# The effect of residual nitrogen fertilization on the yield components, forage quality, and performance of beef cattle fed on Mombaça grass

## Efecto residual de la fertilización nitrogenada sobre los componentes de la producción, la calidad de forraje y la performance del ganado de carne en la gramínea mombaça

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### ABSTRACT

The objective of this study was to evaluate the effect of residual nitrogen (N) on pastures of Mombaça grass and its impact on pasture structure and the nutritive value and performance of beef cattle. The experiment analyzed randomized blocks subdivided into plots, with three replications. The research focused on a number of pastures having received three annual doses of N (100, 200 and 300 kg ha$^{-1}$) from 2015 to 2017, with no N fertilization in 2018. The results indicated that pastures under residual effect of 300 kg ha$^{-1}$ of N were characterized by higher ($P<0.05$) rates of forage accumulation than those under the residual effect of 100 kg ha$^{-1}$ N. Furthermore, this study indicated no effect ($P>0.05$) on the pasture nutritive value and average daily gain (0.490 kg day$^{-1}$). The stocking rate was higher ($P<0.05$) in pastures under the residual effect of 300 kg ha$^{-1}$ of N, and lower in those at 100 kg ha$^{-1}$ of N, while weight gain per area followed the trend observed in the stocking rate. The results thus suggest that the suspension of N fertilization for one year after three years of sequential fertilization was responsible for an immediate loss of 50 and 55% of the productivity of plants and animals, respectively.

### Keywords
pasture fertilization • forage accumulation • *Panicum maximum* • stocking rate

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## Resumen

El objetivo fue evaluar el efecto del nitrógeno residual y su impacto en la estructura y valor nutritivo del forraje y variables productivas del ganado vacuno de carne en pasturas de Mombaça. El diseño experimental fue en bloques al azar, en parcelas subdivididas, con tres repeticiones. Las pasturas recibieron tres dosis anuales de nitrógeno (N) (100, 200 y 300 kg ha$^{-1}$) de 2015 a 2017. La fertilización se suspendió en 2018, para estimar el efecto residual del nutriente. Las pasturas que recibieron 300 kg ha$^{-1}$ de N mostraron un efecto residual en tasa de acumulación de forraje más alto (P<0,05) que las que recibieron 100 kg ha$^{-1}$ N. No hubo efecto (P>0,05) para valor nutricional de forraje ni ganancia diaria promedio (0,490 kg día$^{-1}$). La carga animal fue mayor (P<0,05) en pasturas bajo el efecto residual de 300 kg ha$^{-1}$ de N, y menor en el efecto residual de 100 kg ha$^{-1}$ de N, y el aumento de peso por área siguió la tendencia observada en la carga animal. La suspensión de la fertilización nitrogenada durante un año después de tres años de fertilización secuencial en Mombaça pastoreados por ganado promueve pérdidas inmediatas de 50 y 55% de la productividad de plantas y animales, respectivamente.

**Palabras clave**

fertilización de pasturas • acumulación de forraje • *Panicum maximum* • carga animal

## Introduction

Beef cattle production in Brazil represents an essential segment of the economy. The high potential for the use of tropical grasses established since the 1990s, is the responsible factor for the increase of productivity indexes in livestock. Despite the large pasture area, many production units do not yet fulfill their full production capacity due to poor management of the soil-plant-animal system. Failures in grazing management (stocking rate adjustments) and pasture maintenance fertilization lead to an unsuccessful activity, which reduces the ability to generate income making it financially unsustainable over the years.

Nitrogen (hereinafter N) fertilization along with maintenance fertilization are fundamental to ensure pasture productivity (22, 35), and the failure to adopt these technologies is considered one of the primary triggers of degradation. The productivity of a pasture is evaluated based on the individual performance of the animals and the stocking rate used (13, 18). The individual performance depends on the genetic potential of the animal (19) and the quantity, quality, and form of forage that it is fed (15). Also, the N fertilization promotes increases in forage accumulation (5), altering pasture dynamics (20, 28) with direct reflexes in animal and per area production (16).

Although forage production can improve with N fertilization (6, 20), increasing secondary productivity (9), the use of N has been limited by cost, due to the extension of the areas involved and the need for frequent applications. In addition, N can be easily lost when not associated with the organic fraction of the soil (37). Research evaluating the residual effect of nitrogen has shown promising results for agricultural crops (29, 36). Thus, a better

understanding of the responses of forage plants and animals to residual fertilization with N may suggest an alternative way to reduce costs by managing inputs, mechanization and labor, in addition to revealing the impact of not using N fertilization on productivity (35).

The current study tests the hypothesis that suspending N fertilization of Mombaça grass for one year after three years of sequential fertilization with the same doses, promotes a residual effect of N on pasture structure, as well as on the forage nutritive value and the performance of beef cattle. To determine this, the research evaluates the residual effect of N on Mombaça grass and the impact of this effect on structure and nutritive value of the sward and performance of beef cattle.

## MATERIAL AND METHODS

### Experiment location and edaphoclimatic monitoring

The experiment was carried out at Embrapa Beef Cattle in Campo Grande, Mato Grosso Sul (figure 1, page XXX). The experimental area is situated at latitude 20°27' S and longitude 54°37' W and boasts an average altitude of 530 m above sea level. The experiment took place over 196 days from 11/07/2017 to 05/22/2018.

According to the Köppen climate classification, this region is of type AW: a tropical, rainy savannah, with a dry period lasting from May to September, the historical average temperature is 23.4°C. All precipitation that occurred in the area during the experimental period was documented (figure 2, page XXX). Climatic data was extracted from the National Institute of Meteorology (2018) database and gathered by the meteorological station located at Embrapa Beef Cattle. The average temperature and monthly precipitation were used to calculate the water balance (figure 3, page XXX). The soil water storage capacity was determined to be 75 mm. The soil of the experimental area is Red Latosol, with clay contents between 30 and 35%. Before the start of the experiment, the soil was sampled in the 0-10, 0-20 and 20-40 cm layers for chemical analysis (table 1, page XXX).

