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Article

Forage availability in Xaraés grass pastures subjected to nitrogen sources of the slow and fast release

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Abstract:

The N-(*n-butyl*) thiophosphoric triamide (NBPT), a urease inhibitor, has been reported as one of the most promising compounds to reduce losses by volatilization, and to maximize the use of urea nitrogen (N) in agricultural systems. A field study was carried out to examine urease inhibitors' potential about volumetric density and forage mass grass (*Brachiaria brizantha* cv. Xaraés) to N application. The experiment was carried out from September 2017 to September 2018. The experimental design used was complete randomized blocks in the 3×2×4 factorial array, considering: three periods of the year (wet season, dry season, and the transition), two sources of urea (conventional urea and NBPT–treated urea), and four N rates (0, 80, 160 and 240 kg N ha^{-1} yr^{-1}), replicated three times. Nitrogen sources promoted a positive effect (P<0.0001) on bulk density, forage mass, and in the grazing stratum during the wet season and the transition season, with increasing N rates in pastures. The leaf: stem ratio decreased linearly (P<0.0045) as increased N rates, and the higher ratio during the wet season and lower in the dry season of the year. For the rates of 80 kg N ha^{-1} yr^{-1}, there was a significant difference (P=0.0042) between sources, with greater (P=0.0006) forage mass of 0–30 cm, post-grazing forage mass (P=0.0042) and forage volumetric density (P=0.0006), when utilized the conventional urea. The application of N, regardless of the source, provides an increase in forage mass and volumetric density in Xaraés grass pastures up to a dose of 240 kg N ha^{-1} yr^{-1}, in the transition season and wet season.

Key words: *Brachiaria brizantha*, Nutrient use efficiency, Pastures, Ammonia volatilization.

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Introduction

Nitrogen fertilization has been used as an important strategy to increase forage supply in quantity and quality. Nitrogen (N) is an important constituent of proteins and the main nutrient for maintaining productivity. When applied, it is assimilated by the plants, promoting the increase of cellular constituents(1) and, consequently, increasing the regrowth vigor and the total production of green dry matter of the plant under favorable climatic conditions.

Urea [$CO(NH_2)_2$] is the fertilizer that has had more problems with the topdress soil due to N losses through volatilization of NH_3(2,3). Changes in the amount of N available in the system and in the nitrate:ammonium ratio in the soil solution affect N recovery and use efficiency, dry matter yield, and chemical composition of pastures(4). Nevertheless, this source is considered one of the most important due such as high N concentration (46 % N) and lower production costs compared to other N sources(5-9).

Many researchers have worked in order to mitigate NH_3 losses from urea treating it with a urease inhibitor, of which N-(*n-butyl*) thiophosphoric triamide (NBPT) is the most studied and utilized compound (10-17). Even though most studies have proved the potential of urea treated with NBPT-based products to reduce NH_3 losses(18-21), the benefits of urea treated with NBPT compared with untreated urea are less consistent to increase forage production, with no yield difference under some conditions(23,24,25).

Such inconsistencies in certain studies probably are associated with the weather and soil conditions at the time of fertilizer application. The increasing N rates(26,27), the application of urea over to soils with high moisture and temperature, usually cause enhanced NH_3 loss(20,26) and hence, makes the use of urease inhibitors more attractive as a tool to increase N use efficiency. Conversely, low temperature or dry conditions may limit urea hydrolysis and, thus NH_3 losses(20,28).

In view of the above, there are uncertainties regarding the advantages of using NBPT-treated urea under such conditions for increasing pasture yield. This study aimed to evaluate the effect of the potential of urease inhibitors regarding forage volumetric density and in the forage mass grass (*Brachiaria brizantha* cv. Xaraés) to N application.

