# Supplementation for beef cattle on Marandu grass pastures with different herbage allowances

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**Abstract.** The objective of this study was to evaluate the performance of beef heifers on Stapf. cv. Marandu grass pastures that were managed at three herbage allowances under continuous grazing with a variable stocking rate and were provided with mineral mix supplement or supplements with energy and protein. Seventy-two test heifers and 48 put-and-take heifers were used in a randomised design in a $3 \times 2$ factorial arrangement [three herbage allowances (1.5, 2.0, and 2.5 kg of green dry matter/kg of bodyweight, and two supplementation levels (mineral mix or 0.3% bodyweight of a mineral–protein–energy supplement)], with two replicates per treatment (paddocks), to maintain the pre-established forage allowance. No significant difference was observed in the gain per hectare as a function of the herbage allowance, but 2.5 kg green dry matter/kg bodyweight provided the greatest average daily gain of bodyweight (0.605 kg/animal/day). The energy/protein supplementation provided the greatest average daily gain compared with animals fed only the mineral mix. The supplements in the diet of beef heifers fed at 0.3% of bodyweight increased bodyweight gains without compromising the gain per hectare at different herbage allowances.

**Additional keywords:** continuous grazing, heifers, performance, productivity.

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## Introduction

*Brachiaria brantha* (Hochst.) Stapf. cv. Marandu (Marandu grass) is the most widely cultivated forage plant in Brazil and plays a key role in pasture-based systems. However, due to its production potential, the productivity, efficiency and sustainability of its use in production systems falls short of its optimal potential, especially due to inappropriate pasture management.

Herbage intake is the main factor affecting animal performance, and it is closely related to the herbage allowance and sward structure (Da Silva *et al.* 2013). An increase in herbage allowance can promote increased individual performance, but when the stocking rate is reduced, the production per area decreases (Reis *et al.* 2013).

Recent studies with tropical grasses have confirmed that the management strategy based on monitoring the availability and controlling the sward height generates highly consistent relationships between the responses of the forage plant and animals, which increases the understanding of the effects of sward-structure variations on the production and persistency of plants (Barbosa *et al.* 2007) and on animal performance (Casagrande *et al.* 2011).

Distinct grazing heights or herbage allowances, developmental stages and herbage-production seasonality modify the structure and, consequently, the quality of a pasture. Studies evaluating the intake and performance of grazing animals with different herbage allowances require descriptions of the availabilities and structural conditions of pastures for the interpretation and comparison of results (Gontijo Neto *et al.* 2006).

According to Moore *et al.* (1999), the use of supplements can result in changes of forage dry matter (DM) intake. Casagrande *et al.* (2011) suggests there has been a great interest in adjusting the pasture production system through supplementation, and supplementation has been used in the dry/rainy season transition as an option to provide limiting nutrients and to increase the efficiency of pasture utilisation, which ultimately increases productivity.

The hypothesis of this study was that providing an energy/protein supplement for beef heifers during the rainy season and rainy/dry season transition can improve their performance compared with animals fed only a mineral mix without compromising the productivity per hectare on Marandu pastures using different herbage allowances under continuous grazing.

## Materials and methods

### Geographic location and experimental period

The study was conducted during the rainy season, from January to May, with January as a period of adaptation and February,

March and April as Periods 1, 2 and 3, respectively. These pastures belonged to the Department of Animal Science of the Faculty of Agricultural and Veterinary Sciences at São Paulo State University, located in Jaboticabal/SP, Brazil, (21°15′22″S latitude, 48°18′58″W longitude and 595-m elevation). The *Brachiaria brizantha* (Hochst ex A. Rich) Stapf cv. Marandu pastures were established in 2001 in a Hapludox soil type. The climate in Jaboticabal City is a subtropical Awa type, with rainy summers and dry winters (Table 1).

