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# Sward canopy structure and performance of beef heifers under supplementation in *Brachiaria brizantha* cv. Marandu pastures maintained with three grazing intensities in a continuous stocking system

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**ABSTRACT** - The objective of this study was to assess the sward canopy structure of *Brachiaria brizantha* cv. Marandu pastures maintained in three grazing intensities under continuous stocking system during the rainy season, along with the behavior and performance of grazing beef heifers supplemented with mineral salt or an energy/protein supplement. Three levels of forage allowance were assessed: 2.0, 2.5 and 3.0 kg of forage/kg of live weight, combined with two supplements (*ad libitum* mineral salt, and an energy/protein supplement at 0.3% of live weight/day, supplied daily). The experiment was designed as a randomized block study with two replications. The supplements did not influence the variables related to the canopy structure. Canopy height was greater at higher forage allowances during the late summer and early fall. Similarly, the stem mass was greater in pastures with higher forage allowances. Animals fed protein supplement spent less time grazing than animals supplemented with mineral salt. Stocking rate was higher in pastures with lower forage allowance levels, which increased the live weight gain per grazing area. Daily weight gain did not vary according to the forage allowance levels. The use of an energy/protein supplement did not affect the stocking rate; however, it increased individual live weight gain and live weight gain per grazing area compared with mineral salt supplementation. The use of energy/protein supplements is an efficient alternative to enhance animal performance and production under grazing systems during the rainy season.

Key Words: canopy height, forage allowance, grazing time, number of feedings supplementation time

## Introduction

The Brazilian beef cattle industry is primarily based on the use of pastures. In this setting, grasses belonging to the genus *Brachiaria* are extremely important, regardless of whether the production system used is intensive or extensive. Among the forage plants of this genus, *Brachiaria brizantha* cv. Marandu stands out for its high productivity and its potential of response to the intensification of production systems.

One of the main factors for the intensification of animal production systems based on grazing is the correct management of pastures. Therefore, the adjustment of the stocking rate to maintain optimum grazing pressure is essential. Thus, studies on forage allowance resulted in a better understanding of the response of forage crops and animals to pasture intensity. Sollenberger et al. (2005) proposed a new method to calculate forage allowance in kilograms of forage per kilograms of live weight. This method consists of a mathematical formula that only considers the relationship between forage mass and stocking rate without including the effect of time, thus facilitating the use of the technique, since that estimates of forage accumulation are laborious and the results yielded often have low precision, especially under continuous stocking systems. Because this technique is easy to use, it allows the development of recommendations for pasture utilization, which may be adopted by producers to increase the efficiency of animal production under grazing systems.

In addition to the correct management of pastures, the use of concentrated feed supplements is a technique that enables greater system efficiency, not only during the dry period but also during the rainy period, enabling an increase in pasture carrying capacity and supporting additional gains (Reis et al., 2009). However, the interactions between pasture management and the use of concentrate supplementation must be considered. Reis et al. (2006) observed during data collection that pasture structure was responsible for large variations in animal response. These authors concluded that, in well-managed pastures, a small amount of supplements can achieve similar or superior animal performance compared with the use of large amounts of supplements in poorly managed pastures. This results in a reduction in supplementation costs without decreasing

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gross income; therefore, it is possible to increase the profitability of the activity.

Based on the aforementioned results, this study was conducted to assess the quantitative, qualitative and structural variables of forage canopies, in addition to the feeding behavior and performance of beef heifers supplemented with mineral salt or an energy/protein supplement and kept in *Brachiaria brizantha* cv. Marandu pastures under a continuous stocking system with different forage allowances during the rainy season.

## Material and Methods

The experiment was conducted at Forragicultura of Departamento de Zootecnia da FCAV/UNESP, Jaboticabal Campus, São Paulo, Brazil, located at 21º15' 22" S and 48º18' 58" W, 595 m above the sea level. The experiment was set up in an area of 20 ha of *Brachiaria brizantha* (Hochst ex A. Rich) Stapf cv Marandu pastures established in 2001 on red latosol (Santos et al., 2006).

From the available area, 12 ha were used as the experimental area and 8 ha as a reserve area. Maintenance fertilization was split into two applications: the first fertilization occurred in early December 2006, with 250 kg/ha of the formula N $P_2O_5$ $K_2O$ 20:05:20; the second fertilization occurred in early January 2007, with 50 kg/ha of nitrogen as urea, totaling 100, 12.5 and 50 kg/ha of N, $P_2O_5$ and $K_2O$, respectively, at the end of the rainy season. According to the Köppen classification, the climate of Jaboticabal is characterized as Awa, or subtropical with dry winters and rainy summers (Table 1).

