600 m away from the experimental area.

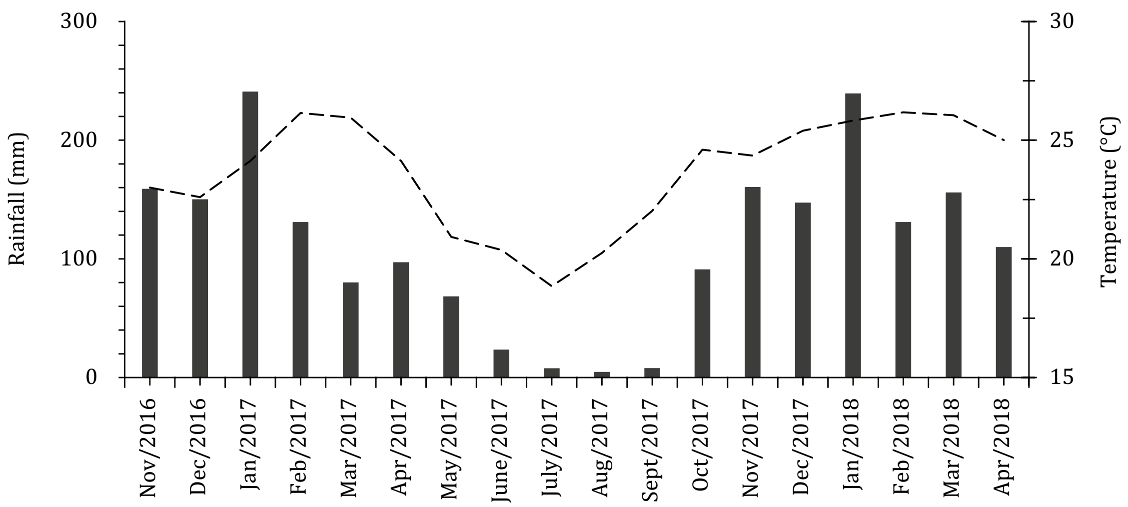


Figure 1 - Cumulative monthly rainfall (columns) and average monthly temperature (dotted line) from November 2016 to April 2018.

The soil in the experimental area was classified as a Distrophic Red-Yellow Latosol with a medium-clayey texture (Embrapa, 2013). A soil analysis (0 to 20 cm) performed before the experimental period revealed the following values: 0.6, 0.2, and 5.0 $cmol_c dm^{-3}$ of magnesium, aluminum, and potential acidity (H + Al), respectively, and 0.9 $cmol_c dm^{-3}$ of calcium. The average phosphorus (Melich-1) content was 4.1 mg dm^{-3}, and potassium was 142 mg dm^{-3}. In August 2015, the entire area was plowed and tilled. In September of the same year, dolomitic limestone at the rate of two tons per hectare was applied to increase the base saturation level to 60%. On November 20, phosphate fertilization was applied at a rate of 80 kg ha^{-1} P_2O_5.

The experimental area comprised 6 ha, and the study was established following a completely randomized block design with three replicates. Each replicate had 10 paddocks of 830 m^2. The treatments were two cultivars of *Megathyrsus maximus* (BRS Zuri and BRS Quênia).

Sowing was done in December 2015 using 4 kg ha^{-1} of live seeds. The first grazing was performed in January 2016 by dairy heifers to improve pasture establishment; afterwards, they received 150 kg ha^{-1} of a commercial fertilizer (NPK 20-05-20). During the whole year of 2016, pastures were managed under rotational grazing system with non-lactating cows. In November 2016, a first grazing was performed according to established management goals (95% LI and 50% of the canopy lowering based on the pre-grazing canopy height). On December 09, 2016, the experimental evaluations were started, which extended until April 05, 2018.

The pastures were managed under rotational grazing, with three days of occupation of the paddocks. The rest period of the paddocks was based on the 95±2% of LI by the canopy. Evaluation of canopy LI was performed weekly during the rest period of each grazing cycle, using the Accupar LP 80 canopy analyzer equipment (Decagon Devices, Pullman, WA, USA). Measurements were taken at nine random locations per paddock between 10:30 and 12:00 h.

Twenty-four Holstein × Zebu cows, four for each replicate, were distributed according to milk production, number of lactations, body weight, and their genetic composition. In addition, when necessary, extra non-lactating cows were used to ensure the canopy lowering during the three days of paddock occupation.