The following chemical characteristics of the soil (upper layer, 0–20 cm) were: pH, 5.1; organic matter, 22.5 g/DM$^3$; phosphorus in resin, 8.8 g/DM$^3$; potassium, 2.3 mmol$_c$/DM$^3$; calcium, 13.6 mmol$_c$/DM$^3$; magnesium, 9.7 mmol$_c$/DM$^3$; H$^+$Al, 25.2 mmol$_c$/DM$^3$; sum of bases, 26.1 mmol$_c$/DM$^3$; CEC, 50.9 mmol$_c$/DM$^3$, at pH 7 (T); and base saturation of 51.5%. Based on this soil analysis, maintenance fertilisation for Marandu grass was performed in January by applying 200 and 160 kg ha$^{-1}$ year$^{-1}$ of N and K$_2$O in the forms of urea and potassium chloride.

The experimental area consisted of a 12-ha pasture, which was divided into 12 paddocks of 1.3, 1.0 and 0.7 ha; the treatments with the lowest herbage allowance were installed in the smallest paddocks, and vice versa. The size of each paddock was modified so that the number of animals tested in them was similar to avoid interference with grazing behaviour. In addition, a reserve area of 8 ha was allocated to the animals used to control the forage allowance.

### Animals and grazing method

Six test animals were used in each paddock, totalling 72 experimental heifers. In addition to these, 48 heifers were used to control the stocking rate (put-and-take) and to maintain the pre-established herbage allowance in the treatments. Crossbred heifers (Santa Gertrudis × Nellore cows and Braunvieh bulls) were ~7 months old with an initial bodyweight (BW) of 200 kg that were from the same farm. At the beginning of the experiment, the animals were weighed and randomly distributed across the treatments and endo- and ecto-parasites were controlled at that time. Animal performance was determined by weighing them at time zero (after an adaptation period of 18 days) and subsequently every 28 days thereafter, always after a previous solid- and liquid-deprivation period of 15 h.

The grazing method utilised was continuous grazing with a variable stocking rate, using beef heifers in the growth phase. The number of heifers was adjusted every fortnight according to the BW of the animals in each paddock in relation to the herbage mass. This was done to maintain the herbage allowance, according to the method of Sollenberger and Cherney (1995) with the following formula: herbage allowance [kg green dry matter (GDM)/kg BW] = green mass (kg/ha)/BW (kg/ha). Of the heifers present in each paddock, six were considered test animals that had an average daily gain that was estimated. The BW gain per hectare was estimated as the product of the average daily gain of the tested heifers by the stocking rate of the paddock, expressed as days-heifer/ha.

### Experimental treatments

The treatments were arranged in a 3 × 2 factorial design, i.e. three herbage allowances (1.5, 2.0 and 2.5 kg GDM kg$^{-1}$ of BW) (Sollenberger and Cherney 1995) with two types of supplementation (mineral–protein–energy supplement or mineral salt), with two replicates, totalling 12 paddocks. The protein–energy supplement contained 25% crude protein (CP) and 67% total digestible nutrients (TDN) and was composed of citrus pulp (51.2%), cottonseed meal with 38% CP (38.96%), urea (2.69%) and minerals (7.27%), and the other was a mineral mix, both of which were provided by a commercial enterprise (Table 2). Supplements were supplied daily at 1400 hours in a fashion that did not interfere with the grazing behaviour of the animals; the protein–energy supplement was offered at an amount of 0.3% BW day$^{-1}$, and the mineral mix was available *ad libitum* (~50 g animal$^{-1}$ day$^{-1}$).

### Herbage quantitative analyses

Total herbage mass was evaluated throughout the experimental period using a double-sampling technique (Sollenberger and Cherney 1995), in which destructive sward-height readings were taken using the rising-plate technique. Total herbage mass was estimated by a regression equation with the plant height compressed, as evaluated from a cut made at the soil level. The cut area corresponded to the dimensions of the rising plate, i.e. 0.246 m$^2$ of area, using iron rings.

