

Article

Effect of Season and Nitrogen Fertilization on the Agronomic Traits and Efficiency of Piatã Grass in Brazilian Savanna

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Abstract: The aim of the present study was to evaluate the agronomic traits in the pre- and post-grazing and the nitrogen use efficiency of Piatã grass that was subjected to nitrogen fertilization throughout the seasons of the year. The experiment was performed in a randomized block design with four treatments (0, 150, 300, and 450 kg ha⁻¹ N). Grazing was performed with sheep when the forage canopy reached 95% light interception up to 20 cm height of post-grazing. The pre-grazing forage mass of the Piatã grass showed a behavior ($p < 0.05$) linear to nitrogen fertilization, with higher and lower values in spring and winter, respectively. The post-grazing forage mass responded linearly ($p < 0.05$) to nitrogen fertilization, with an increase of 43.12% for the dose of 450 kg ha⁻¹ N in relation to pastures without nitrogen fertilization. When the non-fertilized pasture was compared with the highest nitrogen dose, a reduction of 21.79% dead tissue was observed in the post-grazing forage mass. The highest nitrogen use efficiency was obtained with the dose of 450 kg ha⁻¹ N. The forage mass production of the Piatã grass in the pre- and post-grazing conditions are positively influenced by nitrogen fertilization and the seasons of the year, with lower values in winter.

Keywords: *Brachiaria brizantha*; ecophysiological management; intermittent grazing; mass production; sheep

1. Introduction

To make competitive the use of pasture as a forage resource for the feeding of ruminants, it is necessary to use the pasture adequately in order to ensure production and harvest efficiency [1]. Thus, studies that are conducted based on the physiology and ecology of forage grasses are extremely important [2–4].

Based on the ecophysiological management of grasses, when the forage canopy reaches 95% light interception (LI), the maximum forage accumulation rate is maintained, while there is sufficient leaf

area to intercept almost all incident light [5]. Subsequent increases in leaf area index occur from 95% LI and, in response to competition for light, the plant initiates an intense stem elongation process, leading newer leaves to be positioned above the older leaves under conditions of full light. This leads to reduced leaf accumulation and increased accumulation of stems and dead material, with an increase in the amount of tissues without photosynthetic (senescent) tissues [6]. Thus, [7] demonstrated that the optimal point for interrupting the regrowth of pastures subjected to cutting regimes would actually be the one with the highest average rate of forage accumulation and nutritional quality.

As the pattern of forage accumulation depends on the interception and competition for light, the faster the pasture regrowth, the faster it will be able to be grazed again [8], which indicates that the management of the grazing interval based on fixed calendars is quite limited and can cause serious damage to forage quality and livestock production [5].

A practice that has provided a reduced grazing interval and increased bearing capacity of pastures is the nitrogen fertilization. This is because soil nitrogen from the mineralization of organic matter is not sufficient to meet the demand of grasses with productive potential [9]. Nitrogen is a macronutrient that participates in the structure of several organic compounds, such as proteins and enzymes, and, thus, have direct action on the metabolic function, through the modulation of the expression of nucleic acids and also because it is one of the main components of chlorophyll, due to this the N accelerates the formation and growth of new leaves by increasing the vigor of regrowth after defoliation [10,11] and, therefore, can promote the improvement of the economic performance of rural properties [12]. Although the nitrogen fertilization can be used to accelerate the growth of grasses. The dynamics of nitrogen in the soil is complex due to the high permeability of in the soil, bacterial changes in the N-fertilizer, plus the losses in the form of volatilization, in addition to the variation in the nitrogen requirement of the forages due to the climatic condition and pressure grazing, these factors hinder the reduction losses and maximize the use of N-fertilizer, resulting in increased costs. Because of the different climatic conditions of the seasons, affecting the time necessary for regrowth, plus the search for a more efficient use of nitrogen fertilization, it is hypothesized that grazing control based on 95% of light interception when considering ecophysiological concepts can promote a more efficient recommendation for nitrogen fertilization throughout the seasons.

Thus, the present study aimed to evaluate the agronomic traits in the pre- and post-grazing and the nitrogen use efficiency in the Piatã grass throughout the seasons of the year.

2. Materials and Methods

2.1. Location and Climatic Conditions

The study was conducted at the Experimental Farm of the Federal University of Mato Grosso from February 2014 to March 2015. This research station is located at 15°04'36" S, 56°04'36" W and it is 141 m above sea level.

According to Koppen's classification, the climate is Aw, with a tropical mega-thermal climate, characterized by two well-defined dry (May to September) and rainy (October to April) seasons. The mean annual rainfall is 1500 mm, with maximum intensity during January, February, and March. The mean rainfall, insolation, and temperature during the experimental period are shown in Figures 1–3.