The maintenance fertilizations occurred during the rainy season (November to March) of the experimental period with 50 kg ha^{-1} N and K_2O, at 20-05-20 (N-P-K), after each grazing event according to the recommendations for pasture fertilization of intensive scale.

The experimental cows were milked daily at 7:00 and 14:00 h. Between the milking sections, the cows remained in an area near the corral provided with shade and water. Water and mineral salt were provided (*ad libitum*) for all animals throughout the experimental period.

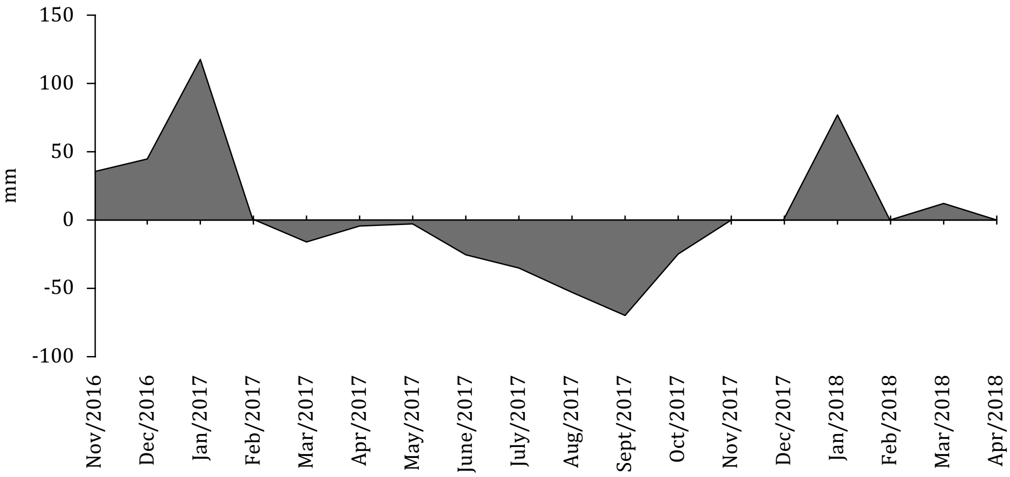


Figure 2 - Monthly water balance from November 2016 to April 2018, according to Pereira (2005).

The average canopy height of each paddock was assessed using a ruler at 20 random points per paddock. The height of each point corresponded to the height of the curvature of upper leaves around the scale, as described by Carnevalli et al. (2006). The canopy height readings were obtained in the pre- and post-grazing conditions. To find the post-grazing height corresponding to 50% of the pre-grazing height within the three-day occupation period, at the end of the second occupation day, an evaluation of the average canopy height was made. When necessary, extra animals (non-lactating cows) were added to the group of experimental cows according to the put-and-take technique (Allen et al., 2011). Based on the pre- and post-grazing canopy height data, the canopy lowering (i.e., proportion of canopy height removal) was calculated.

Herbage samples were taken at three points for each sampled paddock. These points were representative of the average canopy condition of the pasture in terms of height and coverage. Each sampling point corresponded to a metal frame of 1.0 × 0.50 m. The forage contained in each frame was cut at 5 cm from the soil, placed in plastic bags and weighted for the determination of forage mass, after drying in forced-air oven at 60 °C for 72 h. To evaluate the morphological composition, a 400-g sample was taken, from which the leaf blade, stem (stem + sheath), and dead material were separated. After drying, these fractions were weighed in an electronic scale for estimation of the leaf blade, stem, and dead material dry masses.

In the pre-grazing samples, the number of tillers was counted for determining tiller population density (TPD) per m^2. The variables evaluated were: pre- and post-grazing pasture height, canopy lowering percentage (CLP), forage mass (FM), leaf blade mass (LBM), stem mass (SM), dead material mass, leaf:stem ratio (LSR), tiller population density (TPD), and forage bulk density (FBD). Forage bulk density was calculated by dividing the FM by the average canopy height in the pre-grazing condition. The pre-grazing LSR was calculated by dividing LBM by the SM.

The experimental period was divided into five rainfall periods based on the monthly rainfall, and classified as: high, medium, and low, corresponding to rainfall ranges from 547 to 397.1, 397 to 36.2, and less than 36.2 mm monthly, respectively. Thus, the periods were divided into: period 1 - high rainfall: December 2016, January and February 2017; period 2 - medium rainfall: March, April, and May 2017; period 3 - low rainfall: June, July, and August 2017; period 4 - high rainfall: November and December 2017 and January 2018; and period 5 - medium rainfall: February, March, and April of 2018. The rainfall distribution during the experimental period corresponded to 30, 14, 2, 31, and 23% during periods 1, 2, 3, 4, and 5, respectively.