Fifty readings were randomly taken using the height-compressed sward samples, in addition to another five

**Table 1.    Meteorological data during the rainy and rainy/dry season transition corresponding to the period that affects the experimental data in Jaboticabal, São Paulo, Brazil**

MaxT, maximum temperature; MinT, minimum temperature; MeanT, mean temperature; RH, relative air humidity; ND, number of days with rain. Source: Agrometeorological Station of the Department of Exact Sciences of FCAV/UNESP

| Month | MaxT°C | MinT°C | MeanT°C | RH% | Precipitation mm | ND | Insolation hours |
|---|---|---|---|---|---|---|---|
| November | 31.4 | 18.8 | 24.3 | 67.6 | 41.7 | 7 | 220.2 |
| December | 29.5 | 19.2 | 23.5 | 77.7 | 242.6 | 19 | 204.3 |
| January | 31.3 | 20.3 | 25.0 | 74.7 | 237.0 | 18 | 236.0 |
| February | 30.7 | 20.3 | 24.2 | 82.9 | 416.4 | 15 | 181.1 |
| March | 31.0 | 20.4 | 24.5 | 81.4 | 136.9 | 16 | 221.0 |
| April | 29.5 | 17.2 | 22.4 | 74.8 | 10.4 | 4 | 255.2 |
| May | 26.6 | 12.8 | 18.7 | 70.1 | 4.0 | 3 | 249.4 |

| Component | Mineral–protein–energy supplement | Mineral mix |
|---|---|---|
| *Analysed* | | |
| Crude protein (%) | 25.3 | – |
| NDF (%) | 17.3 | – |
| ADF (%) | 15.8 | – |
| Lignin (%) | 4.2 | – |
| IVOMD (%) | 76.0 | – |
| *Guaranteed levels* | | |
| Sodium (g/kg) | 13 | 13 |
| Calcium (%) | 2.3 | 15.85 |
| Phosphorus (%) | 0.6 | 7.81 |
| Sulfur (g/kg) | 3 | 40 |
| Zinc (mg/kg) | 148 | 5000 |
| Copper (mg/kg) | 40 | 1350 |
| Manganese (mg/kg) | 30 | 1040 |
| Iodine (mg/kg) | 3 | 100 |
| Cobalt (mg/kg) | 2.4 | 80 |
| Selenium (mg/kg) | 0.8 | 26 |
| Monensin (mg/kg) | 80 | 0 |

readings at points with greater and lower sward heights, the herbage of which was collected at the soil level according to the border limits of the disk. The average total herbage mass was estimated from the adjusted linear regression between height and dry weight of the 10 herbage samples harvested and from the average of the readings randomly taken in each paddock. In the first and last destructive sampling, samples were collected to estimate the available quantities of leaf and stem.

*Herbage qualitative analyses*

Forage chemical composition was estimated in monthly samplings with extrusa samples. One esophageal-cannulated Nellore animal (500 kg of BW) was fitted with a screen-bottom fabric collection bags that were used to drain the excess saliva. On the day before collection, the animal was deprived of solid food for ~12 h. On the collection days, the oesophageal cannula was removed and the collection bag was placed. The animal was monitored for 20 min, without interference to its grazing behaviour. At the end of the sampling period, the bag was removed and the extrusa sample was homogenised and dried in an oven at 55°C for 72 h and was then processed in a Wiley mill with a 1-mm mesh sieve.

The CP content was determined using the Kjeldahl method (Association of Official Analytical Chemists - AOAC 1990). The neutral detergent fibre (NDF) and acid detergent fibre (ADF) content were determined using the analytical techniques described by Mertens (2002), except for the use of polyester filter bags (25-µ porosity). The lignin was determined by the solubilisation of cellulose with sulfuric acid according to the methods of Van Soest and Robertson (1985). The fractionation of N compounds (fraction A) was determined following the methodology of Licitra *et al*. (1996), and the N fractions

N-NDF ($B_3$) and N-ADF (C) were determined by the system proposed by the Cornell Net Carbohydrate and Protein System, according to Sniffen *et al*. (1992).

A gas production analysis, to determine the *in vitro* DM digestibility, and the TDN were performed according to the methodology used by Theodorou *et al*. (1994) and modified by Mauricio *et al*. (1999).