Material and methods

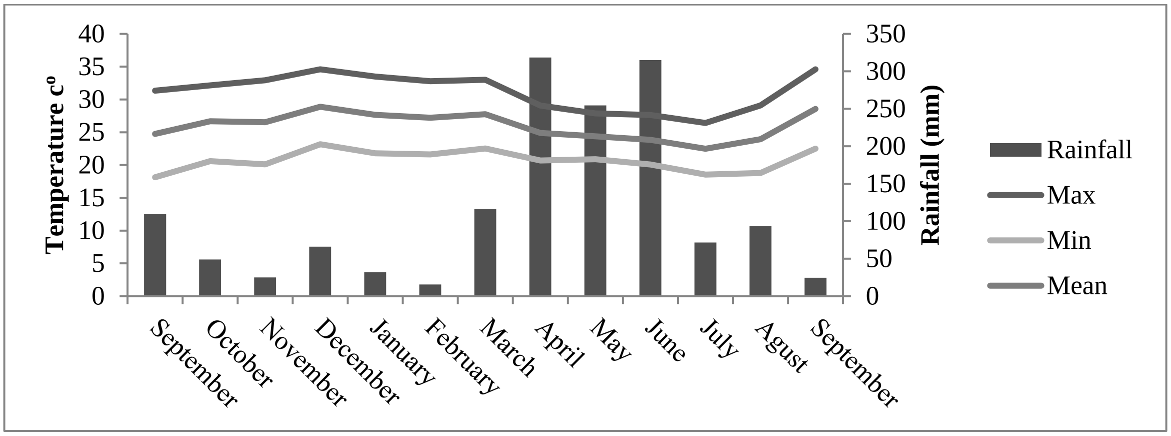
Location of the experiment and climatic conditions

The experiment was carried out from September 2017 to September 2018, on the Talitha farm located in the district of Monte Gordo, Camaçari city, state of Bahia, Brazil, located at 12°41'51" latitude, 38°19'27" longitude, and 36 m altitude. The average annual temperature is around 23.3°C and an average rainfall of 1,466.5 mm. The soil in the experimental area with free sand soil showed the following chemical and physical characteristics: organic matter (OM)= 21.0 g dm^{-3}; pH (H_2O)= 5.3; P= 4.0 mg dm^{-3}; K= 0.2 mmolc dm^{-3}; Ca= 13.0 mmolc dm^{-3}; Mg= 7.0 mmolc dm^{-3}; Na= 0.0 mmolc dm^{-3}; Al= 0.0 mmolc dm^{-3}; H + Al = 18.0 mmolc dm^{-3}; SB= 20.0 mmolc dm^{-3}; CTC= 38.0 mmolc dm^{-3}; V= 53%; sand= 894 g dm^{-3}; slime 18 g dm^{-3}; clay= 88 g dm^{-3}.

Treatments and experimental design

The experimental design used was complete randomized blocks in the 3 × 2 × 4 factorial array, considering: three periods of the year (wet season, dry season, and the transition), two sources of urea (conventional urea and NBPT-treated urea), and four rates N (0, 80, 160 and 240 kg N ha^{-1} yr^{-1}), with three replications. The experimental period lasted 380 d, being monitored temperature, rainfall index (Figure 1), and water balance (Figure 2) using a water storage capacity of 50 mm(29).

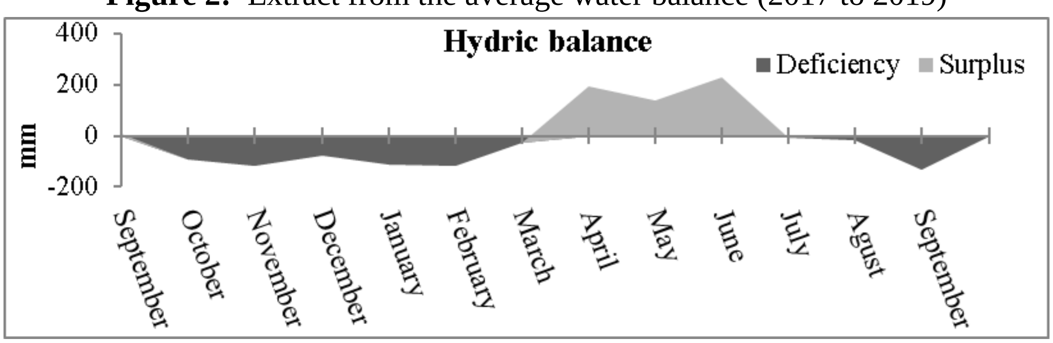
Figure 1 : Precipitation index and monthly average temperature (2017 to 2018)



The fertilizing and planting operations were implemented on June 26, 2016. For planting 15 kg ha^{-1} was used of *Brachiaria brizantha* cv. Xaraés seeds, 70 kg P_2O_5 ha^{-1} (single superphosphate), 60 kg KCL ha^{-1} (potassium chloride), and 50 kg of N ha^{-1} in coverage, throughout the experimental area.

The total experimental area including corridors, management area, and spacing between plots was 0.66 ha, divided into three blocks, each plot measuring 10 m × 10 m, totaling 100 m^2. All plots received an application of 30 kg P_2O_5 ha^{-1}, 200 kg KCL ha^{-1}. The application of N was done in coverage, except in the 0 rates of N. Superphosphate was applied in a single dose in the first cycle, but potassium chloride and N were divided into four applications of equal amounts (beginning and end of the rainy period).