Between mid-April and the end of August 2017, due to drop in temperature and low rainfall, the rest period of the paddocks exceeded 30 days. Thus, extra paddocks (in addition to the 10 experimental ones for each replicate) were used to complete the grazing cycle. Besides, during this period, corn silage was given to the cows to supplement the pasture. Between the end of August and the end of October 2017, due to low pasture growth, pasture assessments were interrupted.

Data was analyzed using mixed models in the SAS® software (Statistical Analysis System, version 9.0), with two cultivars treatments (BRS Zuri and BRS Quênia) and measures repeated (five rainfall periods), in a completely randomized block design with three replications. The cultivar, rainfall period, and their interactions were considered as fixed effects, while the blocks and errors were considered as random effects. The choice of the covariance matrix was based on the Akaike information criterion (AIC; Wolfinger, 1993). For the cultivar effect, the mean values were compared by Fisher's Least Significant Difference test at 5% error probability, using the PDIFF option of the LSMEANS command. For the rainfall period effect, the mean values were compared by Tukey's test at 5% error probability.

3. Results

The pre-grazing LI did not vary between cultivars nor between the periods studied. The average values were 94.3, 93.1, 92.2, 93.6, and 93.3%, respectively, for periods 1, 2, 3, 4, and 5.

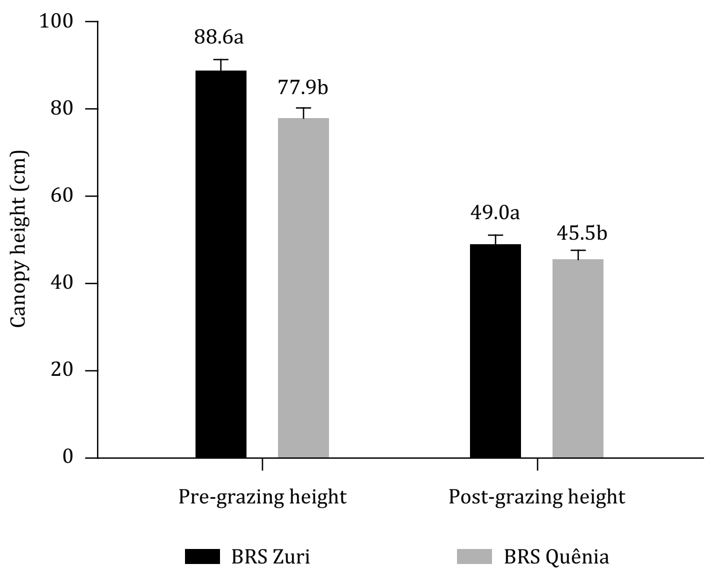
There was effect of rainfall period (P<0.0001) and cultivar (P = 0.004) on pre- and post-grazing canopy heights (Table 1, Figure 3). Taller pre-grazing canopy heights were observed at the beginning of the experiment (Period 1) with an average value of 94 cm, while the lowest average height was observed in period 3 (72 cm; Table 1). For the post-grazing canopy height, the higher values were observed in the first period (61 cm) and the lowest in the fourth period (38 cm). The comparison between cultivars showed taller canopies in both conditions (pre- and post-grazing) in BRS Zuri compared with BRS Quênia. The average pre-grazing canopy was 89 and 78 cm, respectively, for BRS Zuri and BRS Quênia (Figure 3). The post-grazing canopy height was 49 and 45 cm, respectively, for BRS Zuri and BRS Quênia. Canopy lowering (%) varied with rainfall period (P<0.0001; Table 1). There was an increase in CLP of the pastures between the first and second rainfall periods. However, there was a reduction in the third period, increasing again in the fourth and fifth periods (Table 1).