The incubation period was 72 h, in which pressure readings were taken at 2, 4, 6, 8, 10, 12, 24, 26, 28, 30, 32, 36, 48, 52, 56, 60 and 72 h of incubation. The results were corrected for the blank (a bottle containing a buffered rumen solution, without a sample) and for the standard (Tifton 85 grass hay) at 24 h of incubation, and together with the levels of the chemical components of the feed (ash, protein and ether extract), they were used to predict the energy value and the *in vitro* organic matter digestibility of the incubated samples.

The data pertaining to pressure readings (psi) were converted to volume (mL) by the equation described below, which was obtained with pressure readings from different known amounts of gas volumes in the bottles and was maintained at the same temperature conditions as in the incubation (Mota *et al*. 2005):

$$Y = 5.5452 \times -0.1569,$$

where $Y$ is the gas volume (mL) and $\times$ is the pressure (psi).

The *in vitro* organic matter digestibility (IVOMD) and metabolisable energy (ME) were calculated using the equations recommended by Menke and Steingass (1988):

$$ME \ (MJ/kg \ DM) = 2.20 + (0.136 * gas24) + (0.0057 * CP) + (0.00029 * EE) \ and$$

$$IVOMD \ (g/kg \ DM) = 14.88 + (0.889 * gas24) + (0.045 * CP) + (0.065 * MM),$$

where gas24 is the gas production *in vitro* during 24 h of incubation (mL/0.2 g DM); the CP, ether extract (EE) and mineral matter (MM) values are expressed as g/kg DM.

Subsequently, all these values were converted to TDN using the following equations recommended by the National Research Council (NRC) (2001);

$$DE \ (Mcal/kg \ DM) = ME/0.82$$

$$TDN \ (\%) = DE/4.409 * 100.$$

*Experimental design and statistical analyses*

The experimental design was randomised blocks with two replicates in a $3 \times 2$ factorial arrangement with three herbage allowances (1.5, 2.0 and 2.5 kg GDM/kg of BW) and two supplementation types (mineral mix and mineral–protein–energy supplement). The statistical analysis was performed in a randomised block design with measures repeated over time (months), using the PROC MIXED procedure of the SAS (SAS Institute 2002) statistical package. The best covariance structure was chosen using the minimum Schwarz's Bayesian Criterion value as a criterion. Regression analysis was used to compare the herbage allowance, and the means were compared ($P < 0.10$) for the effects of the period, supplementation and interactions between the factors under study.
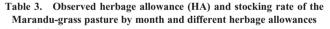
## Results

During the adaptation period and Period 1, the herbage allowances observed were close to the pre-established values; however, as the experiment progressed, it was not possible to maintain the desired herbage allowances of 1.5, 2.0 and 2.5 kg GDM/kg BW, especially during the final experimental period (Table 3). The analysis and interpretation was based on the forage allowance pre-established, because although there have been changes during the experimental periods, we cannot rule that such changes are the result of pre-established treatments. The stocking rates varied according to the interaction between herbage allowance and the studied months ($P < 0.10$). The greatest stocking rates were obtained at the lowest herbage allowance, which were reduced in accordance with the increase in forage availability. There was no difference between the herbage allowances of 2.0 and 2.5 kg GDM/kg BW in the third period.

The sward height was affected by the interaction between the evaluated months and the herbage allowance ($P < 0.10$). In February, the greatest height was obtained in the pastures managed with the lowest herbage allowance (Table 4). In the following month, there was an inversion, with the lowest height observed in the pastures managed under the lowest herbage allowance. Comparing the first 2 months evaluated, it was observed that the sward height decreased by 13.5 cm in pastures with lower forage availability, whereas in those managed with 2.0 and 2.5 kg GDM/kg BW, the sward height decreased by 5.1 and 5.3 cm, respectively. No difference between the herbage allowances was found in April, and the lowest height was also observed during this month, which is a direct reflection of the observed climatic conditions (Table 1).

Herbage chemical composition data are described in Tables 5 and 6. No differences were found for the chemical composition of the herbage; however, during the experimental period, the lowest CP value was 8.38, which was observed in April. This was due to the greater proportion of dead material observed in the forage harvested in that period.