Although the experimental period started in November 2006, in January of the same year, the experimental paddocks were managed using different forage allowances during the rainy period. In the dry season, all pastures were managed so they would be approximately 15 cm tall at the onset of spring (Oliveira, 2010) to allow greater tillering and growth at the beginning of the rainy season, simulating what occurs in commercial properties. In November 2006, animals were taken away from the experimental paddocks, allowing the forage crops to grow until the forage mass reached 3,000 kg of dry matter/ha, when the animals were again introduced to the experimental units. The number of animals in each paddock was calculated as a function of the area and specific forage mass of each experimental unit. Between November 25 and December 14, 2006, animals were habituated to the treatments and to the daily handling. During this period, the forage mass was measured only to maintain the predetermined forage allowances. The experimental period lasted 121 days, from December $14^{th}$, 2006 to April $14^{th}$, 2007.

Three forage allowance levels were studied in combination with two supplements, using randomized blocks with a 3 × 2 factorial design, totaling six treatments with two replications (paddocks) and considering four assessment grazing periods. The forage allowances were 2.0, 2.5 and 3.0 kg of green forage mass per kilogram of live weight (kg of GFM /kg of LW), a strategy proposed by Sollenberger et al. (2005). The supplements were mineral salt and an energy/protein supplement with 26% crude protein and 82% TDN (formulated with 36% citrus pulp, 38% cottonseed meal, 15% Megalac®, 3% urea and 8% minerals) (Table 2).

The animals used were 9-month-old crossbred heifers (¼ Nellore × ¼ Santa Gertrudis × ½ Braunvieh) with initial live weight of 215.5 ± 2.1 kg. The grazing management system adopted was continuous stocking, with a stocking rate that varied according to the proposed forage allowances. Six test animals were placed in each paddock, totaling 72 experimental animals; animals were kept in the same paddock for the duration of the study. To maintain the established forage allowances, put-and-take animals were added to each paddock according to need. The study required 35 heifers for this purpose. The amount of the energy/protein supplement supplied was 0.3% LW/day from 11 a.m. to 1 p.m. Mineral salt was offered *ad libitum* and replaced weekly.

The paddock areas varied according to the allowances; paddocks with an area of 0.7, 1.0 and 1.3 ha had forage allowances of 2.0, 2.5 and 3.0 kg of GFM/kg of LW,

Table 1 - Rainfall and mean monthly air temperature minimums, averages and maximums during the experimental period

| Month | Rainfall (mm) | Days of rain | Minimum Temperature (ºC) | Average Temperature (ºC) | Maximum Temperature (ºC) |
|---|---|---|---|---|---|
| Nov/2006 | 166.8 | 14 | 19.0 | 24.1 | 30.6 |
| Dec/2006 | 221.0 | 24 | 20.6 | 24.4 | 29.9 |
| Jan/2007 | 644.6 | 25 | 21.0 | 23.9 | 28.9 |
| Feb/2007 | 154.7 | 12 | 19.8 | 24.4 | 31.1 |
| Mar/2007 | 156.3 | 13 | 20.0 | 24.9 | 31.7 |
| Apr/2007 | 53.7 | 7 | 18.7 | 23.6 | 30.5 |

Data obtained from the Departamento de Ciências Exatas of FCAV/Jaboticabal, located 800 m away from the experimental area.

Table 2 - Minimum levels of components in the mineral salt and protein supplements used during the rainy period of 2007

| Component | Mineral salt | Energy and protein supplement |
|---|---|---|
| Calcium (g/kg) | 154 | 23 |
| Phosphorus (g/kg) | 90 | 6 |
| Magnesium (g/kg) | 10 | 1 |
| Sulfur (g/kg) | 40 | 3 |
| Sodium (g/kg) | 125 | 13 |
| Copper (mg/kg) | 1670 | 40 |
| Manganese (mg/kg) | 1290 | 30 |
| Zinc (mg/kg) | 6200 | 148 |
| Iodine (mg/kg) | 124 | 3 |
| Cobalt (mg/kg) | 100 | 2.4 |
| Selenium (mg/kg) | 32 | 0.8 |
| Monensin (mg/kg) | 0 | 80 |

respectively. Thus, the number of animals was the same for every paddock, despite the large differences in stocking rate. Treatments were distributed according to the history of grazing intensities from the previous year, so the paddocks that had higher grazing intensities were assigned the lowest forage allowances, and vice versa. The experiment was divided into four periods, delimited by the weights of the animals, which were weighed on 12/14/2006, 01/11/2007, 02/14/2007, 3/12/2007 and 4/14/2007.