The LSR and TPD varied as a function of the interaction cultivar × rainfall period (P<0.0001) (Table 2). Higher LSR values were observed for BRS Zuri during the first, second, and fourth rainfall periods. For both cultivars, the highest LSR was observed in the fourth period (3.4 and 2.9 for BRS Zuri and BRS Quênia, respectively). The TPD of BRS Zuri cultivar was similar from the first to the third, followed by a reduction in the last two rainfall periods (Table 2). The TPD of cultivar BRS Quênia was higher in

Table 1 - Pre- and post-grazing canopy heights and canopy lowering of *M. maximus* cultivars over five rainfall periods

Rainfall period[1]					SEM
1	2	3	4	5	
Pre-grazing height (cm)					
94A	86B	72C	82B	84B	2.0
Post-grazing height (cm)					
61A	48B	47C	38D	42D	0.6
Canopy lowering (%)					
34.2C	40.6B	30.2D	51.0A	50.5A	1.1

SEM - standard error of the mean.
[1] Rainfall periods: 1 = high rainfall; 2 = medium rainfall; 3 = low rainfall; 4 = high rainfall; 5 = medium rainfall.
Means followed by distinct letters differ by Tukey's test (P<0.05).



Means followed by distinct letters differ by Fisher's test (P<0.05).

Figure 3 - Pre- and post-grazing canopy heights in BRS Zuri and BRS Quênia pastures.

periods 2 and 3 and lower in period 4. The BRS Quênia showed higher TPD in comparison with BRS Zuri in all periods evaluated with mean values of 477 and 260 tiller m^{-2}, respectively (Table 2).

There was an effect of cultivar × grazing period interaction (P<0.03) for FBD (Table 2). Only in the second rainfall period a higher value for BRS Quênia compared with BRS Zuri was observed, with similar values between cultivars in the other rainfall periods.

Pre-grazing FM did not differ between cultivars (P = 0.237), with an average value of 5,855 kg ha^{-1}. However, there was a season effect (P<0.001) (Table 3). In general, FM and its components were higher in the first two periods studied and decreased in the following periods. The pre-grazing LM varied between cultivars (P = 0.024) with higher value for cultivar BRS Zuri (3,451 × 2,898 kg ha^{-1}). There was also an effect of the periods evaluated (P<0.001) (Table 3). The pre-grazing LM was higher in the first three periods evaluated in relation to the last two. There was a reduction in SM from the first to the fourth period, from 2,405 to 1,028 kg ha^{-1}, a 57% reduction. The DFM showed higher value in period 3 (1,161 kg ha^{-1}) in relation to periods 1, 2, and 5 (average value of 666 kg ha^{-1}). The value observed in period 4 (1,042 kg ha^{-1}) did not differ from the others.

The post-grazing FM varied in response to grass × period interaction (P = 0.0156). Higher post-grazing mass values were observed for cultivar BRS Zuri in periods 1 and 2, while in the other periods, there

Table 2 - Leaf:stem ratio, tiller population density, and forage bulk density of *M. maximus* cultivars during five rainfall periods

Cultivar	Rainfall period[1]					SEM
	1	2	3	4	5	
			Leaf:stem ratio			
BRS Zuri	2.0Ba	2.0Ba	2.6Ba	3.4Aa	2.3Ba	0.9
BRS Quênia	1.5Cb	1.8Ca	2.5Ba	2.9Ab	1.9Ca	
			Tiller population density (tillers m^{-2})			
BRS Zuri	288Ab	257ABb	288Ab	236Bb	233Bb	15
BRS Quênia	422Ba	575Aa	589Aa	349Ca	451Ba	
			Forage bulk density (kg ha^{-1} cm^{-1})			
BRS Zuri	67Ba	71Bb	88Aa	63Ba	52Ca	4
BRS Quênia	71Ba	89Aa	90Aa	54Ca	56Ca	

SEM - standard error of the mean.
[1] Rainfall periods: 1 = high rainfall; 2 = medium rainfall; 3 = low rainfall; 4 = high rainfall; 5 = medium rainfall.
Means followed by different uppercase letters in the same line differ by Tukey's test (P<0.05), and those with lowercase letters in the same column by PDIFF (P<0.05).

Table 3 - Pre-grazing total forage mass of *M. maximus* cultivars and forage components during five rainfall periods

Rainfall period[1]					SEM
1	2	3	4	5	
		Total forage mass (kg ha^{-1})			
6,653AB	6,885A	6,197B	4,892C	4,651C	160
		Leaf mass (kg ha^{-1})			
3,645A	3,402A	3,368A	2,792B	2,662B	96
		Stem mass (kg ha^{-1})			
2,405A	2,632A	1,668B	1,028C	1,441B	82
		Dead forage mass (kg ha^{-1})			
603B	850B	1,161A	1,042AB	547B	129

SEM - standard error of the mean.
[1] Rainfall periods: 1 = high rainfall; 2 = medium rainfall; 3 = low rainfall; 4 = high rainfall; 5 = medium rainfall.
Means followed by distinct letters differ by Tukey's test (P<0.05).

was no difference between cultivars (Table 4). For BRS Zuri cultivar, the lowest post-grazing FM was observed in period 3, with no difference between the other periods. For BRS Quênia, the lowest values occurred in periods 2 and 3 (Table 4).