Table 7 shows the average animal gains per area and per animal according to the herbage allowances and supplementations. No significant difference was observed for the gain per area according to the herbage allowance. However, it should be noted that the gain per area at the lowest forage

availability (1.5 kg GDM/kg BW) in February was greater in the two levels of supplementation in relation to the other forage allowance treatments. This occurred during the period of greatest leaf mass and green material.

Supplementation in the rainy season at moderate levels (0.3% of BW) enabled greater weight gains compared with

**Table 4. Herbage mass and sward structure of Marandu grass pasture in different periods and with different herbage allowances (HA)**
Means followed by the same lowercase letter in the row and uppercase letter in the column do not differ by a *t*-test ($P < 0.10$)

| Month | Intended HA | | |
|---|---|---|---|
| | 1.5 | 2.0 | 2.5 |
| | *Fresh herbage mass (kg/ha)* | | |
| January | 4868Aa | 4223Ab | 4526Aab |
| February | 3791Ba | 4167Aa | 3975Ba |
| March | 3005Cb | 3595Ba | 3283Cab |
| | *Height (cm)* | | |
| January | 27.4Aa | 23.6Ab | 23.3Ab |
| February | 13.9Bb | 18.5Ba | 18.0Ba |
| March | 13.3Ba | 16.5Ba | 15.8Ba |
| | *Leaf (kg/ha)* | | |
| January | 2332Aab | 2140Ab | 2434Aa |
| February | 1135Bb | 1409Ba | 1336Bab |
| | *Stem (kg/ha)* | | |
| January | 2536Aa | 2084Ab | 2092Ab |
| February | 1870Bb | 2186Aa | 1862Ab |

**Table 5. Mean data for crude protein (CP) and fractionation of the protein from extrusa of cattle on *Brachiaria brizantha* cv. Marandu pastures under continuous grazing with different herbage allowances (HA) and supplementation**
CP is expressed as the percentage of dry matter

| Month | HA | CP | CP fractions (% CP) | | | |
|---|---|---|---|---|---|---|
| | | | A | B1 + B2 | B3 | C |
| | | | *Mineral* | | | |
| January | 1.5 | 12.09 | 30.14 | 17.99 | 35.63 | 16.24 |
| | 2.0 | 12.27 | 32.18 | 28.33 | 22.94 | 16.55 |
| | 2.5 | 11.59 | 28.93 | 31.62 | 26.23 | 13.22 |
| February | 1.5 | 8.59 | 27.17 | 18.13 | 35.16 | 19.54 |
| | 2.0 | 8.54 | 35.71 | 21.64 | 21.51 | 21.14 |
| | 2.5 | 8.78 | 35.67 | 18.98 | 27.69 | 17.66 |
| March | 1.5 | 9.25 | 34.91 | 28.60 | 22.18 | 14.31 |
| | 2.0 | 8.38 | 26.72 | 29.97 | 27.68 | 15.63 |
| | 2.5 | 9.43 | 34.38 | 27.70 | 25.23 | 12.69 |
| | | | *Mineral–protein–energy supplement* | | | |
| January | 1.5 | 10.81 | 33.04 | 24.66 | 28.15 | 14.15 |
| | 2.0 | 11.34 | 27.45 | 24.41 | 31.34 | 16.80 |
| | 2.5 | 10.11 | 23.25 | 30.02 | 27.51 | 19.22 |
| February | 1.5 | 9.26 | 29.80 | 15.61 | 33.96 | 20.63 |
| | 2.0 | 9.87 | 27.83 | 25.51 | 31.70 | 14.96 |
| | 2.5 | 8.60 | 27.21 | 25.64 | 29.15 | 18.00 |
| March | 1.5 | 8.67 | 37.61 | 25.29 | 17.55 | 19.54 |
| | 2.0 | 9.19 | 28.51 | 26.59 | 31.92 | 12.98 |
| | 2.5 | 10.08 | 25.54 | 33.34 | 28.37 | 12.75 |