Forage mass was determined by using the double sampling method (Sollenberger & Cherney, 1995), where destructive estimates were associated with the assessment of canopy height using a rising plate. A rising plate calibration equation was performed every 28 days. The height of the canopy was measured with the rising plate in nine sites per paddock: three at medium height; three at higher heights; and three at lower heights. At these nine sites, all of the forage included within the perimeter of the rising plate (0.25 $m^2$) was collected at the soil level, placed into marked plastic bags and taken to the laboratory, where it was weighed and separated into green matter (stems and leaves) and dead matter (stems and leaves with more than 50% of their lengths in senescence). Subsequently, the different fractions were dried in a forced ventilation oven at 55ºC for 72 hours and weighed again. After obtaining data for the heights and masses of green forage, linear regressions were determined. Every two weeks, the canopy heights of 100 points were randomly measured and recorded with the rising plate in each paddock, thus obtaining the average height of the pasture. From the calibration equations, the height values were transformed into green forage masses per hectare.

The canopy height was also measured every 28 days using a grazing stick graduated in centimeters. One hundred readings were randomly taken per paddock. The quantitative and structural components of the forage canopy were measured using the samples collected from the sites at medium height and separated into leaf blades (lamina), stems and leaf sheaths (stems) and dead matter. After separation, fractions were weighed, dried in a forced ventilation oven at 55ºC for 72 hours and weighed again.

To study the behavior of grazing animals, assessments were conducted on the 26$^{th}$ and 27$^{th}$ of January 2007. The grazing times during the day (12 hours) were recorded for each of the six test animals per paddock. Observations were made with the aid of binoculars and timers in five-minute intervals from four observation sites located in strategic positions outside the paddocks, allowing the visualization of the entire experimental area without influencing the behavior of the animals. At the end, the grazing activities of each animal during the daytime were summed. The daytime was divided into four intervals: early morning (7 a.m. to 9.55 a.m.), late morning (10 a.m. to 12.55 p.m.), early afternoon (1 p.m. to 3.55 p.m.) and late afternoon (4 p.m. to 6.55 p.m.).

Number of feedings per animal was also determined. The start of feeding was considered as when animals had been grazing for two consecutive assessments 10 minutes apart. Similarly, the end of a feeding was when an animal had not been grazing for two consecutive assessments. The time of each feeding was determined by dividing the time spent grazing by the number of feedings.

Bromatological composition of the heifers' diets was assessed using the esophageal extrusa of two heifers with esophageal fistulas which belonged to the same genetic group as those used for the experiment. Before samples were taken, heifers fasted (no solid feed) for 15 hours. After fasting, the cannulae were opened, and collection bags, which were mesh-bottoms, were placed inside the animals. Animals were then taken to each paddock for sampling, remaining on average 20 minutes in each paddock.

Forage samples collected were placed in aluminum trays and dried in a forced ventilation oven at 55 °C for 72 hours. Samples were then ground in a Wiley mill with a 1-mm mesh sieve and subsequently sent for bromatological analysis. Organic matter, crude protein, neutral detergent fiber and acid detergent fiber contents were determined using the methodology described by Silva & Queiroz (2002). Cellulose was solubilized using 72% sulfuric acid, thus obtaining the lignin content (Robertson & van Soest, 1985). B3 and C fractions of crude protein content were determined according to the methodology proposed by Sniffen et al. (1992).

Individual animal performance was measured by weight changes during successive weightings of test animals, which were taken on the above-mentioned dates after a 12-hour period of complete fasting (no solids or liquids). Stocking rate and gain by grazing area were also calculated.

Statistical analyses were conducted using a mixed model via the MIXED procedure with SAS software, version 9.2 (SAS, 2008). First, the best covariance structure was selected using Schwarz's Bayesian criterion (BIC). The main effects of height, supplementation and months were analyzed using Tukey's test at 10% probability. The interactions between the factors studied were divided using the SLICE option of SAS, with time periods as division factors.

## Results and Discussion

In the pastures managed for a forage allowance of 2.0 kg of GFM/kg of LW, the allowance observed was close to the specified for all experimental periods (1.81 kg GFM/kg LW), while in paddocks with a forage allowance of 2.5 kg GFM/kg LW, the average allowance in the first three time periods was 2.44 kg GFM/kg LW; however, during the last period, there was a trend toward increasing allowance (3.29 kg GFM/kg LW). In pastures kept with a forage allowance of 3.0 kg GFM/kg LW, the increase in forage allowance observed during the last period was the most pronounced, approximately 52% of the predetermined allowance. Forage allowances were similar between supplement types (1.8, 2.7 and 3.3 in pastures that used mineral salt, and 1.8, 2.6 and 3.3 in those that used the energy/protein supplement); this was expected, since that the criteria used for the maintenance of forage allowance were the same in all combinations.