Table 4 - Post-grazing forage mass of *M. maximus* cultivars during five rainfall periods

Cultivar	Rainfall period[1]					SEM
	1	2	3	4	5	
	Post-grazing forage mass (kg ha^{-1})					
BRS Zuri	3,214Aa	3,014Aa	2,511Ba	3,189Aa	3,002Aa	129
BRS Quênia	2,723Ab	2,238Bb	2,269Ba	3,038Aa	2,884Aa	

SEM - standard error of the mean.
[1] Rainfall periods: 1 = high rainfall; 2 = medium rainfall; 3 = low rainfall; 4 = high rainfall; 5 = medium rainfall.
Means followed by different uppercase letters in the same line differ by Tukey's test (P<0.05), and those with lowercase letters in the same column by PDIFF (P<0.05).

4. Discussion

Higher pre- and post-grazing canopy heights were observed in BRS Zuri compared with BRS Quênia pastures (Figure 3), mostly due to the inherent morphological differences (Jank et al., 2017) such as leaf length and number and size of tillers. Although forage production depends on a number of factors, usually taller forage plants in the pastures offer higher potential for forage production than the shorter ones, such as Mombaça grass (Carnevalli et al., 2006) compared with Tanzania grass (Barbosa et al., 2007). However, pastures with lower canopies are convenient to manage, in addition to being preferable for grazing due to the lower participation of support structures such as lignified stems (Benvenutti et al., 2008; Carvalho et al., 2013; Canto et al., 2013). Benvenutti et al. (2008) demonstrated the negative effect of *M. maximus* stems on the bite size and forage intake rate of cattle.

The pre-grazing canopy height observed by Tesk et al. (2020) for BRS Quênia was 55 cm. This value is lower than that found in the present study (78 cm; Figure 3). In that article, the evaluations started three months after planting. Between planting and the beginning of the evaluations, the authors determined the canopy height that represented the 95% LI. Furthermore, in that paper, the authors evaluated the residual heights of 35 and 20 cm representing the grazing intensities of 30 and 60%, respectively. In the present study, the post-grazing residue sought was 50% of the pre-grazing height (canopy lowering). Another difference concerns the occupation period of the paddocks. While in the present study the period of occupation of the paddocks was three days, Tesk et al. (2020) used the mob-stocking technique with a canopy lowering time of 4-20 h. Under these conditions, high stocking density is used (Allen et al., 2011), providing a more uniform post-grazing residue.

The highest pre-grazing heights recorded at the beginning of the experiment (periods 1, 2, and 3) are due to the delay in the arrival of the experimental animals and the decision to manage the pasture without the use of mechanical mowing. The first grazing (conditioning grazing) was expected to start in mid-November 2016. However, the experimental animals were only available in late November. Thus, the pasture grew about two weeks beyond what was desired. Due to the stem elongation, this grazing event did not reach the recommended post-grazing heights. However, all the other grazing events were carried out at 95% LI. Tall plants present high tensile stems that impairs bite formation (Moreira et al., 2018) and ultimately, can increase stubble height (Gomide et al., 2007).

A 50% of canopy lowering in relation to pre-grazing height has been recommended for the management of tropical pastures seeking to optimize bite mass and herbage intake rate (Schmitt et al., 2019). Despite the difference in the pre-grazing height observed between cultivars, the percentage of lowering was similar, with an average value of 41.3%.

The data show that from the fourth period, it was possible to lower the initial height to 50%, as an intended goal. This result suggests that the canopy structure was "shaped" with successive grazing cycles and evaluation periods. It is worth mentioning that this response coincides with the lowest SM values observed in periods 4 and 5 (Table 3). Benvenutti et al. (2008) showed how the presence of stems in *Megathyrsus maximus* pasture interferes in the intake of forage by calves and, consequently, in the lowering of the canopy (Santos et al., 1999).