### Experiment area and management

The Mombaça grass (*Panicum maximum cv.* Mombaça) studied was initially planted in January 2008 (Blocks I and II) and November 2010 (Block III) and has since been used for the intermittent grazing of beef cattle. The experimental area of 13.5 ha was divided into three blocks, with each block further subdivided into three modules of 1.5 ha, each module into six paddocks of 0.25 ha each.

Over three consecutive years 2014/2015, 2015/2016, and 2016/2017, the pastures received three annual doses of N in the form of urea (100, 200, and 300 kg ha$^{-1}$ of N) and cover fertilization (80 kg ha$^{-1}$ of P2O5 and 80 kg of K2O) (2, 3). Starting in the rainy season of 2017, there was no maintenance or N fertilization.

Intermittent grazing with a variable stocking rate was used, involving five days of occupation and 25 days of rest in the first five grazing cycles (summer) and seven days of occupation and 35 days of rest in the sixth grazing cycle (fall). Fifty-four Nellore male, uncastrated bovine animals initially weighing 205 ± 26.0 kg (the data is displayed average ± standard error) were used and remained in the paddocks during the entire experimental period.
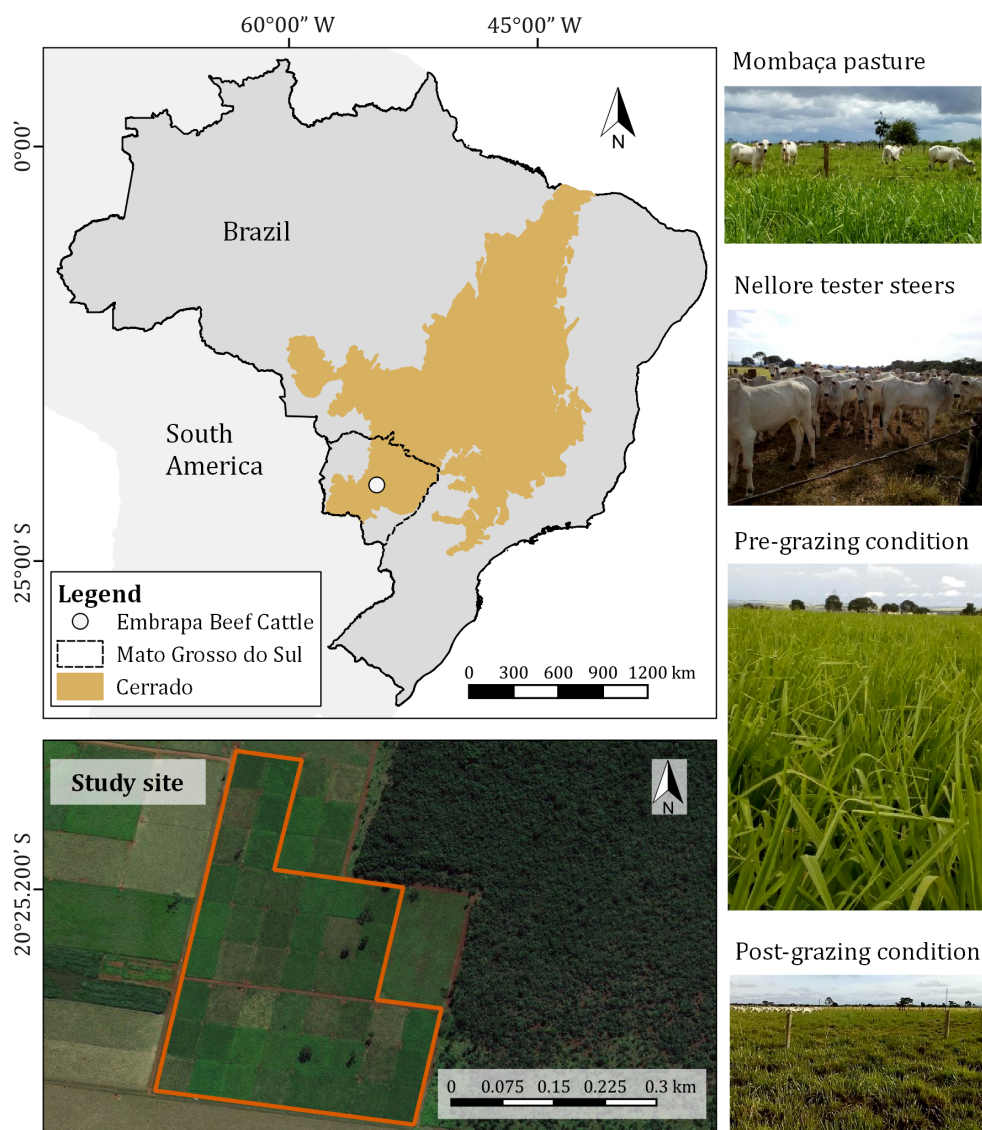
**Figure 1.** Geographic location of the experimental area and experimental conditions.
**Figura 1.** Ubicación geográfica del área experimental y condiciones experimentales.
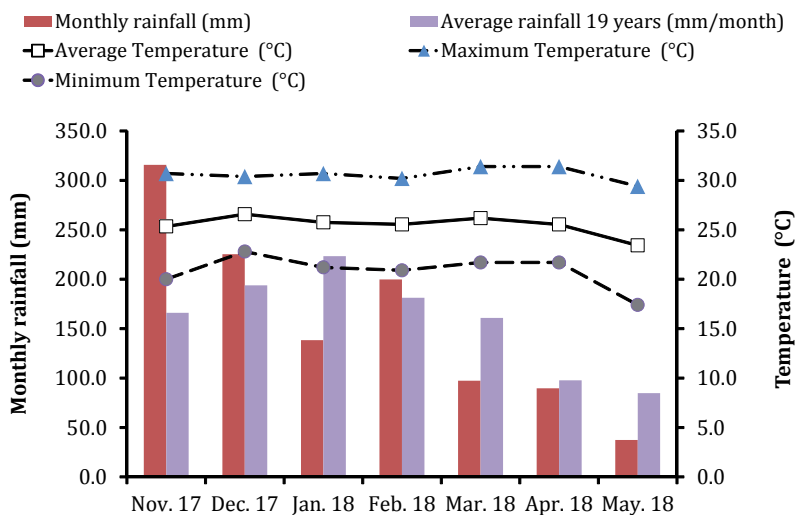
**Figure 2.** Precipitation and average, minimum, and maximum temperatures during the experimental period and average rainfall for the period year 1 - year 19.