The height of the canopy only varied as a function of the interaction between forage allowance and experimental period (P<0.10). During the first and second experimental periods, there was no variation (P>0.10) in canopy height among the forage allowances (Table 3). In these periods, the overall mean was 30.2 and 26.9 cm, respectively. In the third and fourth periods, the height of the canopy was lower in paddocks maintained with a forage allowance of 2.0 kg GFM/kg LW and higher in those with a forage allowance of 3.0 kg GFM/kg LW; these did not differ from paddocks with a forage allowance of 2.5 kg GFM/kg LW. In pastures managed for 2.5- and 3.0-kg GFM/kg LW allowances, there were no changes in height as the experimental period progressed (P>0.10). Nevertheless, in the paddocks with a 2.0-kg GFM/kg LW allowance, there was a reduction in canopy height in the last experimental periods.

As mentioned above, records of pasture management were kept according to increasing grazing intensities in the rainy season of the previous year; however, during the rainy season, the canopy heights in all paddocks lowered to about 15 cm. After this procedure, the forage crop was free to grow until the start of grazing, which occurred once all paddocks had similar forage mass and height. Thus, the effect of different grazing intensities was only observed two months after the start of the study. This indicates that, in this type of study, even with the records from the previous year, there is a need for a longer period of stabilization of the sward structure. Therefore, 19 days of adaptation were not enough for the sward structure to reach equilibrium.

In pastures managed with a 2.0-kg GFM/kg LW forage allowance, the lowest height was observed with the highest stocking. Despite the gradient of forage allowance and canopy height, the range was small. Casagrande (2010), in a study on *Brachiaria brizantha* cv. Marandu under a continuous stocking system, observed that the forage allowance varied from 1.2 to 4.2 kg GFM/kg LW in swards with heights of 15 and 35 cm, respectively. These results indicate that the range of forage allowance in this study was small, which probably also determined the delay in the observation of forage allowance effects on sward structure characteristics.

The total, green and dead forage masses and the ratios of green/dead masses did not vary (P>0.10) between forage allowances or types of supplementation, nor were they influenced by any interactions involving these factors.

Table 3 - Sward canopy height (cm) of *Brachiaria brizantha* cv. Marandu grass managed with three forage allowance levels under a continuous stocking system during the rainy season

| Experimental period | Forage allowance (kg of green forage mass/kg of live weight) | | | CV, % |
|---|---|---|---|---|
| | 2.0 | 2.5 | 3.0 | |
| First | 27.8aA | 31.6aA | 31.3aA | 12.9 |
| Second | 25.2aAB | 28.3aA | 27.2aA | 9.7 |
| Third | 21.0bB | 27.0abA | 25.4aA | 14.4 |
| Fourth | 21.9bB | 27.1abA | 26.8aA | 13.8 |

Means followed by the same lower-case letter (for rows) or upper-case letter (for columns) were not significantly different according to Tukey's test at 10% probability. CV = coefficient of variation; Experimental periods: First: 12/14/2006 to 01/11/2007; Second: 01/11/2007 to 2/14/2007; Third: 02/14/2007 to 3/12/2007; Fourth: 3/12/2007 to 4/14/2007.

These variables were affected only by the experimental periods (P<0.10). The total forage mass in the second experimental period was lower than in the first; from then on, it increased as the experimental period progressed (Table 4). The reduction in total forage mass observed in the second period was due to a reduction in dead matter because the green forage mass did not differ (P>0.10) between the assessments performed during this period.

Dead matter mass in the second period was 26% lower than that observed in the first experimental period. The greater total forage masses in the third and fourth experimental periods were due to an increase in dead matter in the third period and caused reductions in the ratios between green and dead forage mass (Table 4).

In the last period, there was an increase in total forage mass, but without variation of the ratio of green/dead mass. The sharp increase in green forage mass in the assessment made in the fourth period was related to the intensification of the flowering process of *Brachiaria brizantha* cv. Marandu at the end of summer, which resulted in higher stem mass (Table 5), especially in swards managed with greater forage allowances. The greater forage masses resulted in larger quantities of residues, favoring senescence, and an increase of dead material.

The masses of leaves and the ratios of leaves/stems varied among the experimental periods (P<0.10). Ratios of leaves/stems were higher in the first two periods and decreased in the last two (Table 4). The reduction in the ratios of leaves/stems during the third period was related to the reduction in leaf mass (Table 4) and to the increase in stem mass during this period, stressing the increased forage allowance studied (Table 5). In the fourth period, there was a similar increase in the proportion of leaves and stems, which kept the percentages of these components the same in relation to the mass of green forage. The change in the sward structure in relation to the months was due to intense flowering at the end of the summer, which resulted in an increase in stem mass in the highest forage allowances (Table 5).

