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Herbage intake by cattle in kikuyugrass pastures under intermittent stocking method[1]

Consumo de forragem por bovinos em pastos de capim-quicuiu sob lotação intermitente

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ABSTRACT - Two complementary experiments were conducted to investigate the relationships between the canopy structure of *Pennisetum clandestinum* (kikuyugrass) pastures created by intermittent stocking strategies and daily herbage intake by cattle. The first experiment (Exp. I) evaluated the relationship between different pre-grazing heights (10, 15, 20, and 25 cm) and a single defoliation intensity (50% reduction in the initial heights). In the second experiment (Exp. II), four defoliation intensities (40, 50, 60, or 70% reduction in height) were combined with a single pre-grazing height (25 cm). The following variables were analyzed: i) plant-part composition, herbage mass, and bulk density of the grazing layer; and ii) daily herbage intake. The data were analyzed using orthogonal polynomial contrasts. The Tukey-Kramer test was used to compare daily herbage intake means so that the differences among treatments could be characterized. In general, herbage intake decreased as the pre-grazing canopy height decreased (Exp. I; P = 0.03) and as defoliation intensity increased (Exp. II; P = 0.02). These response patterns were associated with canopy structure, both that existing before and that created during the stocking period. In conclusion, pre-grazing heights lower than 25 cm or defoliation intensities greater than 40% reduce daily herbage intake by cattle in kikuyugrass pastures under intermittent stocking.

Key words: Grazing management. *Pennisetum clandestinum.* Rotational stocking. Defoliation severity.

RESUMO - Dois experimentos complementares foram conduzidos para investigar as relações entre a estrutura do dossel de pastagens de *Pennisetum clandestinum* (capim-quicuiu) criadas por estratégias de lotação intermitente e o consumo de forragem por bovinos. O primeiro (Exp. I) avaliou o efeito de diferentes alturas em pré-pastejo (10, 15, 20 e 25 cm) associadas com uma única severidade de desfolhação (50% das alturas iniciais). No segundo (Exp. II) quatro severidades de desfolhação (40, 50, 60 ou 70% da altura total) foram combinadas com uma única altura inicial (25 cm). As variáveis analisadas foram: i) composição morfológica, massa e densidade do estrato de pastejo; ii) consumo de forragem. Os dados foram analisados por contrastes de polinômios ortogonais. Entretanto, para uma melhor caracterização das diferenças entre tratamentos, optou-se por comparar as médias de consumo pelo teste de Tukey. De modo geral, o consumo de forragem diminuiu com a redução da altura em pré-pastejo (Exp. I; P=0,03) ou com o aumento da severidade de desfolhação (Exp. II; P=0,02), em resposta as estruturas criadas antes e durante o processo de ocupação. Ademais, houve uma aparente abdicação dos animais em compensar estas condições com ajustes no comportamento ingestivo. Concluiu-se que alturas em pré-pastejo menores que 25 cm ou severidades de desfolhação maiores que 40% reduzem o consumo de forragem por bovinos em pastos de capim-quicuiu sob lotação intermitente.

Palavras-chave: Lotação rotativa. Manejo do pastejo. *Pennisetum clandestinum*. Severidade de desfolhação.

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INTRODUCTION

Previous research in forage plant ecophysiology and the plant-animal interface has defined more efficient grazing management practices. For example, the concept of the critical leaf area index (*critical* LAI; a condition in which the canopy intercepts 95% of the incident radiation), originally applied to cool-season grasses, was found to be useful in deciding when the regrowth of some warm-season grasses subjected to the intermittent stocking method should be interrupted (SILVA; SBRISSIA; PEREIRA, 2015). This is because the use of the *critical* LAI improves leaf dry matter production (ZANINI; SANTOS; SBRISSIA, 2012), herbage nutritive value (CONGIO *et al*., 2018; VOLTOLINI *et al.*, 2010), the foraging process (PALHANO *et al.*, 2007; TRINDADE *et al.*, 2007), and animal performance (CONGIO *et al*., 2018; GIMENES *et al.*, 2011) compared with longer regrowth intervals.

Recently, an alternative interpretation of the *critical* LAI has been suggested. This new interpretation suggests that the canopy height corresponding to this condition should be considered as the upper limit (instead of ideal limit) for interrupting the regrowth of pastures under the intermittent stocking method. Sbrissia *et al.* (2018) demonstrated that kikuyugrass (*Pennisetum clandestinum* Hochst ex. Chiov) pastures managed with pre-grazing heights between 15 and 25 cm (the latter corresponding to *critical* LAI) and defoliated to remove 50% of their initial height did not differ in herbage accumulation, and the herbage in the upper half of the canopy was composed primarily of leaves. These studies suggested some flexibility in the canopy height targets for pastures subjected to the intermittent stocking method, which was similar to the results reported for the continuous stocking method (BIRCHAM; HODGSON, 1983).