Figure 2: Extract from the average water balance (2017 to 2019)



The monitoring of the canopy height started after post-grazing, performed three times a week until reaching pre-grazing height (30 cm). Twelve readings were performed for each experimental unit using a graduated stick and a radiographic film sheet, according to

Pequeno[30]. The pasture defoliation was carried out by adding or removing regulating animals ("mob grazing")[31] simulating a rotational grazing scenario.

Traits measured

The forage cuts were performed at a height above 15 cm, which resulted in the forage mass in the grazing stratum, and at ground level (0 – 15 cm in height) in the pre-grazing, the result of the sum of these cuts corresponded to the mass of forage of 0–30 cm. As for the post-grazing forage mass sampling, the cuts were performed at ground level. Forage samples corresponding to each of the canopy strata were weighed and then placed in an air forced circulation oven at 65 °C until constant weight. Subsequently, the samples were used for the analysis of dry matter (DM) content using the Next Infrared Reflectance Spectroscopy System (NIRS) according to procedures Marten *et al* [32]. The reflectance data of the samples, in the wavelength range of 700–2,500 nm, were stored by a spectrometer (model Unity Scientific SpectraStar ™ 2500 XL).

With the result of dry matter yield (DMY), the forage volumetric density was determined calculated by dividing the forage mass in the pre-and post-grazing by the corresponding pasture height, with values expressed in kg ha^{-1} cm^{-1} of DM, according to the methodology of Stobbs[33]. Thus, the forage volumetric density (kg DMY ha^{-1} cm^{-1}) was obtained, corresponding to the stratum from 0 to 30 cm in height, and the volumetric density of the grazing stratum (kg DM ha^{-1} cm^{-1}) from 15 to 30 cm in height.

After removing the animals, two groups of ten tillers were identified at random in different areas of the experimental unit (paddock)[34], and at the end of the grazing cycle, they were cut close to the soil surface. Then, the morphological separation in leaf, stem, and dead material was carried out with respective weighing and drying at 65 ºC for 72 h for further analysis. Subsequently, the leaf:stem ratio was determined by dividing leaf grams and stem grams.

Statistical analysis

The variables were subjected to analysis of variance using the PROC MIXED of SAS (Statistical Analysis System - version 9.2 for Windows®) as described by model below:

$$\mathbf{Y_{ijkl}} = \mu + B_i + S_j + D_k + (SxD)_{jk} + e_{ijk} + P_l + (SxP)_{jl} + (DxP)_{kl} + (SxDxP)_{jkl} + \varepsilon_{ijkl}$$

Where:

$\mathbf{Y}_{ijkl}$ = observed value;

$\boldsymbol{\mu}$= overall mean;

B_i= random effect of the blocks;

S_j = fixed effect of the N source;

D_k= fixed effect of N rate;

$(SxD)_{jk}$= interaction effect of source *x* rate;

e_{ijk} = random error associated with source and rate of N;

P_l = fixed effect of the period of the year;

$(SxP)_{jl}$ = interaction effect of source *x* period;

$(DxP)_{jL}$= interaction effect of rate *x* period;

$(SxDxPx)_{jkl}$ = interaction effect of source *x* rate *x* period;

$\mathcal{E}_{ijkl}$ = random error associated with period effect.

The results for the of quantitative factors (rate) were evaluated by regression analysis, and for qualitative factors (source and period) the Tukey test, both considering 5% probability to type I error.

Results

Forage mass (0–30 cm) varied with sources of urea (*P*=0.0145), periods of the year (*P*=0.0230), N rates (*P*<0.0001), and interaction (*P*=0.0020). In the interaction, there was a positive linear effect (*P*≤0.05) for the conventional urea and NBPT-treated urea, in the forage mass of 0–30 cm, as there was an increase in rates in pastures, however with similar mass values between sources. However, for the rate of 80 kg of N ha^{-1} yr^{-1} there was a significant difference (*P*=0.0006) between the sources (conventional urea and NBPT-treated), with the means, respectively, of 4,093.28 and 3,450.44 kg DM ha^{-1} (Table 1).

A positive linear effect was observed during the wet season and the in transition, resulting in more N pasture growth as N rate increased. However, in the dry season, the N rate had no effect on pasture growth (Table 1). The pastures that did not receive fertilization and those that received rates of 80 kg of N ha^{-1} yr^{-1}, the forage mass (0–30 cm) did not show significant differences (*P*>0.05) with the periods of the year. The rates of 160 (*P*=0.0372) and 240 kg of N ha^{-1} yr^{-1} the forage mass was higher (*P*≤0.05) during the wet season and the transition when compared to the dry season.