Stem mass varied compared with the interaction between forage allowance and experimental periods (P<0.10). In the first two periods, there were no effects of forage allowance (Table 5). In the third period, stem mass increased with increased forage allowance (P<0.10), and in the fourth period, there was greater stem mass in pastures managed with a high forage allowance, regardless of the type of feed supplement used. The increase in stem mass with the reduction of grazing intensity could be related to the

Table 4 - Total forage mass and mass of the components in *Brachiaria brizantha* cv. Marandu pastures managed with three forage allowances levels (kg of green forage mass/kg of live weight) under a continuous stocking system, including supplementation with mineral salt or an energy/protein supplement during the rainy season

| Variable | Forage allowance | | | Supplement | | Experimental period | | | | CV, % |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2.0 | 2.5 | 3.0 | Mineral salt | Protein and energy | 1st | 2nd | 3rd | 4th | |
| Forage mass (kg/ha) | 7399 | 8028 | 8285 | 7967 | 7807 | 7576b | 6702c | 7137bc | 10134a | 11.0 |
| Green forage mass (kg/ha) | 4525 | 5094 | 5588 | 5153 | 4978 | 4901b | 4729b | 4478b | 6154a | 11.8 |
| Dead forage mass (kg/ha) | 2878 | 2944 | 2647 | 2814 | 2829 | 2675b | 1973c | 2659b | 3979a | 19.5 |
| Green forage mass % | 62.1 | 64.4 | 68.2 | 65.2 | 64.6 | 64.6b | 71.3a | 63.1b | 60.5b | 7.9 |
| Dead forage mass % | 37.9 | 35.6 | 31.8 | 34.8 | 35.4 | 35.4a | 28.7b | 36.9a | 39.5a | 14.6 |
| Green/dead forage mass ratio | 1.76 | 1.95 | 2.24 | 1.98 | 1.98 | 1.89b | 2.66a | 1.78b | 1.61b | 31.2 |
| Leaf mass (kg/ha) | 2180 | 2338 | 2620 | 2474 | 2284 | 2563a | 2481a | 1823b | 2649a | 19.1 |
| Leaf mass % | 48.0 | 46.1 | 47.4 | 47.9 | 46.4 | 51.8a | 52.6a | 40.8b | 43.5b | 10.9 |
| Stem mass % | 52.0 | 53.9 | 52.6 | 52.1 | 53.6 | 48.2b | 47.4b | 59.2a | 56.5a | 9.7 |
| Ratio leaf/stem | 0.95 | 0.90 | 0.95 | 0.96 | 0.91 | 1.12a | 1.13a | 0.70b | 0.79b | 23.6 |

Means followed by the same lower-case letter per row for each analyzed factor were not significantly different according to Tukey's test at 10% probability.
CV = coefficient of variation; Experimental periods: 1st: 12/14/2006 to 01/11/2007; 2nd: 01/11/2007 to 02/14/2007; 3rd: 02/14/2007 to 3/12/2007; 4th: 3/12/2007 to 4/14/2007.

Table 5 - Stem masses of *Brachiaria brizantha* cv. Marandu pastures managed with three forage allowance levels under a continuous stocking system during the rainy season

| Experimental period | Forage allowance (kg of green forage mass/kg of live weight) | | | CV, % |
|---|---|---|---|---|
| | 2.0 | 2.5 | 3.0 | |
| First | 2276aA | 2449aB | 2290aC | 18.3 |
| Second | 2176aA | 2205aB | 2361aC | 14.6 |
| Third | 2297bA | 2606abB | 3061aB | 13.3 |
| Fourth | 2631bA | 3724aA | 4160aA | 11.7 |

Means followed by the same lower-case letter (for rows) or upper-case letter (for columns) were not significantly different according Tukey's test at 10% probability.
CV = coefficient of variation; Experimental periods: First: 12/14/2006 to 01/11/2007; Second: 01/11/2007 to 02/14/2007; Third: 02/14/2007 to 3/12/2007; Fourth: 3/12/2007 to 4/14/2007.

developmental stage of tillers. Tillers in the reproductive stage tend to present greater stem elongation in relation to those in the vegetative stage; thus, pastures with a large proportion of reproductive tillers have greater stem masses in relation to swards that have more vegetative tillers.