Although productive capacity of the pasture was not affected over a range of pre-grazing height targets, this is not sufficient evidence to conclude that animal performance will be unaffected across this range. Animal performance depends on herbage production, and on how management strategies affect canopy structure, grazing behavior, and ultimately, daily herbage intake. The daily herbage intake by grazing animals is dependent on the amount prehended per bite (bite mass), the biting frequency (biting rate), and the time spent grazing (grazing time) (ALLDEN; WHITTAKER, 1970). Studies that evaluated components of grazing behavior over short time scales and their relationships with management targets have recommended a narrow range of pre-grazing canopy heights and defoliation intensities (up to 40–50%) in order to optimize bite mass and herbage intake rate (AMARAL *et al.*, 2012; FONSECA *et al.*, 2012; MEZZALIRA *et al.*, 2014). Because both biting rate (MEZZALIRA *et al.*, 2014) and grazing time (PÉREZ-PRIETO; DELAGARDE, 2012; RIBEIRO FILHO *et al.*, 2011) seem to be less efficient behavioral compensatory mechanisms under intermittent stocking, we hypothesize that pre-grazing heights lower than 25 cm and defoliation intensities greater than 50% reduce the daily herbage intake of animals grazing kikuyugrass pastures. Against this background, two complementary experiments were designed to evaluate the canopy structure and the daily herbage intake by cattle on kikuyugrass pastures under intermittent stocking.

MATERIALS AND METHODS

Two complementary experiments were conducted in Lages, Santa Catarina, Brazil (27°47′S, 50°18′W, 913m a.s.l.) between January and May 2012 (Experiment I) and 2014 (Experiment II). According to the Köppen climate classification, the region has a Cfb-type climate (humid subtropical under oceanic influences) with cold winters, mild summers, and well-distributed rainfall throughout the year. Weather data from both experimental periods are shown in Table 1. The experimental area was a 1.8-ha kikuyugrass pasture established in the early 1990s and grazed by dairy cattle since then. The area was divided into three blocks containing four pastures, for a total of twelve 1500-m^2 experimental units. Before the beginning of each experiment (December 2011 and 2013), the plots were mowed to 10-cm stubble height and fertilized with 140 kg N ha^{-1} as urea (45% N). In January 2012 and 2014, when the pastures had reached their intended pre-grazing heights, grazing followed by mowing was performed to adjust the intended residual heights, defining the beginning of the experimental period.

Due to operational reasons, it was not possible to use the same technique to estimate the daily herbage intake in both experiments. Therefore, some adaptations to both protocols were necessary.

Experiment I

In this experiment, the treatments were four pre-grazing heights (10, 15, 20 and 25 cm) combined with a defoliation intensity of 50% (residual heights were 5.0, 7.5, 10.0, and 12.5 cm, respectively). The pre-grazing heights were based on previous light interception measurements, which showed that 10, 15, 20 and 25 cm in height intercepted 51, 75, 91 and 95% of the incident light, respectively. The defoliation intensity was based on studies which suggested that a 40–50% removal threshold could be used to maintain the instantaneous herbage intake rate at its maximum (FONSECA *et al.*, 2012; MEZZALIRA *et al.*, 2014). Furthermore, it favors the regrowth of kikuyugrass pastures managed within a

Table 1 - Monthly weather data during the experimental period in Lages, SC, Brazil

	Jan	Feb	Mar	Apr	May
			2012		
Max. temperature (°C)	26.8	28.4	27.2	23.0	19.2
Min. temperature (°C)	15.5	17.4	14.2	12.1	9.2
Avg. temperature (°C)	20.2	21.9	19.3	16.4	13.3
Rainfall (mm)	192.1	195.5	56.1	84.9	28.9
			2014		
Max. temperature (°C)	27.9	28.3	24.2	21.6	18.6
Min. temperature (°C)	16.3	15.3	14.0	12.2	8.8
Avg. temperature (°C)	22.1	21.8	19.1	16.9	13.9
Rainfall (mm)	183.2	210.7	121.3	94.2	235.3

range of pre-grazing heights 15-25 cm; (SBRISSIA *et al.*, 2018). The canopy heights were monitored using a sward stick at 50 points per pasture, every three days during the regrowth period and every 12 hours during the stocking period.

The grazing animals were Holstein (*Bos taurus*) heifers and dry cows that had been previously adapted to the experimental procedures. Cattle received no supplementation. From this group, six heifers with similar body conditions were grouped into pairs and assigned to blocks for daily herbage intake assessments. Therefore, each pair of tester animals was subjected to all treatments in the assigned block. Twenty put-and-take animals were also used, as needed, for stocking rate adjustments. Stocking rates were calculated based on the assumption that the herbage mass in the grazing layer (determination described below) would be removed over 5 days and the animals would consume less than 3% of their live weight (LW). In order to more carefully regulate the grazing process, stocking rate adjustments were also performed on the third day during the stocking period.