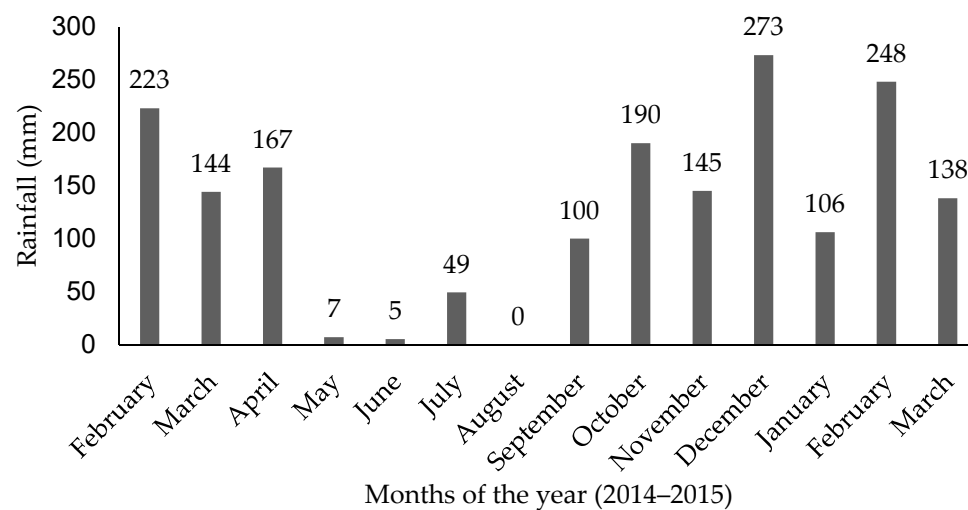


Figure 1. Monthly rainfall during the experiment.

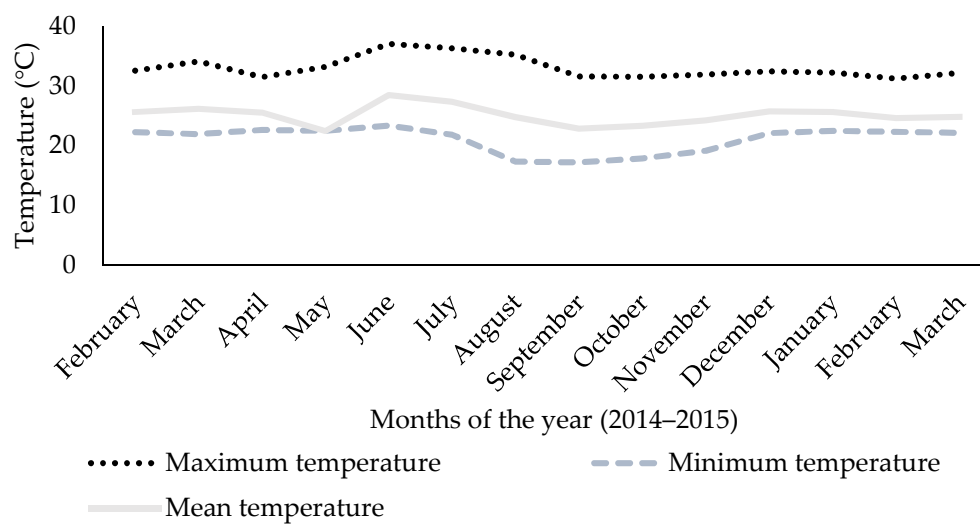


Figure 2. Mean, maximum, and minimum temperatures during the experiment.

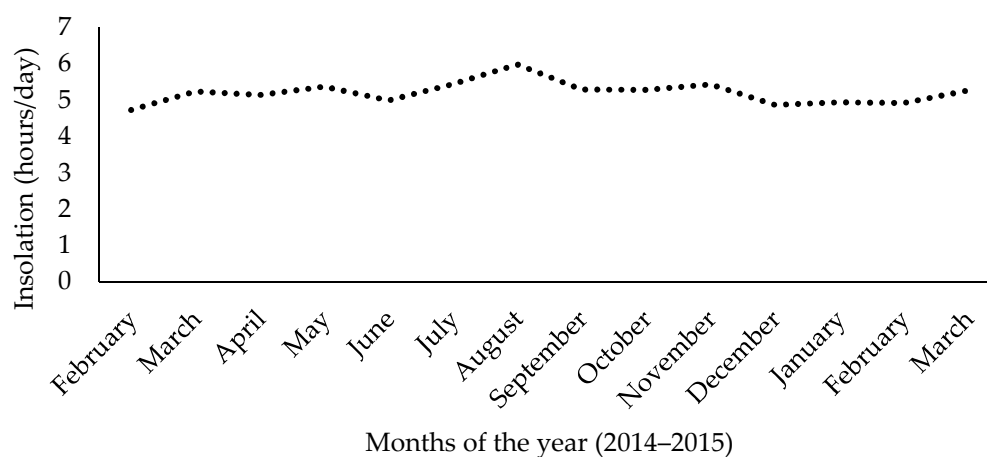


Figure 3. Insolation (hours/day) during the experiment.

2.2. Treatments and Experimental Design

An established *Brachiaria brizantha* cv. *piatã* pasture was used. The experimental area was subdivided into 12 paddocks of 6×6 m, separated from each other by electrified fences and screens. A randomized complete block design in a split-plot arrangement with three replications was used. The main plots were the applications of 0, 150, 300, and 450 kg of N in the form of urea, and the subplots were seasons of the year: late summer/fall, winter, spring, and summer.