According to Azenha (2010), there is greater tiller renewal in swards subjected to greater grazing intensities due to the decapitation of tillers as a result of grazing. Consequently, the mean age of these swards is lower than those of swards managed with lower grazing intensities. Thus, the likelihood of finding tillers in the reproductive stage is greater in pastures with low grazing intensities (i.e., with high forage allowance). Casagrande et al. (2010), in a study on *Brachiaria brizantha* cv. Marandu under an intermittent grazing system with forage allowances that varied from 4 to 13% of LW/day, found a linear increase in stem elongation rates with increased forage allowances. Thus, stem elongation can justify the larger mass of this component in the last experimental periods with higher forage allowances. This greater stem mass helps to explain the higher sward height obtained in pastures managed with larger forage allowances in the last periods assessed (Table 3) and also the difficulty in controlling the pre-established forage allowances in the treatments with higher allowances at the end of the experimental period.

Sward characteristics did not vary (P>0.10) according to forage allowance, except for sward height and stem mass (P<0.10). Casagrande et al. (2010) found variation only in stem elongation and pasture height in a study on the same cultivar, in which mophogenetic and sward structure characteristics were assessed under forage allowances of 4 to 13 % of LW/day and intermittent grazing. The similarity of the other variables among forage allowances could be related to the small range of forage allowances studied, even when they generated stocking rates that varied from 3.7 to 5.6 AU/ha in allowances of 3.0 and 2.0 kg GFM/kg LW, respectively. Furthermore, the homogenization of sward height during the previous dry season could also be a factor related to the similarity of values obtained. As the experiment started when all the paddocks had similar forage masses and the range of forage allowances was small, it would probably be necessary to have a longer experimental period to confirm the more consistent differences. This need for a longer experimental period is due to the fact that forage allowance is not only dependent on the forage mass of the plant (i.e., forage allowance is a relationship between forage mass and stocking). Thus, to obtain initially similar forage allowance effects, there is a need for time so that higher stocking, which allows for greater forage removal per area, can affect the components that determine sward structure.

In the assessment of animal behavior, there was no effect (P>0.10) of forage allowance on grazing behavior during the assessment. On average, the animals grazed for six hours during the daytime. In this period, they had seven feedings that lasted on average 55 minutes each, which was expected because there was no effect of forage allowance on sward structure in the first experimental periods, when the behavioral assessments were performed. Thurow et al. (2009) found an effect of forage allowance on the grazing behavior of heifers in native pasture in the state of Rio Grande do Sul, Brazil. The authors concluded that the forage allowance changed the pasture structure, and as a result, the grazing time of heifers decreased with increasing forage allowances; in addition, the number of feedings increased, albeit with shorter meals. According to Carvalho & Moraes (2005), when there is forage abundance, the number of feedings is greater, and the length of each feeding is shorter.

The animals that were given energy and protein supplement grazed for 5.5 hours during the daytime. However, animals that were supplemented with mineral salt grazed 54 minutes longer than those which received the energy and protein supplement (P<0.10). The number of feedings and the time spent in each feeding did not change because of the type of supplement, forage allowance or the interaction between the two (P>0.10). When dividing the grazing time into four daytime periods, there was an effect of supplement type and hours of the day. In the late afternoon, more time was spent grazing (1.8 hours) compared with the other periods of the day, which did not differ (1.39 hours/period). In all periods of the day, the grazing time of animals given an energy and protein supplement was shorter in relation to those animals that consumed mineral salt; nevertheless, the greatest difference was observed during the period of the day when the energy and protein supplement was provided. According to Bremm et al. (2005), in a study on beef heifers, grazing time is shorter when animals are supplemented with concentrates compared with animals that are not supplemented. According to the authors, the reduction in grazing time occurs because of greater time spent at the trough, which increases with the amount of supplement provided. Bremm et al. (2008), in a study with sheep, also concluded that animals supplemented with concentrates spent less time grazing as they spent more time in the trough; however, there were no differences in bite size.

The bromatological analyses of esophageal extrusa samples did not find variation (P>0.10) in the nutritive value of the forage consumed according to the type of supplement (Table 6). The crude protein, B3 fraction of crude protein,