**Figura 2.** Precipitación y temperaturas promedio, mínima y máxima durante el período experimental y precipitación promedio el período año 1 - año 19.
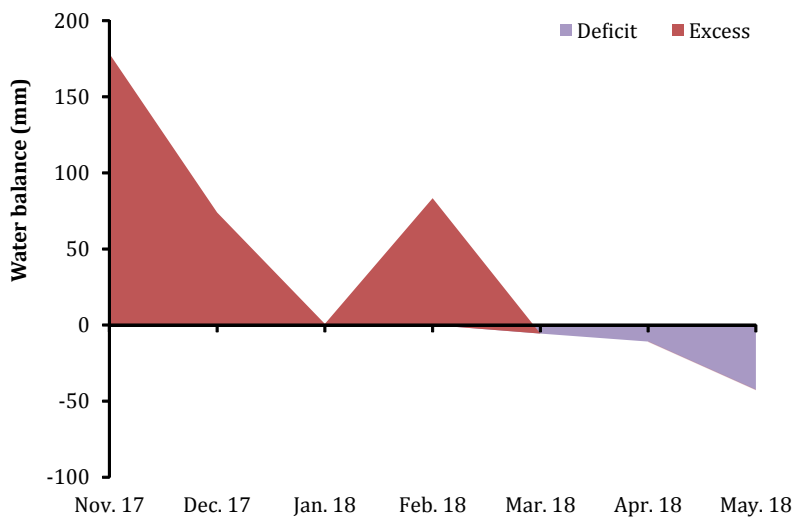


**Figure 3.** Water deficit and excess in the soil during the experimental period from 11/07/2017 to 05/11/2018.

**Figura 3.** Déficit y exceso de agua en el suelo durante el período experimental del 07/11/2017 al 11/05/2018.

**Table 1.** Chemical characteristics of the soil in the experimental area, in the depths of the layers of 0 - 10, 0 - 20 and 20 - 40 cm.

**Tabla 1.** Características químicas del suelo en el área experimental, en las profundidades de las capas de 0-10, 0-20 y 20-40 cm.

| Layer | pH | Ca$^{++}$ | Mg$^{++}$ | K$^+$ | Al$^{+3}$ | H+Al | BS | T | t | V | m | OM | P* |
|-------|-----|-----|-----|-----|-----|------|-----|-----|-----|------|-----|-----|--------|
| | CaCl$_2$ | ------------ cmolc/dm$^{-3}$------------ | | | | | | | | % | | | mg/dm$^{-3}$ |
| 0-10 | 5.7 | 2.5 | 1.3 | 0.4 | 0.2 | 3.5 | 4.1 | 7.6 | 4.1 | 54.2 | 0.4 | 4.2 | 8.4 |
| 0-20 | 5.6 | 2.4 | 1.2 | 0.3 | 0.1 | 3.1 | 3.9 | 7.0 | 3.9 | 5 6.0 | 0.3 | 3.9 | 4.9 |
| 20-40 | 5.5 | 1.3 | 0.9 | 0.2 | 0.2 | 3.0 | 2.4 | 5.4 | 2.4 | 44.9 | 0.8 | 2.9 | 2.9 |

Ca$^{++}$: Calcium; Mg$^{++}$: Magnesium; K$^+$: Potassium; Al$^{+3}$: Aluminum; BS: Base sum; T: Cation exchange capacity (CEC) at pH 7.0; t: Effective CEC; V: saturation by base; m: saturation by aluminum; OM: Organic matter; P*: Phosphorus by method - Mehlich -1.

Ca$^{++}$: calcio; Mg$^{++}$: magnesio; K$^+$: potasio; Al$^{+3}$: aluminio; BS: suma base; T: capacidad de intercambio catiónico (CEC) a pH 7,0; t: CEC efectiva; V: saturación por base; m: saturación por aluminio; OM: materia orgánica; P*: Fósforo por método - Mehlich -1.

A group of six steers serving as test subjects were also present in each paddock during the experimental period. Twenty-six steers were kept in a reserve pasture (5 ha Massai grass) and used as necessary to maintain a post-grazing height of 40-50 cm, as suggested by Euclides *et al.* (2015). The animals all had access to water and mineral salt ad libitum.

**Pasture assessments**
Pasture evaluations were always performed in the same previously chosen paddock of each module and both the pre- and post-grazing conditions were assessed during each cycle. The sward height was measured with a centimeter ruler at 40 different points distributed along five imaginary straight lines across each paddock. The sward height at each point was determined as the average height of the curvature of the leaves around the ruler. The average of each paddock was calculated based on these 40 points.

The forage mass (FM) was estimated by cutting the forage contained in nine rectangular areas of 1 m² distributed randomly across the paddock. The samples were conditioned in paper bags, weighed, and dried in a forced air ventilation oven at 55°C until the weight stabilized, at which point they were again weighed to estimate the forage dry mass.