The pasture of *Brachiaria brizantha* cv. *Piatã* was established in December 2011, the pasture area followed by sheep grazing at an average height of 20 cm until November 2013. Before the beginning of the experiment, at the end of November of 2013, the pasture was cut at a height of 5 cm from the soil. Based on the soil analysis results, the soil was limed with dolomitic limestone, with 80% of lime's total relative neutralization (LTRN) carried out on the surface, aiming to raise the base saturation to 50%.

The fertilizer doses used were close to the recommendations of [13], according to the requirement of the grass. After regrowth, the average height of 20 cm was maintained in all paddocks until the study was started. At the end of December 2013, 120 kg ha^{-1} of P_2O_5 and 80 kg ha of K_2O using single superphosphate and potassium chloride, respectively, was applied. The source of phosphorus was applied in a single dose and the potassium in two doses, all of these performed before the beginning of the experiment. Experimental treatments were based on the Nitrogen fertilization amounts and were divided into four doses according to the number of grazing cycles (Table 1).

Table 1. Nitrogen fertilization (kg/ha of N) applied to each paddock and its respective date of application during the experimental period.

Level *	Block	1st Application		2nd Application		3rd Application		4th Application		Total
		Date	kg/ha	Date	kg/ha	Date	kg/ha	Date	kg/ha	
0	I	-	-	-	-	-	-	-	-	0
0	II	-	-	-	-	-	-	-	-	0
0	III	-	-	-	-	-	-	-	-	0
150	I	2/8/14 *	37.5	3/26/14 **	37.5	5/8/14	37.5	11/2/14	37.5	150
150	II	2/8/14 *	37.5	3/26/14 **	37.5	5/8/14	37.5	11/2/14	37.5	150
150	III	2/8/14 *	37.5	3/26/14 **	37.5	5/8/14	37.5	11/2/14	37.5	150
300	I	2/8/14 *	75	3/19/14 **	75	10/6/14	75	11/9/14	75	300
300	II	2/8/14 *	75	3/19/14 **	75	10/6/14	75	11/9/14	75	300
300	III	2/8/14 *	75	3/19/14 **	75	10/6/14	75	11/9/14	75	300
450	I	2/8/14 *	112.5	3/12/14 **	112.5	10/19/14	112.5	11/17/14	112.5	450
450	II	2/8/14 *	112.5	3/12/14 **	112.5	10/19/14	112.5	11/17/14	112.5	450
450	III	2/8/14 *	112.5	3/12/14 **	112.5	10/19/14	112.5	11/17/14	112.5	450

*: First application of K_2O ; **: Second application of K_2O .

The grazing management with rotational stocking strategy was characterized by the animal entry into and exit from the paddocks when the pasture showed 95% of light interception (LI95%) (pre-grazing) and 20 cm of height (post-grazing), respectively.

The pasture was grazed by sheep with average body weights of 50 kg while using the mob-grazing technique [14]. Grazing occurred on the same day for all replicates of the evaluated treatments, i.e., LI was considered as the average of the three replicates under the same treatment. After grazing, the sheep were removed from the paddocks, placed in a one-hectare reserve pasture, and returned when the pasture of *Piatã* grass reached the established pre-grazing target.

The monitoring of light interception and leaf area index (LAI) were done using the sward analyzer AccuPAR Linear PAR/LAI ceptometer, Model PAR 80 (DECAGON Devices) in 10 places per paddock, in W-shaped trajectories (representative locations of the average conditions of the pasture during the sampling). Two readings were taken at each point: one above the sward and another at the soil surface (below the sward). These measurements were performed every six days until the approximation of the pre-established grazing target and every two days thereafter. The grazing intensity of *Piatã* grass was obtained from the results presented by [15], who used LI as a parameter of grazing frequency.

Chlorophyll was estimated using the Soil Plant Analysis Diagnostic index (SPAD index), which was determined with a chlorophyll meter-SPAD502PLUS (Konika Minolta sensing), the readings were taken on the newly expanded diagnostic sheets +1 and +2, before grazing in eight tillers that were randomly chosen in the experimental plots [9].

2.3. Agronomic Traits and Nitrogen Use Efficiency

Pre- and post-grazing pasture mass was estimated using a metal frame of 0.70×0.35 m. These frames were positioned at points representative of the average pasture height. The samples were cut at ground level and then manually fractionated in leaf blades, stem + leaf sheaths, and dead tissue to determine the percentage of plant components. The fractions were weighed and dried in a forced-air oven at 55°C for 72 h until reaching constant weight, in order to estimate their dry matter (DM) content. From these data, the percentage of plant components was assessed based on DM.

Nitrogen use efficiency (NUE) was estimated according methodology that was described by [16] as follows: (total dry matter production with fertilization (kg)—total dry matter production without fertilization (kg))/nitrogen fertilizer (kg).