**Table 3. Observed herbage allowance (HA) and stocking rate of the Marandu-grass pasture by month and different herbage allowances**
Means followed by the same lowercase letter in the row and uppercase letter in the column (stocking rate) do not differ by a *t*-test ($P < 0.10$)

| Month | Intended HA | | |
|---|---|---|---|
| | 1.5 | 2.0 | 2.5 |
| | *Observed HA (kg FDM/kg BW)* | | |
| January | 1.68 | 1.82 | 2.47 |
| February | 1.45 | 1.75 | 2.01 |
| March | 1.29 | 1.82 | 1.62 |
| | *Stocking rate (AU/ha)* | | |
| January | 6.43Aa | 5.17Ab | 4.06Ac |
| February | 5.81Ba | 5.27Ab | 4.38Ac |
| March | 5.16Ca | 4.39Bb | 4.49Ab |

**Table 6. Mean values of neutral detergent fibre (NDF), acid detergent fibre (ADF), lignin (LIG), hemicellulose (HEM), cellulose (CEL), *in vitro* organic matter digestibility (IVOMD) and total digestible nutrients (TDN) of the extrusa of cattle on *Brachiaria brizantha* cv. Marandu pastures with continuous stocking rate and different herbage allowances (HA) and supplementations**

Data are expressed as the percentage of dry matter

| Month | HA | NDF | ADF | LIG | HEM | CEL | IVOMD | TDN |
|---|---|---|---|---|---|---|---|---|
| | | | | *Mineral mix* | | | | |
| January | 1.5 | 68.38 | 38.78 | 4.94 | 29.60 | 32.77 | 65.85 | 60.86 |
| | 2.0 | 71.55 | 41.08 | 5.48 | 30.46 | 34.00 | 68.25 | 63.61 |
| | 2.5 | 63.37 | 34.63 | 4.44 | 28.75 | 29.36 | 67.97 | 62.04 |
| February | 1.5 | 67.58 | 43.40 | 5.02 | 24.18 | 37.13 | 68.40 | 64.55 |
| | 2.0 | 67.18 | 41.55 | 4.68 | 25.64 | 36.35 | 70.64 | 65.02 |
| | 2.5 | 71.79 | 33.60 | 2.85 | 38.19 | 30.05 | 73.69 | 68.92 |
| March | 1.5 | 66.04 | 34.58 | 4.02 | 31.46 | 30.00 | 64.68 | 62.70 |
| | 2.0 | 66.99 | 37.19 | 4.28 | 29.81 | 32.75 | 65.06 | 63.70 |
| | 2.5 | 66.46 | 34.16 | 4.00 | 32.30 | 29.83 | 65.74 | 63.13 |
| | | | | *Mineral–protein–energy* | | | | |
| January | 1.5 | 68.18 | 36.40 | 4.70 | 31.78 | 30.78 | 66.93 | 60.42 |
| | 2.0 | 67.80 | 31.84 | 4.84 | 35.97 | 26.51 | 70.07 | 68.19 |
| | 2.5 | 67.98 | 35.22 | 4.80 | 32.76 | 29.57 | 66.61 | 62.41 |
| February | 1.5 | 67.64 | 37.56 | 4.50 | 30.09 | 32.14 | 71.21 | 64.84 |
| | 2.0 | 66.06 | 40.44 | 4.37 | 25.62 | 35.29 | 70.43 | 68.84 |
| | 2.5 | 67.48 | 42.97 | 5.16 | 24.51 | 37.61 | 65.89 | 62.55 |
| March | 1.5 | 67.07 | 40.31 | 5.68 | 26.76 | 33.68 | 70.87 | 60.81 |
| | 2.0 | 63.36 | 38.61 | 5.99 | 24.75 | 31.35 | 72.23 | 63.71 |
| | 2.5 | 63.85 | 41.23 | 4.85 | 22.62 | 36.14 | 64.49 | 59.92 |

**Table 7. Weight gain per hectare (kg/ha) and weight gain per animal (kg/animal.day) by heifers on Marandu pastures with different herbage allowances, in different periods, with different supplements**