To evaluate the morphological components, three subsamples were taken and separated into leaf (leaf blade), stem (pseudostem+sheath), and dead material (18). After a manual separation, the components were dried using the same protocol used to evaluate the FM. The leaf to stem ratio was estimated as the product of the mass of leaves and the mass of stems. The net forage accumulation rate (FAR) was calculated by the difference between the FM in the present pre-grazing and after the previous grazing period, considering only the green (leaf and stem) portion, divided by the number of days between the samplings.

The leaf and stem samples obtained in the pre-grazing state were ground using a 1 mm knife mill and later analyzed for the *in vitro* digestibility of organic matter and crude protein, neutral detergent fiber, and acid lignin detergent, using the Near Infrared Reflectance Spectrophotometry (NIRS) system and the methodology proposed by Merten *et al.* (1985).

### Animal evaluations

All steers were weighed every 56 days. The stocking rate was calculated by multiplying the mean weight of the test subject and control steers by the number of days they remained in the experimental module (31).

The average daily gain was calculated by subtracting the weight of the steers at the end of the experimental period from that at the beginning and dividing the result by the number of days (196). The body weight gain per area (kg/ha) was obtained by multiplying the average daily gain of the subjects by the number of animals kept in each experimental plot.

### Experimental design and statistical analysis

The current study employs a randomized block design with subdivided plots. The data gathered was submitted to an analysis of variance, for the variables related to pasture (forage accumulation, structural characteristics, and nutritive value), the residual effect of the N doses was allocated in the plot and the grazing cycles in the subplot. The following model was used: $Y_{ijk} = \mu + D_i + B_j + \alpha_{ij} + C_k + (D*C)_{ik} + \beta_{ijk}$; $Y_{ijk}$ = value observed at dose i, block j, cycle k; $\mu$ = general average effect; $B_j$ = effect of block J; $D_i$ = dose effect i, i = 100, 200 and 300; $\alpha_{ij}$ = effect of the random error attributed to the plot; $C_k$ = effect of cycle k, k = 1, 2, 3, ...; $(DC)_{ik}$ = effect of interaction between dose and cycle; $\beta_{ijk}$ = random error assigned to the subplot.

For the variables related to the animals (average daily weight, body weight gain per area, and stocking rate) the data was submitted to analysis of variance taking into account the randomized block design. The following model was used: $Y_{ij} = \mu + D_i + B_j + \alpha_{ij}$, where: $Y_{ijK}$ = value observed at dose i, repeat j; $\mu$ = general average effect; $D_i$ = height effect i, i = 100, 200 and 300; $B_j$ = effect of block j; $\alpha_{ij}$ = effect of random error attributed to repetition j.

When determined to be significant by the F test, the effects of the sources of variation and their interactions were analyzed using the Tukey test, at 5% significance.

## Results and discussion

The interaction between the residual N effect and the grazing cycles was determined not to be significant (P> 0.05) for the structural variables of the sward, in the pre and post-grazing states. The results revealed no effect of residual N fertilization on canopy height and dead material mass (DMM) in pre-grazing conditions (table 2, page XXX). The forage canopy did not reach 90 cm of height in the pre-grazing at any residual level of N. This height is significant, because it is the height required for Mombaça grass to intercept 95% of the light, causing competition for incident light at the base of the plant and triggering an increase in the accumulation of stem and losses by senescence (10, 17, 18). Although the recommended management of the grazing (fixed days of occupation and rest) was not properly followed, it is possible to infer that there was no elongation of the stem nor any accumulation of dead material in the forage canopy, since the heights remained close at 80 cm (90% of the light intercept, hereinafter LI).

**Table 2.** Structural variables (average ± standard error) of the canopy in the pre-grazing of the Mombaça grass under residual nitrogen effect.

**Tabla 2.** Variables estructurales (media ± error estándar) pre-pastoreo en la canopia de la gramínea Mombaça bajo efecto residual de nitrógeno.

| Variables | Doses of N (kg ha⁻¹ de N) | | | P Value |
|---|---|---|---|---|
| | 100 | 200 | 300 | |
| Canopy height (cm) | 67.1 ±2.7 | 75.2 ± 2.9 | 75.8 ± 2.5 | 0.326 |
| Forage accumulation rate (kg ha⁻¹ DM day⁻¹) | 26.7[b] ± 4.7 | 36.3[ab] ± 6.5 | 43.4[a] ± 6.7 | 0.020 |
| Forage mass (kg ha⁻¹ DM) | 3371.8[b] ± 86.8 | 3637.6[ab] ± 92.4 | 3853.9[a] ± 128.2 | 0.018 |
| Leaf blade mass (kg ha⁻¹ DM) | 1790.2[b] ± 77.6 | 1968.8[ab] ± 111.2 | 2181.7[a] ± 128.4 | 0.019 |
| Stem mass (kg ha⁻¹ DM) | 578.6[b] ± 26.1 | 761.5[ab] ± 27.6 | 856.5[a] ± 43.6 | 0.040 |
| Dead material mass (kg ha⁻¹ DM) | 989.9 ± 77.2 | 905.3 ± 121.8 | 815.3 ± 96.3 | 0.188 |
| Leaf blade:stem rate | 3.3 ± 0.2 | 2.7 ± 0.2 | 2.7 ± 0.1 | 0.204 |

Averages followed by distinct letters in the line differ ($P < 0.05$) by the Tukey test.

Los promedios seguidos de letras distintas en la línea difieren ($P < 0.05$) por la prueba de Tukey.

Adhering to this height therefore seems to be a possible method for successfully managing Mombaça grass [1].