2.4. Statistical Analysis

Variable data when in a single grazing cycle from two seasons were weighted in proportion to the number of days in each season to be grouped in according to the season.

Therefore, the data from the plots with nitrogen levels were grouped into the subplots when considering the four seasons: late summer/autumn (from 8 February to 20 June 2014); winter (from 21 June to 21 September 2014); spring (from 22 September to 20 December 2014); and, summer (from 21 December 2014 to 19 March 2015).

The data were submitted to analysis of variance (ANOVA), the variance residues were tested to normality and homogeneity of using the PROC UNIVARIATE, and regression analysis using the MIXED procedure of SAS version 9.2 [17]. When there was an interaction, the data were unfolded to evaluate the effect of season in each nitrogen dose and the effect of dose in each season. All of the statistical procedures were conducted by using 0.05 as the critical probability level for a type I error. Regression equations were chosen based on the determination coefficient and the significance of the regression coefficients while using the t test, adopting $\alpha = 0.05$.

3. Results

3.1. Number of Cycles and Grazing Intervals Throughout

Tables 2 and 3 present the number of cycles and grazing intervals throughout the experimental period as a function of nitrogen fertilization and seasons of the year.

Nitrogen fertilization with application of 150, 300, and $450 \text{ kg ha}^{-1} \text{ N}$ resulted in two, three, and four additional grazing cycles in relation to grass not fertilized with nitrogen, respectively.

Table 2. Number of grazing cycles of grass pastures *Brachiaria brizantha* cv. Piatã under rotational stocking and fertilized with nitrogen throughout seasons of the year.

Nitrogen ($\text{kg ha}^{-1} \text{ N}$)	Late Summer/Autumn	Winter	Spring	Summer	Total
0	1	2	2	1	6
150	2	2	2	2	8
300	2	2	3	2	9
450	2	3	3	2	10

Table 3. Average grazing interval (days) of grass pastures *Brachiaria brizantha* cv. Piatã under rotational stocking and fertilized with nitrogen throughout seasons of the year.

Nitrogen (kg ha ⁻¹ N)	Late Summer/Autumn	Winter	Spring	Summer
0	58	85	47	61
150	44	72	41	49
300	39	59	38	41
450	32	59	29	35

3.2. Averages for Pre-Grazing Forage Mass

There was an interaction effect between the nitrogen doses and seasons of the year for pre-grazing forage mass ($p < 0.05$) of Piatã grass pastures (Table 4). It was possible to observe a linear increase of forage mass as a function of the nitrogen doses, estimating increases of 3.29, 5.04, 5.43, and 6.86 kg DM for each kg of N added for winter, summer, late summer/fall, and spring, respectively.

Table 4. Averages for pre-grazing forage mass (kg DM ha⁻¹) of *Brachiaria brizantha* cv. Piatã under rotational stocking and nitrogen fertilization throughout seasons of the year.

Seasons of the Year	Nitrogen (kg ha ⁻¹ N)				Regression Equation **	r ²
	0	150	300	450		
Late summer/autumn	2228ab	2621bc	3524b	4646b	$\hat{Y} = 2031.8000 + 5.4364 N$	0.9604
Winter	1806b	2068c	2634c	3266c	$\hat{Y} = 1701.8666 + 3.2980 N$	0.9708
Spring	2503a	3981a	4867a	5641a	$\hat{Y} = 2703.6000 + 6.8662 N$	0.9751
Summer	2420ab	2930b	3868b	4628b	$\hat{Y} = 2327.7000 + 5.0413 N$	0.9883
CV (%)	15.44					

Averages followed by the same lowercase letter on the column for the seasons of the year do not differ ($p < 0.05$) among themselves by Tukey's test. ** Significant at 5% probability.

The highest increments estimated for the forage mass in the summer period resulted in a production of 5793 kg DM ha⁻¹, and for the non-fertilized pasture was estimated a production of 2703 kg DM ha⁻¹ for the same season of year. The lowest forage mass production was observed in the winter, with 3.29 kg DM at each kg of nitrogen applied. In this condition, the production was 1701 kg DM in the absence of fertilization, and 3.185 kg DM with the higher dose (Table 4).

The highest pre-grazing forage mass were verified ($p < 0.05$), especially in spring and summer, followed by winter and late summer/autumn.

Nitrogen use efficiency (kg DM kg⁻¹ N) that was applied by *Brachiaria brizantha* cv. Piatã increased with increasing doses of N (Table 5).

Table 5. Nitrogen use efficiency by *Brachiaria brizantha* cv. Piatã under rotational stocking and nitrogen fertilization throughout seasons of the year.

Nitrogen (kg ha ⁻¹)	Nitrogen Use Efficiency (kg of DM kg ⁻¹ N)
150	17.62
300	19.78
450	20.49

3.3. Percentage of Leaf, Stem and Dead Material in the Pre-Grazing Forage

Figure 4 presents the percentage of leaf, stem, and dead material in the pre-grazing forage mass as a function of the seasons of the year. It was observed that, regardless of nitrogen fertilization, there was a greater contribution ($p < 0.05$) of the leaf blade in all seasons of the year, with an average value of leaf/stem ratio of 1.25.