Grazing layer structural characteristics were assessed by destructive sampling when the pastures reached the intended pre-grazing height of 25 cm. The herbage samples were clipped above the intended residual height, using 0.0625-m^2 quadrats and scissors, at three representative locations per experimental unit. Each sample was separated into the constituent plant-parts (leaf, stem + sheath, and dead material) and dried in a forced-air oven at 65 °C for 72 hours. The dry weights of these fractions were used to calculate plant-part composition (% DM), forage mass (kg DM ha^{-1}), and bulk density (kg DM ha^{-1} cm^{-1}). Finally, the samples were ground in a Wiley mill until they pass through a 1-mm screen and then stored until needed for the n-alkanes determinations.

The daily herbage intake was determined using the n-alkane technique (MAYES; LAMB; COLGROVE, 1986) with the forage C_{31} (n-untriacontane; internal marker) to dosed C_{32} (n-dotriacontane; external marker) ratio. The tester animals were handled as follows: (i) seven days before the experimental period, they were maintained in adjacent kikuyugrass pastures and orally received cellulose stoppers (Carl Roth, GmbH, Karlsruhe, Germany) containing 200 mg of C_{32} twice daily (07:00 am and 07:00 pm); (ii) during the stocking period (days 1–5), besides the administration of cellulose stoppers, fecal grab samples were also taken from the rectum to determine fecal n-alkane concentration; and (iii) at the end of the stocking period (day 6), they were maintained for 24 hours in adjacent kikuyugrass pastures so that two additional fecal collections could be taken and to allow the cellulose stoppers to be administered. The fecal samples were frozen (-20 °C) and stored until the end of the experimental period. Then, they were defrosted, bulked by animal-experimental unit, dried at 60 °C for 48 hours, and ground in a Wiley mill until they passed through a 1-mm screen. We assumed that the herbage mass above the intended residual height represented the material consumed by the animals, and its n-alkane concentrations were the average of the plant-part composition and the n-alkane concentration of each component. The fecal and plant-part samples were subjected to extraction processes and gas chromatography as described by Dove and Mayes (2006) to determine the n-alkane concentrations.

Data were analyzed using PROC MIXED of SAS (version 9.0), with a model including the fixed effects of treatments and blocks. The animals were only considered as random effects in the daily forage intake analysis. Orthogonal polynomial contrasts were used (linear, quadratic, and cubic) to determine the nature of the responses to canopy height because there were four quantitative treatments. Our hypothesis was tested by comparing the daily forage intake means using the Tukey-Kramer test. The significance level was set at 5% ($P \leq 0.05$).

Experiment II

In this experiment, the treatments were four defoliation intensities (reducing the canopy height by 40, 50, 60, and 70% of the initial height) combined with a pre-grazing height of 25 cm (residual heights of 15.0, 12.5, 10.0, and 7.5 cm, respectively). The defoliation intensity range was based on a 40–50% threshold in order to maintain the herbage intake rate at its maximum (FONSECA *et al.*, 2012; MEZZALIRA *et al.*, 2014) and 60–70% to test possible compensation by behavioral mechanisms. The pre-grazing height was based on the results from Experiment I (Figure 1). Therefore, herbage intake was not expected to be restricted by the initial height. To increase the number of daily herbage intake observations (described below) per treatment, the pastures were divided into four strips, and animals were allocated to new grazing strips every morning (between 08:00–10:00 am) during the stocking period. During the first grazing cycle, stocking rate and strip area were adjusted daily to achieve a 4% LW forage allowance above the intended residual height (2.0% of effective intake plus 2.0% for selection/loss opportunities). However, due to difficulties in achieving the residual heights, another grazing cycle was performed and the allowance was reduced to 3% LW. The canopy heights were monitored with a sward stick in 50 random points per evaluation. The heights were measured every three days during regrowth, and at pre- and post-grazing stages in each strip during the stocking period.

The grazing layer structural characteristics were assessed from destructive samples taken before the animals entered a new strip. Herbage samples were clipped above the intended residual height, using 0.1-m^2 quadrats and scissors, at five representative locations per strip (totaling 20 locations per pasture). After collection, the fresh samples were weighed. Then, they were bulked by strip and two subsamples were taken. The first subsample was dried in a forced-air oven at 65 °C for 72 hours to determine the dry matter concentration (% DM). The second subsample was separated into its constituent plant-parts (leaf, stem + sheath, and dead material) and dried as described above. From these data, it was possible to calculate plant-part composition (% DM), herbage mass (kg DM ha^{-1}), allowance (% LW), bulk density (kg DM ha^{-1} cm^{-1}), and some other related variables.

The daily herbage intake was estimated from the difference between the pre- and post-grazing total herbage mass (DOBOS *et al.*, 2009; REEVES *et al.*, 1996), both of which were measured with a rising plate meter (Farmworks®, F200, New Zealand; 0.1 m^2 area). Five locations per grazing strip were selected to represent the range of observed heights at the pre- and post-grazing stages. These locations were evaluated in relation to their compressed canopy height. Then they were clipped to 3 cm above soil level (PÉREZ-PRIETO; DELAGARDE, 2012; REEVES *et al.*, 1996), dried at 60 °C for 48 hours, and weighed. Calibration equations (relationship between compressed canopy height and herbage mass) were developed after comparing the slopes and intercepts as described by Da Silva and Cunha (2003). Since there were no differences ($P>0.05$), the data were grouped according to grazing cycle and grazing period (Table 2). These equations were used to predict the herbage mass from 100 compressed height readings per strip, which had been taken randomly at the pre- and post-grazing stages. Finally, the quotient between the removed herbage mass (kg DM ha^{-1}) and the stocking rate (kg LW ha^{-1}) was used to calculate the average daily intake by the herd (% LW) in each grazing strip.