Furthermore, the swards with a residual effect of 300 kg ha⁻¹ of N were characterized by a higher forage accumulation, FM, leaf blade mass (LBM), and stem mass (SM) than those with a residual effect of 100 kg ha⁻¹ of N. The averages for these variables in pastures under the residual effect of 200 kg ha⁻¹ of N were similar to the those under the effect of the other two levels of residual N (table 2). As pastures were managed with fixed days of occupation and rest, the results of FM, LBM, and SM reflected forage accumulation and soil fertility history according to the previous management, pointing out the residual effect of N on the structural characteristics of the pasture. N accelerates plant metabolism and increases morphogenic processes [4].

The use of higher N rates therefore appears to be responsible for an increase in leaf appearance and leaf elongation rates [4, 30]. These morphogenic variables directly affect the structural variables of the pasture [12, 14, 20] and increase forage accumulation.

Forage accumulation rates were 58.1%, 54.3%, and 47.2% lower for the residual doses of 100, 200 and 300 kg ha⁻¹ of N, respectively than the values observed by Barbosa (2018) in 2017, when the pastures received the doses of N. The lower FAR can be explained by the direct effect of N fertilization on the forage plant, since the nutrient is responsible for significant increases in forage production [5, 9]. Pastures under the residual dose of 100 kg ha⁻¹ of N, presented a pre-grazing FM close to the 3000 kg ha⁻¹ of DMM observed in a study by Brâncio *et al.* (2003a).

This study examines Mombaça grass in pastures fertilized with 50 kg ha$^{-1}$ of N having undergone grazing management habits, temperatures and average precipitation similar to those adopted in the current experiment and in the same place (latitude 20°27' S and longitude 54°37' W). Therefore, it seems that the residual effect of 100 kg ha$^{-1}$ of N on forage production is equivalent to the direct effect of 50 kg ha$^{-1}$ of N.

The pastures with a residual effect of 200 and 300 kg ha$^{-1}$ of N presented higher masses of leaf and stem, whereas those at 100 kg ha$^{-1}$ of N behaved in opposite ways (table 2, page XXX). This explains the absence of an effect on the leaf blade to stem ratio, since this ratio is the product of LBM and stem mass.

The SM was similar across the evaluation months (table 3). Montagner *et al.* (2012) report a stem elongation rate during the rainy season of 0.04 and 0.003 cm/day in the summers of the first and second year of evaluation.

Luna *et al.* (2014) indicate an elongation rate of 0.04 cm/day. These results suggest that the rest period used was adequate to control the sward structure because the low elongation rates and adequate periods of grazing and rest did not increase significantly for stem mass.

The FAR fluctuated during the evaluation months (table 3). The highest FAR was observed in February, without statistical difference for the months of January and March, although with variation in the values.

**Table 3.** Canopy height, forage mass and morphological composition (average ± standard error) in pre-grazing of Mombaça grass under residual nitrogen effect during grazing cycles.

**Tabla 3.** Altura de la canopia, biomasa total de forraje y por componente (media ± error estándar) en el pre-pastoreo de la gramínea Mombaça bajo efecto de nitrógeno residual durante los ciclos de pastoreo.

| Variables | Months | | | | | | P Value |
|---|---|---|---|---|---|---|---|
| | Dec/17 | Jan/18 | Feb/18 | Mar/18 | Apr/18 | May/18 | |
| Canopy height (cm) | 75.2$^{ab}$ ± 2.2 | 82.6$^{a}$ ± 2.7 | 83.2$^{a}$ ± 3.3 | 79.6$^{ab}$ ± 2.3 | 61.1$^{b}$ ± 2.6 | 54.3$^{b}$ ± 1.8 | 0.005 |
| FAR (kg ha$^{-1}$ day$^{-1}$) | 25.2$^{b}$ ± 2.9 | 44.8$^{ab}$ ± 4.5 | 62.2$^{a}$ ± 4.5 | 40.3$^{ab}$ ± 6.4 | 20.4$^{b}$ ± 1.9 | 0.5$^{c}$ ± 0.1 | 0.001 |
| FM (Kg ha$^{-1}$ DM) | 3697.8$^{ab}$ ± 142.2 | 4045.2$^{a}$ ± 68.9 | 4068.2$^{a}$ ± 87.6 | 3019.4$^{b}$ ± 111.6 | 3167.8$^{ab}$ ± 124.9 | 3728,0$^{ab}$ ± 71.6 | 0.001 |
| LBM (Kg ha$^{-1}$ DM) | 2635.5$^{a}$ ± 101.8 | 2295.4$^{ab}$ ± 65.9 | 2170.1$^{b}$ ± 76.4 | 1924.4$^{bc}$ ± 82.2 | 1785.48$^{c}$ ± 104.8 | 1070,5$^{d}$ ± 74.9 | 0.001 |
| SM (Kg ha$^{-1}$ DM) | 668.7 ± 54.2 | 761.6 ± 33.8 | 855.9 ± 36.8 | 628.3 ± 44.5 | 678.7 ± 70.0 | 800,0 ± 62.5 | 0.052 |
| DMM (Kg ha$^{-1}$ DM) | 392.9$^{c}$ ± 55.0 | 988.2$^{b}$ ± 55.1 | 1011.9$^{b}$ ± 41.3 | 466.7$^{c}$ ± 33.4 | 703.6$^{bc}$ ± 67.9 | 1857,5$^{a}$ ± 98.0 | 0.001 |
| Leaf blade:stem rate | 4.3$^{a}$ ± 0.3 | 3.2$^{b}$ ± 0.1 | 2.6$^{b}$ ± 0.1 | 3.1$^{b}$ ± 0.2 | 2.7$^{b}$ ± 0.2 | 1,4$^{c}$ ± 0.1 | 0.001 |

Averages followed by distinct letters in the line differ (P <0.05) by the Tukey test. FAR: forage accumulation rate; FM: forage mass; LBM: leaf blade mass; SM: stem mass; DMM: dead material mass.