The percentage of dead tissue increased ($p < 0.05$) throughout the late summer/autumn and especially in winter (Figure 4).

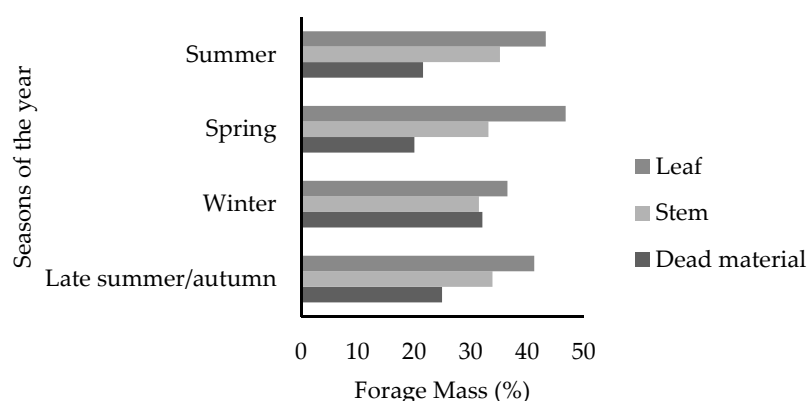


Figure 4. Percentage components of pre-grazing forage mass of *Brachiaria brizantha* cv. Piatã under rotational stocking fertilized with nitrogen throughout seasons of the year.

Nitrogen doses linearly increased ($p < 0.05$) the percentage averages of leaf blade in pre-grazing forage mass (Table 6). When comparing the leaf blade percentage of paddocks without fertilization with the highest nitrogen dose, there was an increase of 5.67, 5.31, 7.15, and 7.11% for the late season of summer/autumn, winter, spring, and summer, respectively.

Table 6. Percentage averages of leaf blade in pre-grazing forage mass of *Brachiaria brizantha* cv. Piatã under rotational stocking and nitrogen fertilization throughout seasons of the year.

Seasons of the Year	Nitrogen (kg ha ⁻¹ N)				Regression Equation **	r ²
	0	150	300	450		
Late summer/autumn	37.36	42.20	41.43	43.93	$\hat{Y} = 38.3933 + 0.0126 N$	0.7720
Winter	34.36	34.50	37.93	39.13	$\hat{Y} = 33.8233 + 0.0118 N$	0.8965
Spring	42.60	46.50	48.06	50.03	$\hat{Y} = 43.2200 + 0.0159 N$	0.9561
Summer	39.16	43.00	44.36	46.63	$\hat{Y} = 39.7266 + 0.0158 N$	0.9599
CV (%)	10.24					

** Significant at 5% probability.

The nitrogen fertilization promoted an increasing linear effect ($p < 0.05$) on the LAI and SPAD indexes in the pre-grazing forage of Piatã grass, the spring season promoted the greatest values of the LAI and SPAD indexes (Table 7).

Table 7. Averages for leaf area index (LAI) and Soil Plant Analysis Diagnostic index (SPAD index) in the pre-grazing forage of *Brachiaria brizantha* cv. Piatã under rotational stocking and nitrogen fertilization throughout seasons of the year.

	Nitrogen (kg ha ⁻¹ N)				Regression Equation **	R ²
	0	150	300	450		
LAI	3.13	3.44	3.65	3.81	$\hat{Y} = 3.1713 + 0.0015 N$	97.60%
SPAD	33.21	36.75	38.56	41.22	$\hat{Y} = 33.5646 + 0.0172 N$	98.44%
Seasons of the Year						
	Late summer/autumn	Winter	Spring	Summer	CV (%)	
LAI	3.48ab	3.12c	4.03a	3.39b	13.64	
SPAD	35.72b	35.36b	41.46a	37.21b	15.72	

Averages followed by the same lowercase letter on the row do not differ ($p < 0.05$) among themselves by Tukey's test. ** Significant at 5% probability.

For the percentage of stem and dead material, there was a significant effect ($p < 0.05$) on the pre-grazing forage mass of *Brachiaria brizantha* cv. Piatã (Table 8). An increase of 0.0048% stem and reduction of 0.0189% senescent material was observed as a function of each kg of nitrogen applied.

Table 8. Percentage averages of stem and dead material in post-grazing forage mass of *Brachiaria brizantha* cv. Piatã under rotational stocking and nitrogen fertilization throughout seasons of the year.

	Nitrogen (kg ha ⁻¹ N)				Regression Equation **	r ²
	0	150	300	450		
Stem	31.88	33.64	33.76	34.28	$\hat{Y} = 32.2950 + 0.0048 N$	0.8196
Dead material	29.72	24.81	23.25	20.78	$\hat{Y} = 28.9033 - 0.0189 N$	0.9440

** Significant at 5% probability.

There was no interaction ($p > 0.05$) for post-grazing forage mass of Piatã grass (Table 9). For the nitrogen doses, there was an increasing linear behavior ($p < 0.05$). When comparing the post-grazing pasture mass of the pasture without fertilization with the highest level of nitrogen fertilization, an increase of 43.12% was observed in the forage mass. When comparing the seasons of the year, higher values were observed in spring and summer due to the best weather conditions (Figures 1 and 2) (Table 9).