Data were analyzed using PROC MIXED of SAS (version 9.0) with a model including the fixed effects of treatments and blocks. Animals (only for daily forage intake analysis) were considered as a random effect and

Table 2 - Calibration equations (compressed canopy height X herbage mass) obtained from kikuyugrass pastures subjected to different defoliation intensities (40, 50, 60 and 70%) and the same pre-grazing height (25 cm)

Stage	Equation	R^2	RSE	Prob>F	N
Cycle 1					
Pre-grazing	$M = -251 + 168H$	0.75	1060	<0.0001	240
Post-grazing	$M = -827 + 191H$	0.78	1171	<0.0001	240
Cycle 2					
Pre-grazing	$M = -5.2 + 183H$	0.79	1136	<0.0001	240
Post-grazing	$M = -621 + 204H$	0.81	1087	<0.0001	240

Abbreviations: M = herbage mass (kg DM ha^{-1}); H = compressed canopy height; RSE = root mean square error; N = number of observations grazing cycle as a repeated measurement. The grazing strips were considered to be repetitions and the data were arranged according to the pasture means. Orthogonal polynomial contrasts were used (linear, quadratic, and cubic) to determine the nature of the responses to defoliation intensities because there were four quantitative treatments. An equidistance between defoliation intensities was not achieved. Therefore, the coefficients were generated by PROC IML in SAS (version 9.0). Our hypothesis was tested by comparing the daily forage intake means using the Tukey-Kramer test. The significance level was set at 5% ($P \leq 0.05$).

RESULTS AND DISCUSSION

Most of the intended grazing height targets in Experiment I were reached (Table 3). An exception was the 10-cm treatment. It did not reach its intended residual height (5 cm), which meant that there was a reduction in the observed defoliation intensity for this treatment (Table 3). This difficulty was related to the close proximity of the residual height to the soil level, which hindered bite formation and, consequently, the ability of cattle to reduce canopy height further by grazing. According to Da Silva *et al.* (2013), grazing horizons shorter than 10 cm lead to a serious restriction in bite formation, which results in a significant bite mass reduction, despite the high proportion of leaves in the herbage consumed.

The increments in pre-grazing height generated grazing layers with differences in total herbage ($HM = 67.5x + 3.2$; $R^2 = 0.81$; $P = 0.047$) and leaf lamina mass ($LLM = 56.4x – 18.5$; $R^2 = 0.82$; $P = 0.051$), but it did not affect plant-part composition (averaging 81% for leaf lamina and 15% for stems + dead material; $P > 0.05$) (Table 4). However, the maximum values for total herbage bulk density ($BD = –0.63x^2 + 23.1x – 56.6$; $R^2 = 0.58$; $P = 0.013$) and leaf lamina density ($LLD = –0.49x^2 + 18.1x – 40.1$; $R^2 = 0.61$; $P = 0.015$) (155 and 127 kg DM ha^{-1} cm^{-1} for bulk and leaf lamina density, respectively) were estimated to be reached when the plants attained a height of 18.3 and 18.5 cm, respectively. These results indicate that, from these canopy heights onward, additional increases in canopy height changed the leaf spatial arrangement, which led to a concomitant reduction in both variables. Although stem + dead material mass ($SDM = 0.38x^3$

Table 3 - Average grazing heights and observed defoliation intensities in kikuyugrass pastures subjected to different pre-grazing heights and the same defoliation intensity (50%)

Variable	Pre-grazing height (cm)				SEM
	10	15	20	25	
Pre-grazing height (cm)	9.9	15.7	20.6	25.5	1.8
Post-grazing height (cm)	5.7	7.9	10.0	12.4	0.7
Obs. defoliation intensity (%)	42.2	49.7	51.2	51.4	0.1

Abbreviation: SEM (standard error of the mean)

Table 4 - Grazing layer structural characterization of kikuyugrass pastures subjected to different pre-grazing heights and same defoliation intensity (50%)