Los promedios seguidos de letras distintas en la línea difieren (P <0,05) por la prueba de Tukey. FAR: tasa de acumulación de forraje; FM: masa de forraje; LBM: masa de lámina hoja; SM: masa de tallo; DMM: masa de material muerto.

The results of December and April were similar to those of January and March, with all presenting higher FAR than observed in May. The values for height of the pasture were higher in December, January, February and March. On the other hand, FM presented its lowest value in March, with no statistical difference for the months of December, April and May, due to the low accumulation of forage caused by a decrease in temperature and a low rate of precipitation. In December, January and February, the water balance was positive (figure 2 and figure 3, page XXX). In fact, the rate of forage accumulation fluctuates throughout the year as a consequence of climatic variations (figure 2 and figure 3, page XXX).

The largest LBM were observed in December and January, while the lowest were in May, a time with increased precipitation and reduced temperature (figure 2, page XXX). The value of DMM was highest in May, accounting for about 50% of the total FM during this period. This can be explained in part by the flowering of the cultivar, which occurs in mid-April in Campo Grande (20°250' S). After the emergence of the inflorescence, no more leaves appear, and there is an increase in the accumulation of dead material (17). This could potentially restrict the consumption of forage (15). However, the dead material, in this condition, was concentrated at the base of the plant (17), forage stratum not exploited by the animals due to the post-grazing height adopted.

In the post-grazing condition, there was no effect ($P>0.05$) of residual N doses on the canopy height ($49.4 \pm 2.3$ cm), FM ($2822.8 \pm 109.3$ kg ha$^{-1}$ DM), LBM ($891.9 \pm 41.4$ Kg ha$^{-1}$ DM), SM ($744.5 \pm 55.1$ kg ha$^{-1}$ DM), DMM ($1186.7 \pm 82.0$ kg ha$^{-1}$ DM), and leaf blade to stem ratio ($1.3 \pm 0.2$). These results are explained by the fact that the stocking rate was adjusted to lower the pastures to 40-50 cm during the period of occupation, as recommended by Euclides *et al.* (2015 and 2017). Even using fixed days of occupancy and rest, the adjustment of the stocking rate was performed weekly based on the control of the target height of the residue. This adjustment was essential to controlling the grazing and maintaining the structural conditions of the canopy. Briske *et al.* (2008) suggest that the adjustment of the stocking rate is the most important tool in managing pastures under intermittent stocking.

The post-grazing height varied over the evaluation months, reaching its highest value in January and February, (table 4, page XXX). In turn, January did not differ from the rest of the months. The average height of the plants in the pastures' post-grazing state was above the established target (40-50 cm). This higher height is likely due to the higher accumulations of forage observed during these months (table 3, page XXX) and indicated that an increase in the number of animals is not sufficient to lowering the pasture to its target height.

The post-grazing FM was highest in February with a similar value to that observed in May, and this was similar to January and December. The higher rainfall (figure 2, page XXX) and daily FAR (table 3, page XXX) in February explain this result. Even though the low FAR was observed in the month of May, the FM results were similar to the months where they had higher TAF. The flowering of Mombaça grass occurs during this period and, because reproductive tillers are larger than vegetative ones, this modifies the structure sward (30, 32, 33). Since reproductive tillers are rejected by animals, this also increases the DMM.

**Table 4.** Canopy height, forage mass and morphological composition
(average ± standard error) in post-grazing of Mombaça grass under residual nitrogen
effect during grazing cycles.

**Tabla 4.** Altura de la canopia, biomasa total de forraje y por componente
(media ± error estándar) en post-pastoreo de la gramínea Mombaça bajo efecto de
nitrógeno residual durante los ciclos de pastoreo.

| Variables | Months | | | | | | P Value |
|---|---|---|---|---|---|---|---|
| | Dec/17 | Jan/18 | Feb/18 | Mar/18 | Apr/18 | May/18 | |
| Canopy height (cm) | 46.0[b] ± 1.6 | 52.8[ab] ± 1.2 | 58.8[a] ± 0.7 | 45.7[b] ± 1.0 | 47.2[b] ± 1.4 | 45.7[b] ± 0.8 | 0.009 |
| FM (kg ha⁻¹ DM) | 2905.1[b] ± 75.8 | 3004.6[b] ± 83.5 | 3341.3[a] ± 73.9 | 2159.4[c] ± 49.5 | 2356.2[c] ± 84.1 | 3166.9[ab] ± 57.3 | 0.001 |
| LBM (Kg ha⁻¹ DM) | 1073.4[a] ± 77.7 | 1213.9[a] ± 28.7 | 1065.0[a] ± 32.9 | 661.8[bc] ± 36.2 | 798.1[b] ± 72.7 | 539.1[c] ± 46.1 | 0.001 |
| SM (Kg ha⁻¹ DM) | 684.3[b] ± 79.6 | 870.8[a] ± 39.7 | 832.6[a] ± 37.5 | 683.3[b] ± 39.8 | 708.1[b] ± 43.4 | 688.1[b] ± 35.1 | 0.001 |
| DMM (Kg ha⁻¹ DM) | 960.9[cd] ± 71.5 | 1106.4[c] ± 41.2 | 1443.7[b] ± 48.2 | 814.3[d] ± 37.4 | 855.0[cd] ± 81.8 | 1939.6[a] ± 75.1 | 0.001 |

Averages followed by distinct letters in the line differ (P <0.05) by the Tukey test. FM: forage mass;
LBM: leaf blade mass; SM: stem mass; DMM: dead material mass.