Table 9. Averages for post-grazing forage mass (kg DM ha⁻¹) of *Brachiaria brizantha* cv. Piatã under rotational stocking and nitrogen fertilization throughout seasons of the year.

Nitrogen (kg ha ⁻¹ N)	0	150	300	450	Regression Equation **	<i>r</i> ²
	1046	1440	1782	2060	Ŷ = 1075.0500 + 2.2564 N	
Seasons of the Year	Late Summer/Autumn	Winter	Spring	Summer	CV (%)	
	1602b	1002c	1984a	1740ab	28.23	

Averages followed by the same lowercase letter on the row do not differ ($p < 0.05$) among themselves by Tukey's test. ** Significant at 5% probability.

The percentage of dead material in post-grazing forage mass increased throughout the late summer/autumn and especially in winter (Figure 5).

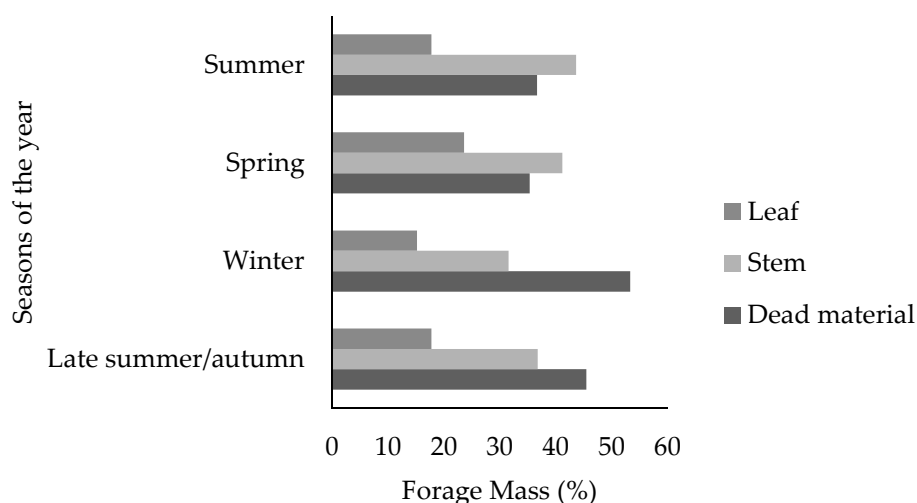


Figure 5. Percentage components of post-grazing forage mass of *Brachiaria brizantha* cv. Piatã under rotational stocking and fertilized with nitrogen.

The leaf blade obtained a significant effect ($p < 0.05$). Through the equation, an increasing linear behavior ($p < 0.05$) was observed in all seasons of the year (Table 10). When comparing the leaf blade percentage of the pasture without fertilization with the highest nitrogen dose, there was an increase of 33.91, 36.25, 70.47, and 18.29% for the late season of summer/autumn, winter, spring, and summer, respectively.

Table 10. Percentage averages of leaf blade in post-grazing forage mass of *Brachiaria brizantha* cv. Piatã subjected to nitrogen fertilization throughout seasons of the year.

Seasons of the Year	Nitrogen (kg ha ⁻¹ N)				Regression Equation **	r ²
	0	150	300	450		
Late summer/autumn	14.36	16.36	18.53	21.70	$\hat{Y} = 14.1166 + 0.0161 N$	0.9873
Winter	11.36	14.50	16.60	18.13	$\hat{Y} = 11.7900 + 0.0149 N$	0.9747
Spring	20.60	23.60	24.06	26.03	$\hat{Y} = 21.0600 + 0.0111 N$	0.9286
Summer	16.83	20.00	20.93	20.96	$\hat{Y} = 17.6833 + 0.0088 N$	0.7775
CV (%)	12.24					

** Significant at 5% probability.

There was no interaction effect ($p > 0.05$) for the percentage of stem and dead material in post-grazing. However, nitrogen fertilization linearly increased ($p < 0.05$) stem percentage and linearly decreased ($p < 0.05$) dead material (Table 11). The production of grass without fertilization in relation to pasture with the highest nitrogen dose provided an increase of 11.62% stem mass and a reduction of 21.79% senescent tissue.

Table 11. Percentage averages of stem and dead material in post-grazing forage mass of *Brachiaria brizantha* cv. Piatã under rotational stocking and nitrogen fertilization throughout seasons of the year.

	Nitrogen (kg ha ⁻¹ N)				Regression Equation *	r ²
	0	150	300	450		
Stem	35.63	37.80	39.27	40.40	$\hat{Y} = 35.9125 + 0.0105 N$	0.9782
Dead Material	48.55	43.59	40.77	37.87	$\hat{Y} = 47.9300 - 0.0232 N$	0.9788

* Significant at 5% probability.