The CLP observed in the first three periods were lower than the established goal (50% of the pre-grazing height of the pastures), due to the grazing difficulties generated by the taller canopies at the beginning of the experimental period. Besides, the variations observed during the rainfall periods is due to seasonal differences (spring-summer during period 1, summer-autumn in period 2, autumn-winter in period 3, spring-summer in period 4, and summer-autumn in period 5), and due to differences in flowering time in the two cultivars (April for BRS Zuri, and February-March for BRS Quênia). However, the highest value of CLP observed during periods 4 and 5, closer to 50% of the pre-grazing height, was due to the better canopy structure observed in the second experimental year. In fact, the SM registered in periods 4 and 5 were lower than those observed in periods 1 and 2 (Table 3). These results show that the strategy of seeking to reduce pasture canopy through grazing without the use of mowing was efficient, although it was achieved practically after one year of management based on the stipulated criteria.

The higher LSR observed for BRS Zuri in the rainfall periods 1, 2, and 4 confirms the benefits of rainfall for leaf accumulation instead of stems of this cultivar in relation to BRS Quênia. The flowering of cultivar BRS Quênia occurred between February and March, while for BRS Zuri, flowering occurred in April. With flowering, there is an induction to stem elongation that contributes to the reduction of LSR. The flowering of BRS Quênia at a time still favorable to growth (summer) allows for a new vegetative cycle. The increase in TPD observed for BRS Quênia in periods 2 and 3 (Table 2) supports this explanation. In fact, with grazing, there is a break in apical dominance that, associated with favorable environmental conditions, promote tillering in grasses (Lemaire, 2001). On the other hand, the flowering of BRS Zuri, such as cultivars Tanzânia and Mombaça, occurs in April when the conditions of rain and temperature do not allow a new vegetative cycle, and there is a sharp drop in pasture growth.

The LSR is one of the most important structural characteristics of the canopy related to animal behavior under grazing (Carvalho et al., 2013) with direct effect on bite size and forage intake (Benvenutti et al., 2008). Thus, the result of the LSR found in this study somehow contradicts the characteristics described by Jank et al. (2017), who presented cultivar BRS Quênia as having the best structure of the canopy and greater easing of forage apprehension by grazing animals. The lower LSR value for BRS Quênia cultivation overturns our hypothesis that, as it is a smaller cultivar, it would present a better canopy structure. However, the structure of the canopy can be characterized by a series of characteristics beyond LSR.

The higher LSR values observed in period 4 for both cultivars can be explained by the increase in grazing pressure (higher stocking rate) promoted in the second experimental year, which even contributed to the reduction in post-grazing canopy height in periods 4 and 5 (Table 1). The works of Carnevalli et al. (2006) and Gomide et al. (2007), who studied Mombaça grass, and Barbosa et al. (2007), who studied Tanzânia grass, also showed the effect of the interval between grazing and post-grazing height on the structural characteristics of the canopy.

Grass tillering dynamics responds to several factors, including climatic conditions and management (Lemaire, 2001), and high appearance rate and low tiller mortality rate are observed in Spring (Sbrissia and Silva, 2008; Santos et al., 2011) as a reflection of the improvement in growth conditions after winter. There was variation in TPD according to the periods evaluated. However, this variation was different between cultivars. For BRS Quênia cultivar, there was a 40% variation between the highest and lowest TDP value (Table 2). An increase in TDP of BRS Quênia from the first to the third rainfall period, followed by a reduction in the fourth and an increase during the fifth rainfall period were observed. The increase during periods 4 to 5 is due to the response to the environmental stimulus, since high temperature and higher precipitation occurred again at the same time (Figure 1). The TDP of BRS Zuri showed less variability in absolute values, the difference between the extremes being only 20%. Higher TDP values were observed in periods 1 and 3 and lower in periods 4 and 5.

Between the cultivars, higher TPD was obtained in BRS Quênia consistently throughout all rainfall periods. This is due to its lower pre-grazing height (Table 1) and the morphological differences between cultivars (Jank et al., 2017). The higher tiller density of cultivar BRS Quênia provided a higher frequency of tussocks and a consequent lower frequency of uncovered soil in relation to cultivar BRS Zuri (Freitas et al., 2018). This is an interesting characteristic to be observed in tall tufted grasses, because it allows the use of this cultivar in slightly more accentuated relief conditions in relation to the other cultivars of *M. maximus*. Gomide et al. (2007) observed in pastures of Mombaça grass under rotational stocking a TPD ranging from 148 to 240 tillers/m^2; values closer to those observed for cultivar BRS Zuri in the present study.