Los promedios seguidos de letras distintas en la línea difieren (P <0,05) por la prueba de Tukey.
FM: masa de forraje; LBM: masa de lámina de hoja; SM: masa de tallo; DMM: masa de material muerto.

The LBM in the post-grazing state decreased over the cycles due to a decrease in the accumulation rate. According to Lopes *et al.* (2011), the amount of leaves remaining indicates the level of grazing pressure exerted by the animal, with a greater mass of foliar leaf in the post-grazing resulting in better regrowth conditions for the plants. Therefore, it impacts subsequent cycles.

The post-grazing SM was highest in January and February due to the higher entry heights recorded in this period, reflecting the higher forage accumulation (table 3, page XXX). The post-grazing DMM was highest in May because of higher values for DMM in the pre-grazing state during this period; the animals reject this component, promoting higher accumulation. The increase in dead material and consequent reduction in leaf mass suggest a loss of efficiency in forage production in periods of lower precipitation and temperature (figure 2, page XXX).

There was no interaction between the effect of residual N and grazing cycles (P> 0.05) for the nutritive values of leaves and stems. There was no difference (P> 0.05) in the residual N doses for crude protein (9.3 ± 0.2%), neutral detergent fiber (75.0 ± 0.4%), lignin (2.9 ± 0.1%), and *in vitro* digestibility of organic matter (55.3 ± 0.1%) of the leaf. There was also no effect (P> 0.05) of residual N doses for crude protein (4.5 ± 0.2%), neutral detergent fiber (77.2 ± 02%), lignin (4.2 ± 0.1%) and in vitro digestibility of organic matter (51.1 ± 0.4%) of the stem.

These results are probably connected to the short rest period adopted, since the pasture heights observed in pre-grazing conditions were similar (table 2, page XXX) and well below 90 cm, a height at which Carnevalli *et al.* (2006) indicate that the canopy intercepts 95% LI. In this context, Sbrissia *et al.* (2013) demonstrate that pastures of Quicuio grass with up to 95% LI present similar nutritive values to those observed in the current study.

Alvarenga *et al.* (2020) also present similar nutritive values for Mombaça grass pastures managed with 90 and 95% of the LI. A significant number of studies examine the influence of plant nutrition on the pastures' nutritive value (5). The current study, however, reveals that the suspension of N fertilization for one year is enough to neutralize the effect of soil fertility on the nutritive value of Mombaça grass.

The nutritive value of the leaf varied over the months of evaluation. In December, January, and February, the highest levels of crude protein and the lowest levels of neutral detergent fiber and acid detergent lignin were observed, altering the *in vitro* organic matter digestibility (table 5), due to the reduction in cellular content with the increase of the fibrous portion. The higher forage accumulation in this period (table 3, page XXX) caused by a higher rainfall (figure 2, page XXX) explains this response. Machado *et al.* (2008) highlight that the availability of water in the soil is a determining factor in the chemical composition of the forage plant. Its presence favors a more intense morphogenesis process, which in turn produces new tissues with a higher nutritive value: such plants, consequently, have a better effect on the animals.

**Table 5.** Chemical composition (average ± standard error) of the Mombaça grass under residual nitrogen effect during grazing cycles.

**Tabla 5.** Composición química (media ± error estándar) de la gramínea Mombaça bajo efecto de nitrógeno residual durante los ciclos de pastoreo.

| Variables | Months | | | | | | P Value |
|---|---|---|---|---|---|---|---|
| | Dec/17 | Jan/18 | Feb/18 | Mar/18 | Apr/18 | May/18 | |
| ------------Leaf------------ | | | | | | | |
| Crude protein | $9.8^{ab} \pm 0.2$ | $11.4^{a} \pm 0.3$ | $9.3^{ab} \pm 0.1$ | $8.6^{b} \pm 0.1$ | $8.8^{b} \pm 0.1$ | $8.0^{c} \pm 0.3$ | 0.001 |
| Neutral detergent fiber | $73.9^{cb} \pm 0.3$ | $73.3^{c} \pm 0.5$ | $75.0^{b} \pm 0.2$ | $73.1^{c} \pm 0.4$ | $76.8^{a} \pm 0.2$ | $78.1^{a} \pm 0.2$ | 0.001 |
| Lignin | $2.6^{c} \pm 0.1$ | $2.6^{c} \pm 0.1$ | $2.9^{b} \pm 0.1$ | $3.1^{ab} \pm 0.1$ | $3.2^{a} \pm 0.1$ | $3.2^{a} \pm 0.1$ | 0.001 |
| IVOMD | $61.0^{a} \pm 0.4$ | $58.3^{b} \pm 0.7$ | $55.3^{c} \pm 0.4$ | $56.1^{c} \pm 0.1$ | $51.2^{d} \pm 0.1$ | $50.0^{d} \pm 0.7$ | 0.001 |
| ------------Stem------------ | | | | | | | |
| Crude protein | $5.2^{a} \pm 0.2$ | $5.0^{a} \pm 0.2$ | $4.5^{b} \pm 0.1$ | $4.5^{b} \pm 0.1$ | $3.6^{c} \pm 0.1$ | $3.9^{c} \pm 0.1$ | 0.001 |
| Neutral detergent fiber | $74.1^{b} \pm 0.2$ | $77.4^{b} \pm 0.2$ | $77.2^{ab} \pm 0.1$ | $77.4^{ab} \pm 0.4$ | $78.3^{a} \pm 0.3$ | $78.8^{a} \pm 0.2$ | 0.001 |
| Lignin | $4.1^{ab} \pm 0.1$ | $4.0^{b} \pm 0.1$ | $4.1^{ab} \pm 0.1$ | $4.1^{ab} \pm 0.1$ | $4.1^{ab} \pm 0.4$ | $4.3^{a} \pm 0.1$ | 0.003 |
| IVOMD | $55.5^{a} \pm 0.4$ | $50.2^{b} \pm 0.7$ | $50.8^{b} \pm 0.2$ | $48.7^{b} \pm 0.9$ | $49.4^{b} \pm 0.1$ | $50.5^{b} \pm 0.4$ | 0.001 |

Averages followed by distinct letters in the line differ from one another by the Tukey test (P <0.05). IVOMD: *in vitro* organic matter digestibility.