4. Discussion

Nitrogen fertilization accelerated pasture growth, reducing recovery time after grazing, which resulted in reduced intervals and an increased number of grazing cycles. These effects provided higher forage mass as the nitrogen dose increased at all seasons of the year studied. These results were similar to those that were reported by [18], who evaluated the effect of nitrogen doses (0, 125, 250, 375, and 500 kg ha⁻¹ N) on the productive characteristics of the *Brachiaria brizantha* cv. Piatã.

It was characterized that even in the winter season, marked by climatic deficits (Figures 1 and 2), the plant with its nitrogen demand supplied, there is an increase of more than 40% in forage production when compared to the pasture without fertilization, which can represent a higher stocking rate in the most critical period of the year. [2] evaluated the morphogenic and structural characteristics of guinea grass by combining the frequencies and intensities of grazing over the seasons, and also verified that the ecophysiological grazing management combined with nitrogen fertilization presented superior responses to even in the period of water deficit. [18] also observed higher forage mass values in the spring/summer season as compared to the autumn/winter season when they evaluated the forage mass production of six grasses (xaraés, mombaça, tanzania, pioneiro, marandu, and estrela) under grazing and fertilized with nitrogen doses (100, 300, 500 and 700 kg ha⁻¹ N year). The authors justified the results by the higher temperatures which increased plant metabolism. In the present study, the results were also a consequence of weather conditions favorable to pasture growth, characterized by higher

rainfall index and nitrogen fertilization (Figures 1 and 2). According to [19], the increase in forage mass production is a function of nitrogen that actively participates in the synthesis of organic compounds, thus forming plant structures, such as molecules of chlorophyll, proteins, vitamins, pigments, and amino acids. Therefore, such results evidenced the need for nitrogen fertilization in the pastures in order to obtain higher yields in tropical regions.

The increases in NUE were below those that were reported by [20] (57 to 31 kg DM kg⁻¹ N, with doses from 75 to 300 kg ha⁻¹ N). According to [9], the reduced efficiency can be explained by the plant's lower capacity to absorb and use the nutrient for production, besides possible soil leaching or accumulation in the tissues.

The greater contribution of the leaf blade showed in all seasons of the year results in higher nutritive value, since the leaves are the fraction of the forage plant with the highest digestibility, and in contrast, the lowest nutritive value, due to the higher presence of stem and material dead [2,21].

Therefore, although tropical grasses lengthen their internodes to raise the apical meristem for emitting the inflorescence, from the vegetative to the reproductive phase [22], which for the Piatã grass occurs in the months of January and February, as can be verified in Figure 3, such behavior was not observed in the present study. Thus, the efficiency of grazing management based on the interruption of pasture growth with 95% LI is independent of greater or lesser doses of nitrogen. Similar behavior to those reported by [2] with *Panicum maximum* Jacq. cv. Tanzania, [6] with *Brachiaria brizantha* cv. Xaraés, [10] with *Brachiaria brizantha* cv. Piatã and [20] with *Brachiaria decumbens*, studies that the grazing management of tropical grasses were based on luminous interception with nitrogen fertilization at different times of the year.

For this reason, it can be considered that grazing management with 95% LI was efficient in promoting a pasture structure with higher proportions of leaf blades while using the rotational stocking method with variable stocking rate. However, the stem proportion was around 32%, which may lead to a perspective that a more frequent grazing management could lead to a higher harvesting efficiency. Thus, the goal of 90% LI could be tested in the future, since sheep are animals with selective behavior in which the tiller select leaf by leaf when grazing, allowing for lengthening the stem.

The increased in percentage of dead tissue during summer/autumn and especially in winter can be explained by unfavorable weather conditions (Figures 1 and 2). At these seasons of the year, it is possible that the plant anticipates the death of tillers and reduces the leaf area by accelerating the senescence of older leaves in order to limit their transpiring surface and delay the worsening of the water deficit [23]. Consequently, there is an increase in the relative participation of dead tissue in the pasture [8].

The 95% of light interception as the regulator for starting grazing sheep, especially in winter, caused a lower leaf: stem ratio in pre-grazing than in other seasons, and it may have provided a greater proportion of dead material in post-grazing than in other seasons of the year. Probably, the selective behavior of grazing sheep and the less availability of leaves blade in the winter may have caused more intense grazing, reducing the amount of photosynthetically active leaves in post-grazing. In the winter, the lower solar incidence and water available plus the less area of photosynthetically active leaf blade from the intensive grazing sheep can increase the stress in the restoration of the pasture structure with 95% of light interception that can decrease the amount of grazing cycles [7]. In this way, perhaps the combination between nitrogen fertilization and the change in light interception to 90% can decrease the proportion of dead material and promote a greater residue of photosynthetically active leaf blades, by increasing the availability of leaves for grazing, and thus favoring the forage recovery, which can increase the amount of grazing cycles in this critical period [8].

Nitrogen doses were efficient in increasing forage mass production of leaf blade at all evaluated seasons. According to [24], the forage mass production of leaf blade is an important feature for forage growth, since the leaf blade is the most photosynthetically active component in the plant. Thereby, a larger area for energy uptake can promote the greater accumulation of biomass [12]. Moreover, leaves are the part of the plant with the highest nutritional value [4].