Lower FBD values were observed during the last two rainfall periods compared with those in periods 1 to 3. As the canopy height is the denominator in calculating FBD, increasing canopy height tends to reduce the density estimate. However, changes in the morphological composition of forage in pastures kept lower, such as the reduction in participation of stems (Carnevalli et al., 2006; Gomide et al., 2007; Anjos et al., 2016), can reduce or offset this effect. The lower FM observed in the last two periods also contributes to this reduction in FBD. Difference between cultivars was observed only in period 2, when BRS Quênia had a higher FBD than BRS Zuri (Table 2). It is interesting to note that the higher FBD values of BRS Quênia observed in periods 2 and 3 coincide with their highest tiller densities. The early flowering of BRS Quênia (February/March) associated with the continuous growth and production, as already discussed, may have contributed to the increase in SM and, thereby, increased FBD in period 2.

The FBD is one of the structural characteristics that are related to the ingestive behavior of grazing cattle (Carvalho et al., 2013). For these authors, under grazing, it is more common to find conditions in which the structure of the pasture is the main element of intake restriction, more than the chemical composition. Canopies with high FBD, notably leaves, favor the forage apprehension and, consequently, the intake of daily dry matter (Burns and Sollenberger, 2002). The high values of LSR and forage density found in this study reveal the good adaptation of these cultivars for use under intensive management.

In general, FM and its components were higher in the first two periods studied and decreased in the following periods. We can list two reasons for such pattern of response: the first refers to the advance of summer to autumn-winter (period 3 in relation to 1 and 2), and the second refers to the continuous search to reach the 50% of canopy lowering resulting in the greater grazing pressure imposed in periods 4 and 5, which reduced the canopy heights.

It is evident that at the highest pre-grazing canopy height in the first period, compared with the last, there was a greater participation of the stem component in the FM. During the grazing cycles, reduction of the stem component in the fm reduces yield, mostly observed in the final cycles (Canto et al., 2013). In tropical forages, stem elongation occurs even during the vegetative growth phase, but can be controlled by pasture management strategies (Gomide and Gomide, 2001).

Despite the longer rest period of paddock, the reduction in pre-grazing FM observed in period 3, in relation to periods 1 and 2, is mainly due to the less favorable climatic conditions observed in autumn-winter (Figure 1), which result, among other factors, in a negative water balance (Figure 2). On the other hand, the lower values in periods 4 and 5 are due to the higher grazing pressure and lower canopy height adopted in the second experimental year (Table 1). Most of this reduction is due to the decrease in the stem percentage in FM. Thus, when comparing periods 1 and 2 with 4 and 5, stem percentages of 35 and 37% were observed in the first two and 19 and 22% in the last two. The contribution of the stem to FM in tussock grasses, despite its deleterious effect on canopy structure as already discussed, has been reported in several studies (Santos et al., 1999; Carnevalli et al., 2006; Barbosa et al., 2007).

Pre-grazing FM values in experiments with Mombaça grass pastures managed with grazing intervals based on the 95% LI were 4,571 kg ha^{-1} DM (Gomide et al., 2007) or 5,375 kg ha^{-1} DM (Carnevalli et al., 2006), with an average rest period of 24 days in the summer period. Thus, the pre-grazing FM found for the two cultivars in this study, considering the rest period around 18 to 20 days in the spring-summer periods (1, 2, 3, and 4), reveals their good forage production and their potential to increase the stocking rate in tropical pastures. At this point it is important to note that animal production on pasture comes from individual production (weight gain per animal or milk per cow) and stocking rate, the latter being the most important in tropical pastures (Gomide and Gomide, 2001).

Pre-grazing LM was higher (P = 0.024) value for cultivar BRS Zuri in relation to BRS Quênia (3,451 × 2,898 kg ha^{-1}). These results corroborate the favorable characteristics of the cultivars that would stand out for their production potential in the case of BRS Zuri and for the lower canopy height and easier grazing management of BRS Quênia (Jank et al., 2017). Pre-grazing LM was higher in the first three periods evaluated in relation to the last two. Again, the explanation given in relation to FM fits, that is, the greater grazing pressure imposed in the second experimental year (periods 4 and 5) reduced the canopy height both in pre- and post-grazing and, consequently, FM. However, this strategy reduced the participation of stems in FM. This effect can be seen in the higher LSR observed mainly in period 4 (Table 2). Tesk et al. (2020), evaluating cultivars BRS Quênia and BRS Tamani of guineagrass under two grazing intensities, observed a higher proportion of leaves (93 vs. 86%) under lenient grazing compared with intensive grazing. However, those authors evaluated the FM harvested above a predetermined residue and not the total FM (cut close to the ground). The grazing intensities evaluated in the work of Tesk et al. (2020) represented a canopy lowering of 30 and 60%, respectively, for lenient and intensive grazing treatments.