Means followed by the same lowercase letter to evaluate the effect of supplement and for period effect do not differ by Tukey's test at 10% probability. Mineral, mineral mix; multiple, multiple supplements (mineral, protein and energy)

| Supplementation | Herbage allowance | January | February | March | Mean |
|---|---|---|---|---|---|
| | | | Month | | |
| Mineral | 1.5 | 263.47 | 48.54 | 23.13 | 348.8b |
| | 2.0 | 209.65 | 97.80 | 58.67 | |
| | 2.5 | 176.67 | 75.32 | 93.34 | |
| Multiple | 1.5 | 314.55 | 120.16 | 140.66 | 513.8a |
| | 2.0 | 257.15 | 155.13 | 96.67 | |
| | 2.5 | 242.26 | 113.29 | 101.57 | |
| Mean | – | 243.9A | 101.7B | 85.7B | – |
| | | *Herbage* | | | |
| | | 1.5 | 2.0 | 2.5 | – |
| Average daily gain | | 0.461b | 0.524ab | 0.605a | – |
| | Herbage allowance | January | February | March | Mean |
| | | | Month | | |
| Mineral | 1.5 | 0.672 | 0.160 | 0.083 | 0.423b |
| | 2.0 | 0.693 | 0.300 | 0.234 | |
| | 2.5 | 0.822 | 0.367 | 0.474 | |
| Multiple | 1.5 | 0.920 | 0.418 | 0.513 | 0.637a |
| | 2.0 | 0.880 | 0.551 | 0.487 | |
| | 2.5 | 1.020 | 0.462 | 0.480 | |
| Mean | – | 0.835A | 0.376B | 0.378B | – |

those observed in animals that were fed only the mineral mix. A significant difference was observed between the herbage allowance on the average daily weight gain, with the highest value achieved with 2.5 kg GDM/kg BW (0.605 kg/animal.day).

## Discussion

The herbage allowances that were lower than the pre-established values, in some periods, were a reflection of the climatic conditions, which varied over the course of the experiment (Table 1). Precipitation decreased sharply in March and especially April, reducing the development of the forage plants. Another contributing factor might have been that the stocking rate was controlled every 15 days. The herbage accumulation rate is determined by climatic conditions; thus, small variations immediately interfere with the growth of the forage plants, and these may not have been detected, hindering the control of the desired factors. Therefore, adjustments to stocking rates should be made in shorter time intervals.

These factors influence the search for more efficient parameters for grazing management. Measuring light interception can be used as a criterion of pasture management, but this is a complicated practice under field conditions and requires specific machinery (a photometer or sward analyser). However, the results for the forage sward height during the experimental period indicate that this is a parameter that could be adopted. According to Da Silva *et al.* (2013), evaluations of tropical pastures using grazing height can be employed consistently.

Overall, the responses of forage plants from temperate, tropical and subtropical climates can follow similar paths, which are conditioned and determined by variations in the structure of the forage sward. These variations are within considerable amplitudes of pasture conditions that can be maintained in practice according to variable management strategies with continuous or intermittent grazing, with no damage to the agronomic performance of the forage plants (persistence and production of herbage).

In a study on growing Nellore and Canchim breeds grazing on Marandu grass pastures, Da Silva *et al.* (2013) obtained optimal intake values, weight gain per animal and weight gain per hectare in a pasture maintained at 30 and 40 cm. Additionally, according to those authors, in a continuous grazing system, Marandu grass pastures can be maintained at between 20 and 40 cm high, and the greatest weight gain per area unit occurs at ~30 cm for growing animals, which is consistent with the values indicated for Xaraes grass (*Brachiaria brizantha* cv. Xaraés).

No differences were observed in the herbage chemical composition, although it should be mentioned that the composition was evaluated based on an extrusa sample and that greater herbage allowances make it easier to select and ingest (leaf over stem and green material over dead material). Therefore, it can be affirmed that the differences in weight gain are a result of differences in the quantitative variables. NDF contents in the extrusa samples were between 63.36% and

71.79% during the experimental period and were lower than those reported by Zervoudakis *et al.* (2002) in samples of Marandu grass (72.5%) in an intermittent grazing system during the rainy season (Table 5). ADF contents varied from 31.84% to 42.97%, which is similar to the values reported by Canesin *et al.* (2007) in simulated-grazing samples of Marandu grass and in whole-plant samples (40.3%).