These results can be explained by favorable climatic factors (Figures 1 and 2) that are associated with nitrogen fertilization, which give the plant greater assimilation of nitrogen that stimulates the tillering and, hence, increases the emergence of leaves [10]. This fact was the main factor responsible for the greater number of grazing cycles at the highest nitrogen dose, as can be observed in Table 2. Pastures fertilized with $450 \text{ kg ha}^{-1} \text{ N}$ obtained four cycles of grazing more than the paddock without fertilization. This also has a direct relationship with the average grazing interval (days), which promoted a reduction of 24 days when comparing to the pasture without fertilization with the highest nitrogen dose. Pasture managed with the rotational stocking method, with a variable stocking rate and higher nitrogen fertilizations, may possibly promote greater individual gain due to the greater number of grazing cycles. In this reality, it is natural to have new tillers, with new leaves and high nutritional value, interesting for productive systems aimed at the termination of animals or greater animal rotation in the system.

The percentage of dead material in post-grazing forage mass during late summer/autumn and winter likely may be increased due to the limitations of weather conditions (Figures 1 and 2) due to the higher senescence rates that were recorded in these seasons. Similar results were observed by [25] in the morphological composition of the forage of xaráes grass, which also varied with the increase of leaf blades throughout the rainy seasons (spring and summer) and the inverse behavior for dead material throughout the year, with higher values in autumn and winter. In addition, the leaf blade percentage in post-grazing forage mass also increased. These results corroborate with the results of [10], which observed a higher production of leaf blade mass in the Piatã grass receiving doses up to $500 \text{ kg ha}^{-1} \text{ N}$.

The morphological composition of the post-grazing forage mass is a very important productive characteristic, because the higher the participation of the leaf blade component in the remaining forage mass, the lesser the mobilization of organic reserves by the apical meristem for the replacement of leaves, since the faster will be the recovery of the photosynthetic apparatus of the pasture [8,26], ensuring the production and continuity of the pasture [5]. In this way, the balance between maintaining sufficient leaf area for photosynthesis and harvesting large amounts of leaves before senescence should be sought in order to favor rational and efficient pasture exploitation [3]. According to [27], after grazing or cutting, in spite of reduced shading, the remaining leaves showed reduced photosynthesis, probably because their development occurred partially under intense shading.

According to [9], the maximum average rate of forage accumulation occurs when the canopy reaches 95% LI, which is the right moment for the interruption of regrowth, since, from that moment on, the lower leaves become completely shaded by the upper leaves, thus decreasing the photosynthetic activity of leaves, passing from the condition of source of photoassimilates to the drainage condition. Thereby, if the regrowth of pasture was not interrupted, there were subsequent increases in leaf area index, thus reducing the pasture accumulation rate as a function of the increase in respiration rates that result from an increase in the amount of tissues without photosynthetic function (senescent) [5].

Thus, nitrogen fertilization levels promoted an increase in yield of the Piatã grass, due to the higher photosynthetic efficiency of leaves [8], that can be observed through the SPAD and LAI indexes (Table 7). The LAI and SPAD indices, when measured and associated with a 95% light interception control, a value that promotes the minimum of self-shading, provided that the forage is harvested with a high leaf: stem and also of biomass production close to the maximum value, in the moment of the best relationship between quality of chemical composition and biomass production, these values are limited by the factors solar irradiation, water, and soil nutrient availability; due to this, the nitrogen fertilization provided greater tissue flows expressed in the LAI and SPAD index values.

This productivity was predominantly composed in its morphological structure by the high percentage of leaf blade. The percentage of stem elongation was maintained to satisfactory values, since the leaf blade production showed positive linear behavior in as much as the nitrogen fertilization increased. Thus, despite nitrogen accelerating the flow of tissues in the grasses [19], the use of light interception (95% LI) as a strategy to define the grazing moment provided an efficient harvest of the pasture of piatã grass by the animals, with a greater percentage of leaves and lower percentages of stem and senescent material, regardless of the seasons of the year.

Thus, the use of the grazing frequency target based on a 95% light interception efficiently controlled the stem, especially in the autumn-winter period, when the apical meristem takes up the temperature change, and induces the plant to leave the vegetative stage for the reproductive stage [9]. This stage change promotes the loss of the pasture structure, due to the increase in stem and dead material, which negatively affects the harvesting process and fiber digestibility by animals.

5. Conclusions

Nitrogen fertilization that is associated with grazing management of 95% LI led to greater productivity in the pasture of Piatã grass, promoting high production of leaf blades, regardless of the seasons of the year. The highest nitrogen use efficiency was obtained with the dose of 450 kg ha⁻¹ N.

In the future, research can be developed to evaluate the grazing management based on combined between the light interceptions on 90% and 95%, with the use of nitrogen fertilizer in according the season of the year, due to the sheep had an ingestive behavior that grazing on pasture with lower structure.

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