Table 6 - Chemical composition of esophageal extrusa samples from crossbred heifers, expressed as a percentage of dry matter, as a function of forage allowances (kg of green forage mass/kg of live weight), during the rainy season of 2008

| Variable | Forage allowance | | | Supplement | | Experimental period | | | CV, % |
|---|---|---|---|---|---|---|---|---|---|
| | 2.0 | 2.5 | 3.0 | Mineral salt | Energy and protein | 2nd | 3rd | 4th | |
| Mineral matter (% DM) | 10.6 | 9.9 | 9.5 | 10.3 | 9.7 | 8.2b | 10.7a | 11.0a | 7.9 |
| Organic matter (% DM) | 89.4 | 90.1 | 90.5 | 89.7 | 90.3 | 91.8a | 89.3b | 89.0b | 1.3 |
| Crude protein (% DM) | 11.3ab | 10.7b | 11.4a | 11.1 | 11.2 | 8.9c | 11.8b | 12.7a | 4.5 |
| Fraction of protein B3 (% CP) | 22.1b | 27.9a | 25.5ab | 25.4 | 25.0 | 32.6a | 23.3b | 19.7c | 14.0 |
| Fraction of protein C (% CP) | 14.2 | 13.3 | 12.8 | 13.6 | 13.3 | 15.0a | 12.7b | 12.7b | 15.7 |
| NDFap (% DM) | 65.4b | 67.8a | 66.1ab | 66.7 | 66.1 | 73.0a | 62.6b | 63.7b | 2.8 |
| ADF (% DM) | 37.1 | 36.9 | 36.3 | 37.2 | 36.3 | 38.7a | 33.5b | 38.1a | 5.2 |
| Lignin (% DM) | 6.7ab | 6.9a | 6.2b | 6.8 | 6.5 | 6.6 | 6.7 | 6.6 | 15.4 |

Means followed by the same lower-case letter per row for each analyzed factor were not significantly different according to Tukey's test at 10% probability.
CV = coefficient of variation; Experimental periods: 2nd: 01/11/2007 to 02/14/2007; 3rd: 02/14/2007 to 3/12/2007; 4th: 3/12/2007 to 4/14/2007.
NDFap = neutral detergent fiber corrected for ash and protein; ADF = acid detergent fiber.

neutral detergent fiber (NDFap) and lignin contents varied depending on forage allowance (P<0.10). Although the differences observed in the nutritive value of extrusa samples were significant, the magnitudes of the variations were small, at 0.7, 2.4 and 0.7 percentage points, compared with dry matter content for crude protein, NDF and lignin contents, respectively. The organic matter, acid detergent fiber and indigestible protein fraction (C fraction) contents were not affected by forage allowance (P>0.10). A detailed analysis of protein fraction in forage is necessary to formulate supplements that indicate what is limiting animal performance.

Reis et al. (2009), in a review article, showed that in many situations, the limiting factor for animal performance is the protein content in tropical forages, even in the rainy season; however, they emphasized that, in fertilized and well-managed pastures, it is not the protein content but the amount of energy that is limiting to animal performance. According to Valadares Filho et al. (2006), for a heifer with a live weight of 250 kg to gain 750 g/day, it is necessary to supply a diet with 12.7% crude protein, which is similar to what was found in this study; however, approximately 13.4% of protein is in the unavailable protein fraction (C fraction), which may result in a small deficiency of nitrogen in the diet. However, in well-managed pastures, and with more than 11% of CP in DM, it is not necessary to use supplements with high protein content, as it has been traditionally marketed. Research has shown that the use of supplements with a low protein content, around 10% of DM, lead to the same result as supplements with approximately 30% protein if the pasture is well-managed and fertilized (Correia, 2006; Vieira et al., 2010).

There was sharp improvement in the nutritive value of the forage consumed by the animals as the experimental period progressed, even with increased stem mass and reduced ratios of leaves/stems, which are characteristics that determine the selectivity of grazing animals. These facts could be justified by two factors. The first is the effect of nitrogen concentration on live leaves, because during the period of transition from summer to fall, there is a decrease in forage growth (Azenha, 2010). Pacciullo et al. (2001) also concluded that the leaf blade and the stem have a higher nutritional value in the fall compared with the summer. Another reason for the variation in nutritive value of the forage crop is the decapitation of tillers, especially reproductive tillers, which stimulates aerial tillering. Aerial tillers, when present in large quantities (rosettes), are characterized by being small, with small leaves and high nutritive value, which also justifies the decrease in the leaf/stem ratio.

The daily weight gain of heifers did not change as the forage allowance increased (P>0.10). There was also no interaction between forage allowance and supplement type or between experimental periods (P>0.10). This result is similar to that obtained for sward structure, which is a determining factor for the intake of forages by grazing animals. Poppi et al. (1987) showed the importance of non-nutritional factors on forage intake by grazing animals. In this scenario, intake is determined by factors related to sward structure and feeding behavior. As there were few differences in pasture structure among the forage allowances, it is possible that forage intake was similar between animals from different treatments. Furthermore, the variations in nutritive value, which can also interfere with animal performance, were reduced as a result of forage allowances. Therefore, individual performance was not affected.