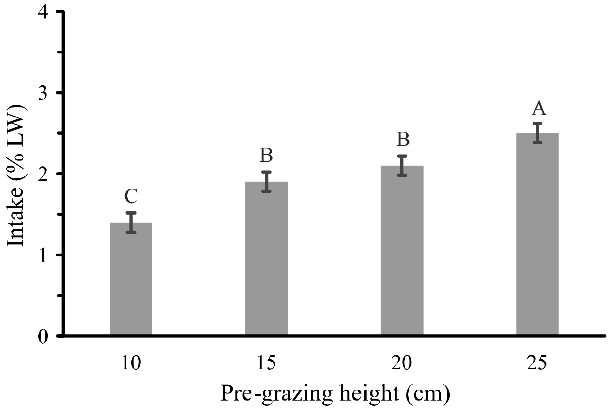
Variable	Pre-grazing height (cm)				SEM	F	Effect
	10	15	20	25			
Herbage mass	530	1240	1430	1610	132.2	19.54	L
Leaf lamina mass	420	1020	1190	1320	109.4	19.15	L
Stem + dead mat. mass	84	220	180	231	27.6	3.01	C
Bulk density	108	152	136	123	4.4	5.67	Q
Leaf lamina density	86	125	112	101	6.0	5.19	Q
Stem + dead mat. density	17	27	17	18	2.4	3.41	C
% Leaf lamina	79.6	82.3	82.8	82.0	0.6	1.23	NS
% Stem + dead material	15.9	17.7	12.1	15.0	1.8	2.35	NS

Abbreviations: L (linear); Q (quadratic); C (cubic); NS (not significant, $P>0.05$); SEM (standard error mean); F (F-value). Units: Mass (kg DM ha^{-1}); Density (kg DM ha^{-1} cm^{-1}); Plant-part composition (% DM)

– 20.8x^2 + 365.2x – 1856; R^2 = 0.73; P = 0.013) and its density (SDD = 0.04x^3 – 2.4x^2 + 40.5x – 190; R^2 = 0.65; P = 0.025) were affected by grazing height (Table 4), both values were relatively low. Therefore, despite the constancy in the plant-part composition in the upper half of the canopy (ZANINI *et al*., 2012), grazing height targets are capable of altering plant density, which effectively modulated the canopy structure offered to grazing animals.

The daily herbage intake was affected by the pre-grazing height (P = 0.032; F = 72.08), and animals grazing pastures where defoliation was initiated at 25 cm had greatest intake (Figure 1). These data corroborate other studies that reported daily herbage intake increased as grazing height increased for both continuous (DA SILVA *et al*., 2013) and intermittent stocking (DOBOS *et al*., 2009; SPÖRNDLY; BURSTEDT, 1996). A convergent point that explains these results is the strong relationship between intake level and bite mass (CARVALHO, 2013). In general, bite mass increases with increasing canopy height, unless structural barriers (e.g. stems) impede the defoliation process. Experiments with microswards have demonstrated that animals prehend heavier bites when the canopy is relatively tall and sparse than when it is short and dense (LACA; UNGAR; DEMMENT, 1992), provided that swards do not contain significant proportions of stems with a high tensile resistance (BENVENUTTI *et al*., 2008). Therefore, based on the grazing layer structural characterization (Table 3), it is likely that bite mass rose as pre-grazing height increased. However, it should be noted that pre-grazing heights greater than 25 cm do not necessarily imply greater intake levels because intensive selection for leaf lamina in more sparse canopies (such as in overgrown pastures) can interfere with this relationship (MEZZALIRA *et al*., 2014).

Figure 1 - Daily herbage intake by cattle in kikuyugrass pastures subjected to different pre-grazing heights and the same defoliation intensity (50%). Means followed by the same letter do not differ by the Tukey-Kramer test (P>0.05)



Another factor that may have influenced the daily herbage intake in Experiment I is a structural constraint imposed by the 50% defoliation intensity. Rocha *et al*. (2016) showed that kikuyugrass pastures defoliated to remove 50% of their initial height had a residual structure composed of leaf laminae shorter than 7 cm. This could make forage prehension difficult at the end of the stocking period. Therefore, it is possible that animals had similar intake levels during the first days of the stocking period, which could be achieved, for example, by using different grazing times. However, over the stocking period, a restrictive condition may have been reached in all treatments, making such a mechanism ineffective. According to Pérez-Prieto and Delagarde (2012), there is a limit to the compensation relationship between intake rate and grazing time because a reduction in the intake rate must be compensated to the same extent by grazing time. Ribeiro Filho *et al.* (2011) did not find a strong relationship between total grazing time and the daily herbage intake of dairy cows in annual ryegrass (*Lolium multiflorum* Lam.) pastures, and they attributed such findings to canopy structure restrictions (such as a leaf lamina length shorter than 10 cm) generated during the stocking period and the grazing cycles.

The defoliation intensities observed in Experiment II were lower than intended (SA = 0.74x + 9.8; R^2 = 0.91; P < 0.001; Table 5). However, a contrast between treatments was generated because residual height decreased (AR = –0.18x + 22; R^2 = 0.90; P < 0.001) as defoliation intensity increased (Table 5). The lower defoliation intensities achieved are possibly related to the allowance levels used in this experiment (above the daily intake capacity), to structural issues that occurred during grazing as canopy height was reduced (described below), and by our choice to not require animals to remain on pastures after they had stopped grazing but the intended residual height was not reached.