The leaves are the most nutritious fraction of pasture and their high availability is important both for the good individual performance of grazing animals (Euclides et al., 1999) and for achieving high stocking rates. Based on data from Cândido et al. (2005), who evaluated Mombaça grass under rotational stocking in good fertility soil during spring-summer period, it is possible to estimate, from the treatment that approaches the management adopted in the present study, an average pre-grazing LM of 2,720 kg ha^{-1}. Comparatively, the average value observed in this study was 3,173 kg ha^{-1}, reinforcing the production potential of the studied cultivars.

The reduction observed in SM from the first to the fourth period highlights the importance of controlling the rest period of tropical cespitous grasses, as demonstrated by Gomide et al. (2007), who evaluated Mombaça grass under three rest periods based on the occurrence of 2.5, 3.5, and 4.5 leaves per tiller. They observed that the post-grazing residues of the last two treatments increased progressively with grazing cycles, as well as the contribution of stem in FM.

The SM values in this study varied similarly to the FM according to the rainfall periods, for which the highest values were observed during periods 1 and 2. Overall, the highest SM values matched those of FM, as also verified in other studies on tropical grasses (Gomide et al., 2007; Anjos et al., 2016).

The higher participation of DFM during periods 3 and 4 (Table 3) can be explained by the reduction in growth factors, mainly temperature and precipitation, since the dry season influences the accumulation of senescent material (Gouveia et al., 2017). The reduction in this variable during period 5 is due to the resumption of pasture growth due to favorable growth conditions and consequent renewal of the tissues (Lemaire, 2001) associated with the reduction in the pre- and post-grazing canopy heights compared with periods 1 and 2 (Table 1).

The post-grazing FM (Table 4) was lower in the period of less rainfall (period 3; Figure 1), as expected. Two points regarding this variable deserve to be highlighted. First, differences between cultivars occurred only at the beginning of the evaluations (periods 1 and 2), when the condition of the pasture still had the effect of delay in conditioning grazing, as already discussed. In both periods, the lower post-grazing FM occurred in BRS Quênia pasture. The second aspect refers to the fact that, for BRS Quênia, there was a reduction in the post-grazing FM in the second period, whereas in BRS Zuri, the reduction occurred only in the third period. These points suggest that it is easier to lower BRS Quênia than BRS Zuri, corroborating Jank et al. (2017), who pointed out this cultivar as being easier to manage.

5. Conclusions

The control of stem dry mass in the pre-grazing forage mass is determinant for the efficiency in the control of canopy structure and forage production in *M. maximus* pastures.

Cultivar BRS Quênia has lower pre- and post-grazing heights and higher tiller density than BRS Zuri. Cultivar BRS Zuri shows a higher forage production, presenting higher pre-grazing total forage mass and leaf mass. Both cultivars are similar in morphological composition and offer high yield potential when managed under a rotational grazing system.

The rainfall period has a strong influence on structural characteristics of the canopy, and in the season of lower rainfall, there is lower pre-grazing canopy height, lower canopy lowering, and higher dead forage mass.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: D.S.C. Paciullo and C.A.M. Gomide. Data curation: P.D. Valote, C.A.S. Freitas and M.J.F. Morenz. Formal analysis: C.A.B. Carvalho, M.J.F. Morenz and D.S.C. Paciullo. Funding acquisition: C.A.M. Gomide. Investigation: P.D. Valote and C.A.S. Freitas. Methodology: C.A.S. Freitas. Project administration: C.A.M. Gomide. Supervision: C.A.B. Carvalho, C.A.S. Freitas, M.J.F. Morenz, D.S.C. Paciullo and C.A.M. Gomide. Visualization: P.D. Valote. Writing-original draft: P.D. Valote and C.A.B. Carvalho. Writing-review & editing: C.A.B. Carvalho, M.J.F. Morenz, D.S.C. Paciullo and C.A.M. Gomide.

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