With the use of an energy/protein supplement, the daily live weight gain per animal increased 175 g/day on average compared with the use of mineral salt (Table 7). The increase in weight gain varied from 90 g/day when forage allowance was 2.0 kg GFM/kg LW to 225 g/day when the animals were kept in pastures managed with 3.0 kg GFM/kg LW. Therefore, with the use of an energy/protein supplement, even in the

Table 7 - Initial and final live weight and performances of crossbred heifers kept in *Brachiaria brizantha* cv. Marandu pastures managed with three forage allowance levels (kg of green forage mass/kg of live weight) and receiving different types of supplementation during the rainy season

| Variable | Forage allowance | | | Supplement | | Experimental period | | | | CV, % |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2.0 | 2.5 | 3.0 | Mineral salt | Protein and energy | 1st | 2nd | 3rd | 4th | |
| Initial live weight (kg) | 214 | 213 | 219 | 216 | 215 | - | - | - | - | 2.5 |
| Final live weight (kg) | 277 | 280 | 292 | 272b | 294a | - | - | - | - | 4.2 |
| Live weight gain (g/day) | 529 | 567 | 638 | 490b | 665a | 769a | 600b | 562b | 380c | 24.4 |
| Stocking rate (AU/ha) | 5.6a | 4.3b | 3.7b | 4.6 | 4.4 | 4.3 | 4.6 | 4.6 | 4.6 | 12.5 |
| Live weight gain per area (kg/ha) | 647a | 543ab | 505b | 509b | 621a | 185a | 173a | 114b | 94b | 34.1 |

Means followed by the same lower-case letter per row for each analyzed factor were not significantly different according to Tukey's test at 10% probability.
CV = coefficient of variation; Experimental periods: 1st: 12/14/2006 to 01/11/2007; 2nd: 01/11/2007 to 02/14/2007; 3rd: 02/14/2007 to 3/12/2007; 4th: 3/12/2007 to 4/14/2007.

rainy period, the individual performances of animals improved, with the possibility of gains of up to 27 kg per animal during the rainy season, which may contribute to reducing the time and age of animals at slaughter. As the experimental period progressed, there were consistent reductions in the individual performances of animals. An opposite effect was observed for the nutritive values of the forages consumed. This seemingly disparate result was probably related to sward structure changes throughout the experimental period, with the formation of large quantities of aerial tillers and low leaf/stem ratios, which make harvesting the forages more difficult for animals. The difficulty in harvesting forage results in smaller bites, which can reduce intake, and consequently, weight gain. Euclides et al. (2008), in a study on three cultivars of *Brachiaria brizantha* (cv. Piatã, Xaraés and Marandu), concluded that the structural characteristics are more important than nutritive value in the control of animal weight gain.

The stocking rate increased 51% (P<0.10) with the reduction of forage allowance from 3.0 to 2.0 kg GFM/kg LW (Table 7). Oliveira (2010) also observed an increase in the stocking rate as forage allowance was reduced from 2.5 to 1.5 kg GFM/kg LW. There was no effect of supplement type, experimental period or the interaction among the factors studied on stocking rate (P>0.10), which did not vary throughout the experimental period if measured in animal units per hectare (P>0.10). Due to the stocking rate and the daily weight gain of animals, the live weight gain per grazing area was greater in pastures with 2.0 kg GFM/kg LW compared with those with 3.0 kg GFM/kg LW, since that the stocking rate was greater under these conditions and that the weight gain did not vary as a function of forage allowance. The live weight gain per area in pastures with 2.5 kg GFM/kg LW did not differ from pastures maintained with 2.0 and 3.0 kg GFM/kg LW.

Live weight gain per grazing area was greater during the first period and decreased as the experimental phase progressed, reflecting individual weight gains. The possible interactions between forage allowance, supplement type and experimental period were not significant (P>0.10). However, live weight gain per area was also higher in paddocks where the animals were given an energy/protein supplement compared with animals supplemented with mineral salt (P<0.10). As the animals that received the energy and protein supplement gained more weight daily, and there was no variation in the number of animals per hectare as a function of supplement type, productivity was higher with the use of protein and energy supplements during the rainy period.

## Conclusions

Sward canopy height and stem mass are the sward structure characteristics most affected by forage allowance. In pastures managed with different forage allowances, the sward structure is not changed with the use of dietary supplements. The use of energy/protein supplements results in a reduction in the time spent grazing, but allows for increased individual live weight gains and gains per area during the rainy season. This technique is recommended to enhance animal production under grazing systems. Among the forage allowances studied, the level of 2.0 kg of green forage mass/kg of live weight must be used, as it provides higher stocking rates without impairing individual animal performances.

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