The increase in defoliation intensity resulted in grazing layers with greater herbage mass (HM = 88.1x – 2351; R^2 = 0.88; P< 0.001), bulk density (BD = 7.8x + 56.7; R^2 = 0.91; P < 0.001), leaf lamina mass (LLM = 34.5x – 356; R^2 = 0.82; P < 0.001), stem + dead material mass (SDM = 43.6x – 1661; R^2 = 0.85; P < 0.001), proportion (%SD = 0.88x – 25; R^2 = 0.77; P = 0.001), and density (SDD = 2.3x – 752; R^2 = 0.73; P = 0.001) (Table 6). Conversely, leaf proportion declined (%L= 0.96x – 120; R^2 = 0.81; P = 0.041) as defoliation intensity increased, and leaf lamina density was not affected by the treatments (P = 0.1196), averaging 120 kg DM ha^{-1} cm^{-1} (Table 6). Therefore, the increase in defoliation intensity promoted progressive animal access to canopy characteristics

Table 5 - Average grazing heights and observed defoliation intensities in kikuyugrass pastures subjected to different defoliation intensities and the same pre-grazing height (25 cm)

Variable	Defoliation intensity (%)				SEM	F	Effect
	40	50	60	70			
Pre-grazing height (cm)	24.4	23.2	24.8	24.3	0.4	NA	NA
Post-grazing height (cm)	15.0	12.6	11.2	9.4	0.3	36.4	L
Obs. defoliation intensity (%)	39	46	54	61	1.2	44.3	L

Abbreviations: L (linear); NA (not evaluated); SEM (standard error mean); F (F-value)

Table 6 - Grazing layer structural characterization of kikuyugrass pastures subjected to different defoliation intensities and the same pre-grazing height (25 cm)

Variable	Defoliation intensity (%)				SEM	F	Effect
	40	50	60	70			
Herbage mass	1390	1710	2980	3910	242	17.25	L
Leaf lamina mass	1090	1230	1840	2030	108	9.39	L
Stem + dead mat. mass	180	320	920	1450	131	15.29	L
Bulk density	150	161	204	269	14.3	12.58	L
Leaf lamina density	117	118	125	121	7.2	3.04	NS
Stem + dead mat. density	19.8	30.3	64.2	86.9	8.1	18.94	L
% Leaf lamina	81.0	73.9	62.8	52.7	2.6	20.20	L
% Stem + dead mat.	10.3	18.1	29.5	35.8	2.7	10.43	L

Abbreviations: L (linear); NS (not significant, P>0.05); SEM (standard error mean); F (F-value). Units: Mass (kg DM ha^{-1}); Density (kg DM ha^{-1} cm^{-1}); Plant-part composition (% DM)

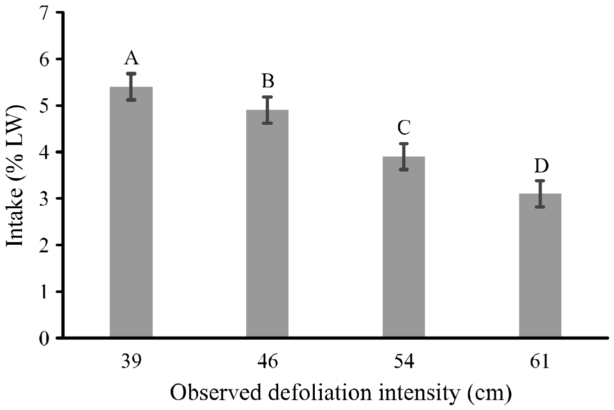
known to restrict the foraging process (FONSECA *et al*., 2012; MEZZALIRA *et al*., 2014), which made it difficult to achieve canopy heights lower than 50% of the initial height.

Daily herbage intake was affected by the defoliation intensity (P = 0.02; F = 39.39), and it decreased as defoliation intensity increased (Figure 2). It is worth mentioning that the values presented in Figure 2 seem to be overestimated. This may be due to the reduction in canopy height being unrelated to herbage harvesting (e.g. height possibly reduced by trampling) and/or that avoiding canopy height measurements in ungrazed rejected areas (e.g. dung patches) increased the probability of taking height measurements in grazed areas, which would lead to an overestimate of the amount of herbage harvested. The forage disappearance method is recommended in situations where the intention is to estimate the average herd consumption over short-time periods, or when minimum handling is required (REEVES *et al*., 1996). However, one of its main disadvantages is to potentially overestimate the herbage intake (DENNIS *et al*., 2012; SMIT *et al*., 2005).

A greater defoliation intensity means more herbage is harvested, although plant-part composition and density can be changed along the vertical profile. This is because forage plants show variation in plant-part composition from top to bottom of the canopy. Leaves occupy the upper strata, whereas stems and dead material predominate in the lower strata (ZANINI *et al*., 2012). During the defoliation process in Experiment II, there was progressive access to grazing horizons that contained greater proportions of stems and dead material (Table 6), which would hinder herbage gathering (BENVENUTTI *et al*., 2008). Therefore, it is probable that all the animals were subject to short-term intake rate restrictions at some point during the grazing period (FONSECA *et al*., 2012; MEZZALIRA *et al*., 2014).