Non-protein N levels obtained herein corresponded to 30.54% of the total N, on average (Table 5), and may be attributed to the contribution of the non-protein N from the herbage itself, which is a typical situation in tropical grasses in periods directly following the occurrence of rainfall (Poppi and McLennan 1995).

In the present study, the digestibility values were satisfactory for the appropriate performance of grazing animals. Hernandez *et al.* (1995) observed similar values in extrusa samples of Marandu under an intermittent stocking rate (66.2%). However, Bittencourt and Veiga (2001) observed a digestibility of 53.3% to 57.5% in leaves of Marandu grass under intermittent grazing. Euclides *et al.* (1993) found a digestibility of 58.7% in samples of leaves of the same cultivar during the rainy season.

According to the data available in the literature (Poppi and McLennan 1995; Moore *et al.* 1999), the supply of readily available energy can minimise the N losses of the herbage due to the greater synchronism between the availability of energy and ammonia in the rumen, which results in an increase in the microbial protein synthesis. Conversely, supplementation with low rumen degradation protein enables the absorption of amino acids in the intestine, resulting in a positive effect on herbage intake and animal performance (Siebert and Hunter 1982).

The supply of bypass protein via supplements for beef cattle on pastures may improve animal performance, even in situations where the herbage meets the N requirement for microbial protein synthesis. It can be inferred that the supplement offered to the animals consuming herbage with this concentration of fraction A should present low protein and high energy values or a greater proportion supply of rumen undegradable protein, leading to an increase in microbial synthesis (Poppi and McLennan 1995).

Supplementing the diet for grazing cattle may result in excess N, and in such situations, performance has a greater correlation with energy uptake (Detmann *et al.* 2014). It should be stressed that during the entire experimental period, the observed CP values were above the critical limit for the proper function of the rumen in all treatments, which in tropical grasses diets is between 6.0% and 7.0% CP (Minson 1990).

According to Poppi and McLennan (1995), CP/DOM (digestible organic matter) ratios above 210 result in N losses by the animal. In contrast, 160 g CP/kg DOM provides optimal conditions for the synthesis of microbial protein, and 130 g CP/kg DOM results in a deficiency. In the present study, the ratios between CP and DOM in the herbage were 168, 128 and 137 g CP/kg DOM for February, March and April, respectively. Based on the calculated values, it can be inferred that the ratios were not appropriate to maximise the synthesis of microbial protein in March and April.

The improvement in performance as herbage allowance increases may continue until it is stable for more generous herbage allowances. However, the gain per area tends to decrease with medium-to-high herbage allowances. In February, when there was greater availability of green forage, the animals presented a greater weight gain, both per area and per animal. From March, when there was a reduction in green material availability, the animals showed a decrease in weight gain. It is noteworthy that even in March and April the observed weight gains were satisfactory for the studied systems. Another factor that should be taken into account is that even at the lowest availability (1.5 kg GDM/kg BW) animals are able to select and ingest the green leaves.

Supplementation during the rainy season at moderate levels, as utilised in this study (0.3% BW), can promote changes in the displacement of curves of individual weight gain and gain per area above those observed in the unsupplemented animals. This finding cannot be attributed to the substitutive-associative effect, which would affect the weight gain of the animals and the stocking rate according to the substitution of the intake of herbage as a concentrate, but rather to an increase in weight gain that is consequently reflected in the gain per area. There is a consensus in the literature that supplementation up to this level is not substitutive but is associative or has combination effects. Therefore, it can be inferred that strategic supplementation can elevate the animal weight gain and gain per area simultaneously.

## Conclusions

Supplying an additional energy and protein source in the diet of beef heifers during the rainy season and the rainy-dry season transition, at the rate of 0.3% of BW, provides a greater weight gain and greater production per hectare, simultaneously, compared with animals receiving only a mineral mix, regardless of the herbage allowance.

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