Los promedios seguidos de letras distintas en la línea difieren entre sí en la prueba de Tukey (P <0,05). IVOMD: digestibilidad *in vitro* de la materia orgánica.

The lower rainfall and consequent soil water deficit and the low temperatures (figure 2, page XXX) starting in March are responsible for the lower values of crude protein and higher values of the less degradable parts of the fiber in March, April, and May. This period is therefore critical in animal nutrition.

The chemical composition of the stem was determined to be similar to that of the leaf, with higher crude protein levels and *in vitro* organic matter digestibility observed during the months with a higher precipitation rate, while higher values of the fibrous fractions were present in the dry-water transition months. The highest canopy heights observed during the rainy season could help increase the plants' support structures. The appearance of tissues with a higher nutritive value (tissue renewal) at this time (24) increases the nutritive value of leaves and stems.

The average daily gain of the animals in the pastures under different doses of residual N varied very little (P = 0.765), with an average of 0.490 ± 0.02 kg day$^{-1}$. This result is like due to the similar nutritive value of the leaves and stems across the pastures. The average daily gain was lower than that found by Araújo (2017) in pastures of Mombaça grass fertilized with three doses of N (100, 200 and 300 kg ha$^{-1}$ of N) during the rainy season of 2014/2015 (0.540 *vs.* 0.490 kg day$^{-1}$). The highest individual performance recorded by Araújo (2017) was probably due to the higher crude protein levels in the leaves (10.9 *vs.* 9.3%) and the higher rate of in vitro organic matter digestibility (62.1% *vs.* 55.3%), due or direct effect of N that alters the crude protein content and forage digestibility (11).

The stocking density was highest for the pasture under the residual effect of 300 kg ha$^{-1}$ of N and lowest for the one under the effect of 100 kg ha$^{-1}$ of N, with intermediate value for the pastures under a residual effect of 200 kg ha$^{-1}$ (table 6). The stocking density followed the same pattern of FAR variation (table 2, page XXX): as the residual level of N increased (table 2, page XXX), more animals were needed to maintain the post-grazing height targets (40-50 cm), which conse-quently increased the stocking density.

**Table 6.** Performance of beef cattle (average ± standard error) in Mombaça pastures under residual nitrogen effect.

**Tabla 6.** Producción del ganado de carne (media ± error estándar) en pasturas de Mombaça bajo efecto de nitrógeno residual.

| Variables | Doses of N (kg ha$^{-1}$ de N) | | | P Value |
|---|---|---|---|---|
| | 100 | 200 | 300 | |
| Stocking rate (AU ha$^{-1}$)* | 2.7[b] ± 0.2 | 3.1[ab] ± 0.2 | 4.0[a] ± 0.1 | 0.013 |
| DWG (kg ha$^{-1}$ of live weight) | 466.7[b] ± 28.3 | 535.9[ab] ± 31.6 | 691.5[a] ± 33.1 | 0.011 |

Averages followed by distinct letters in the line differ from one another by the Tukey test (P <0.05). *Animal unit (1 AU = 450 kg of live weight). DWG: daily weight gain per hectare.

Los promedios seguidos de letras distintas en la línea difieren entre sí en la prueba de Tukey (P <0,05). * Unidad animal (1 AU = 450 kg de peso vivo). DWG: aumento de peso diario por hectárea.

Brâncio *et al.* (2003b) report a stocking density of 2.0 AU/ha and an individual weight gain of 0.500 kg day$^{-1}$ for Nellore cattle fed on Mombaça pasture fertilized with 50 kg ha$^{-1}$ of N, with grazing management similar to that in the current research during the rainy season. Therefore, the residual effect of 100 kg ha$^{-1}$ of N impacts animal production in a way that is equivalent to the direct effect of 50 kg ha$^{-1}$ of N; this repeats the results observed with regard to crop production.

The body weight per area gain was highest in the pastures under the residual effect of 300 kg ha$^{-1}$ of N and lowest in those at 100 kg ha$^{-1}$, with once again an intermediate value at 200 kg ha$^{-1}$ (table 6, page XXX). This result can be attributed to the variation in stocking rate values, since pasture productivity is a result of the combination of individual performance and stocking rate (13, 19). Since there was no difference for individual performance between N doses, the observed behavior for stocking rate was repeated for the body weight gain per hectare.

Suspending N fertilization for one year after sequential fertilization over three years in Mombaça grass pastures can be adopted in strategic cases. As the producer cannot fertilize the entire area every year, this can help determine the fertilization scheduling of pastures. Furthermore, this strategy can help balance the high prices of fertilizer.

Finally, suspending N fertilization is a useful option when the objective of the production unit is not to obtain high gains from animals (such as in the case of producing breeding stock). In fact, this study revealed that the residual effect of 100 N is more or less equivalent to the direct effect of an annual application of 50 kg ha$^{-1}$ of N. The residual dose of 100 kg ha$^{-1}$ of produced approximately 25% less than the residual dose of 200 kg ha$^{-1}$ of and 50% less compared to the residual dose of 300 kg ha$^{-1}$ of N.

## Conclusion

Suspending the N fertilization of Mombaça grass for one year after three years of sequential fertilization with the same doses leaves a residual effect on the pasture structure and performance of beef cattle. However, this management is not advantageous. It reduces the rate of forage accumulation by an average of 50%, causing a 55% decrease in animal productivity.

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