In these situations, animals should increase grazing time as a compensatory mechanism to maintain daily herbage intake levels that meet their nutritional demands. However, this classical mechanism was not observed because at the end of the stocking period, the animals apparently did not continue to graze and, instead, waited to graze a new strip. Similar behavior has been described

Figure 2 - Daily herbage intake by cattle in kikuyugrass pastures subjected to different defoliation intensity and same pre-grazing height (25 cm). Means followed by the same letter do not differ by the Tukey-Kramer test (P>0.05)



in other reports (AMARAL *et al.*, 2012; RIBEIRO FILHO *et al.*, 2011). In this experiment, the behavior can be explained by the preference of animals to graze the edges of the grazing strips, which led to overgrazing in the chosen areas. From this perspective, factors such as lower leaf lamina mass and length (RIBEIRO FILHO *et al.*, 2011), and greater proportions of stems with a high tensile resistance (BENVENUTTI *et al.*, 2008; FONSECA *et al.*, 2012) may have acted additively. This would have led to the creation of a less preferred grazing structure in the grazed areas. In addition, the high temperatures observed during the experimental period may also have discouraged animal grazing, particularly as the temperatures during the daytime from January to March 2014 frequently reached 25 °C (Table 1). This is the upper recommended limit for initiation of management practices that reduce heat stress in dairy cattle (WEST, 2013).

The results from both experiments have important implications for grazing management practices. They showed that despite the existence of a range of grazing height targets where herbage accumulation is similar (SBRISSIA *et al*., 2018), there are fewer management options that optimize daily herbage intake. This is because pre-grazing height reduction and increasing defoliation intensity reduce herbage intake (Figure 1 and Figure 2). Such a response pattern indicates that decisions about grazing height targets depend on the general objective stipulated for a particular production system. For example, if the objective is to maximize daily animal performance from ingested herbage, the most appropriate management for kikuyugrass would be a pre-grazing height of 25 cm and a residual height of 15 cm (defoliation intensity of 40%). However, in situations where there is no need to maximize daily animal performance from ingested herbage (e.g. supplemented animals) or when the objective is to maintain a greater number of animals in the productive process (e.g. cow-calf operation, dry cow herd), then grazing management targets should be more flexible because herbage production is not affected when pre-grazing heights range between 15–25 cm, provided moderate defoliation intensities (up to 50%) are used. Finally, there may be an interaction between pre-grazing height and defoliation intensity such that other treatments, in addition to the one found to maximize daily herbage intake (e.g. 25 cm/40%), may achieve a similar response. For example, similar levels of intake may be obtained with lower pre-grazing heights (e.g. 20 cm) if defoliation intensity is reduced below 40%. If this is confirmed, different arrangements between grazing height targets across grazing cycles should be tested, since it seems unlikely that reducing the residual height (e.g. from 15 to 10 cm) can occur without compromising the foraging process.

CONCLUSION

Pre-grazing height lower than 25 cm or defoliation intensity above 40% compromise the daily herbage intake of cattle in kikuyugrass pastures under intermittent stocking.

REFERENCES

ALLDEN, W. G.; WHITTAKER A. M. The determinants of herbage intake by grazing sheep: the interrelationship of factors influencing herbage intake and availability. **Australian Journal of Agricultural Research**, v. 21, n. 1, p. 755-766.

AMARAL, M. F. *et al.* Sward structure management for a maximum short-term intake rate in annual ryegrass. **Grass and Forage Science**, v. 68, n. 2, p. 271-277, 2012.

BENVENUTTI, M. *et al.* Foraging mechanisms and their outcomes for cattle grazing reproductive tropical swards. **Applied Animal Behaviour Science**, v. 113, n. 1/3, p. 15-31, 2008.

BIRCHAM, J. S.; HODGSON, J. The influence of sward condition on rates of herbage growth and senescence in mixed swards under continuous stocking management. **Grass and Forage Science**, v. 38, n. 4, p. 323-331, 1983.

CARVALHO, P. C. F. Harry Stobbs memorial lecture: can grazing behaviour support innovations in grassland management? **Tropical Grasslands-Forrajes Tropicales**, v. 1, n. 1, p. 137-155, 2013.

CONGIO, G. F. S. *et al.* Strategic grazing management towards sustainable intensification at tropical pasture-based dairy systems. **Science of the Total Environment**, v. 636, n. 1, p. 872-880, 2018.

DENNIS, T. S. *et al*. Effects of co-grazing dairy heifers with goats on animal performance, dry matter yield, and pasture forage composition. **Jornal of Animal Science**, v. 90, n. 12, p. 4467-4477, 2012.

DOBOS, R. C. *et al.* Grazing behaviour and pattern of intake of dairy cows grazing kikuyu (*Pennisetum clandestinum*) grass pastures in relation to sward height and length of grazing session. **Animal Production Science**, v. 49, n. 3, p. 233-238, 2009.

DOVE, H.; MAYES, R. W. Protocol for the analysis of n-alkanes and other plant-wax compounds and for their use as markers for quantifying the nutrient supply of large mammalian herbivores. **Nature Protocols**, v. 1, n. 4, p. 1680-1697, 2006.

FONSECA, L. *et al.* Management targets for maximizing the short-term herbage intake rate of cattle grazing in *Sorghum bicolor*. **Livestock Science**, v. 145, n. 1/3, p. 205-211, 2012.

GIMENES, F. M. *et al.* Ganho de peso e produtividade animal em capim-marandu sob pastejo rotativo e adubação nitrogenada. **Pesquisa Agropecuária Brasileira**, v. 46, n. 7, p. 751-759, 2011.

LACA, E. A.; UNGAR, E. D.; DEMMENT, M. W. Effects of sward height and bulk density on bite dimension of cattle grazing homogenous swards. **Grass and Forage Science**, v. 47, n. 1, p. 91-102, 1992.

MAYES, R. W.; LAMB, C. S.; COLGROVE, P. M. The use of dosed and herbage n-alkanes as markers for the determination of herbage intake. **The Journal of Agricultural Science**, v. 107, n. 1, p. 161-170, 1986.

MEZZALIRA, J. C. *et al.* Behavioural mechanisms of intake rate by heifers grazing swards of contrasting structures. **Applied Animal Behaviour Science**, v. 153, n. 1, p. 1-9, 2014.

PALHANO, A. L. *et al*. Características do processo de ingestão de forragem por novilhas holandesas em pastagens de capim-mombaça. **Revista Brasileira de Zootecnia**, v. 36, n. 4, p. 1014-1021, 2007. Suplemento.

PÉREZ-PRIETO, L. A.; DELAGARDE, R. Meta-analysis of the effect of pre-grazing pasture mass on pasture intake, milk production, and grazing behavior of dairy cows strip-grazing temperate grasslands. **Journal of Dairy Science**, v. 95, n. 9, p. 5317-5330, 2012.

REEVES, M. *et al.* A comparison of three techniques to determine the herbage intake of dairy cows grazing kikuyu (*Pennisetum clandestinum*) pasture. **Australian Journal of Experimental Agriculture**, v. 36, n. 1, p. 23-30, 1996.

RIBEIRO FILHO, H. M. N. *et al.* Inter-relação entre o tempo de pastejo diurno e o consumo de forragem em vacas leiteiras. **Ciência Rural**, v. 41, n. 11, p. 2010-2013, 2011.

ROCHA, C. H. *et al.* Padrões de deslocamento de bovinos em pastos de capim-quicuiu sob lotação intermitente. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v. 68, n. 6, p. 1647-1654, 2016.

SBRISSIA, A. F. *et al*. Defoliation strategies in pastures submitted to intermittent stocking method: underlying mechanisms buffering forage accumulation over a range of grazing heights. **Crop Science**, v. 58, n. 2, p. 945-954, 2018.

SILVA, S. C. da *et al.* Grazing behaviour, herbage intake and animal performance of beef cattle heifers on marandu palisade grass subjected to intensities of continuous stocking management. **Journal of Agricultural Science**, v. 151, n. 5, p. 727-739, 2013.

SILVA, S. C. da; CUNHA, W. F. Métodos indiretos para estimar a massa de forragem em pastos de *Cynodon* spp. **Pesquisa Agropecuária Brasileira**, v. 38, n. 8, p. 981-989, 2003.

SILVA, S. C. da; SBRISSIA, A. F.; PEREIRA, L. E. T. Ecophysiology of C4 forage grasses: understanding plant growth for optimising their use and management. **Agriculture**, v. 5, n. 3, p. 598-625, 2015.

SMIT, H. J. *et al.* Comparison of techniques for estimating herbage intake of grazing dairy cows. **Journal of Dairy Science**, v. 88, n. 5, p. 1827-1836, 2005.

SPÖRNDLY, E.; BURSTEDT, E. Effects of sward height and season on herbage intake of strip-grazed dairy cows. **Acta Agricultura Scandinavica, Section A - Animal Science**, v. 46, n. 2, p. 87-96, 1996.

TRINDADE, J. K. *et al.* Composição morfológica da forragem consumida por bovinos de corte durante o rebaixamento do capim-marandu submetido a estratégias de pastejo rotativo. **Pesquisa Agropecuária Brasileira**, v. 42, p. 883-890, 2007.

VOLTOLINI, T. V. *et al.* Características produtivas e qualitativas do capim-elefante pastejado em intervalo fixo ou variável de acordo com a interceptação da radiação fotossinteticamente ativa. **Revista Brasileira de Zootecnia**, v. 39, n. 5, p. 1002-1010, 2010.

ZANINI, G. D. *et al.* Distribuição de colmo na estrutura vertical de pastos de capim Aruana e azevém anual submetidos a pastejo intermitente por ovinos. **Ciência Rural**, v. 42, n. 5, p. 882-887, 2012.

ZANINI, G. D.; SANTOS, G. T.; SBRISSIA, A. F. Frequencies and intensities of defoliation in Aruana guineagrass swards: morphogenetic and structural characteristics. **Revista Brasileira de Zootecnia**, v. 41, n. 8, p. 1848-1857, 2012.

WEST, J. W. Effects of heat-stress on production in dairy cattle. **Journal of Dairy Science**, v. 86, n. 6, 2003.