For forage mass in the grazing stratum (15–30 cm), significant effects (*P*≤0.05) were observed too for the periods of the year, N rates, and interaction. In the interaction, there was a positive linear effect during the wet season (*P*<0.0001) and the transition (*P*<0.0001) season, plants that had more water were able to respond to the N added. However, for the dry season there was no rates effect (*P*>0.05) when adjusted to the linear and quadratic functions (Table 1).

When comparing periods of the year with N fertilization rates, the forage mass in the grazing stratum did not differ (*P*>0.05) for pastures that did not receive fertilization and those that received rates of 160 kg of N ha^{-1} yr^{-1}. However, for the rates of 80 and 240 kg of N ha^{-1} yr^{-1}, the periods during the wet season and the transition, presented higher mass production in the potentially grazing stratum (Table 1).

Table 1: Forage available by stratum of the Xaraés grass in response to the N rates during periods of the year (wet season, dry season, and the transition)

	Rates (kg N ha^{-1} yr^{-1})				**Effect**	
Period of year	**0**	**80**	**160**	**240**	***L***	***Q***
Forage mass (0 – 30 cm) (kg DM ha^{-1})						
Wet	3136.2^a	3765.5^a	3876.1^a	4023.9^a	<0.0001[1]	0.2534
Dry	3477.9^a	3730.9^a	3339.2^b	3350.3^b	0.2393	0.4207
Transition	3360.9^a	3819.2^a	3527.9^b	4330.5^a	<0.0001[2]	0.1022
P-value	0.2456	0.9174	0.0372	<0.0001		
Forage mass in the grazing stratum (kg DM ha^{-1})						
Wet	1005.8^a	1152.6^a	1164.1^a	1259.3^a	<0.0001[3]	0.4761
Dry	1021.0^a	904.5^b	1048.2^a	990.9^b	0.8301	0.5496
Transition	947.1^a	1121.9^a	1105.7^a	1338.1^a	<0.0001[4]	0.5228
P-value	0.4946	0.0001	0.1355	<0.0001		
Post-grazing forage mass (kg DM ha^{-1})						
Wet	1879.0^b	2346.5^a	2250.5^a	2481.8^a	0.0004[5]	0.4476
Dry	2394.6^a	2226.7^a	2344.4^a	2245.1^{ab}	0.4604	0.7318
Transition	2045.3^b	2083.1^a	2164.8^a	2050.4^b	0.8395	0.2411
P-value	0.0022	0.1836	0.4484	0.0136		

L= linear; Q= quadratic; N= nitrogen; DM= Dry matter.

[ab] Mean values followed by different letters, in the same column, are different at 5 % probability by Tukey's test.

Regression equations: [1]$\hat{Y} = 3.4671x + 3284.4$ $R^2 = 0.84$; [2]$\hat{Y} = 3.2719x + 3367$ $R^2 = 0.63$; [3]$\hat{Y} = 0.9649x + 1029.7$ $R^2 = 0.91$; [4]$\hat{Y} = 1.4463x + 954.66$ $R^2 = 0.87$; [5]$\hat{Y} = 2.1404x + 1982.6$ $R^2 = 0.73$

In post-grazing, the forage mass of the cultivar Xaraés a significant effect (*P*≤0.05) was observed depending on the period of the year, period × N rates interaction, and source × N rates interaction. In the interaction, a positive linear effect was observed during the wet season as N rates increased (Table 1). The pastures, where fertilizer was not applied, had higher (P=0.0022) forage mass during the dry season. However, no differences (P>0.05) were observed for the rates of 80 and 160 kg of N ha^{-1} yr^{-1} over the period of the year. Pastures that received rates of 240 kg of N ha^{-1} yr^{-1} had higher forage mass during the wet season, but the dry season was similar (P>0.05) to the transition season.

In the interaction, the fast-release N source (conventional urea) was not influenced (P>0.05) by the rates when adjusted to the functions linear and quadratic for forage mass after grazing. However, the interaction showed a positive linear effect (P= 0.0358), as the N rates increased, when using the NBPT-treated urea. For the rate of 80 kg N ha^{-1} yr^{-1}, there was a significant difference (P=0.0042) between sources, with higher post-grazing forage mass using conventional urea and lower the NBPT-treated urea, with means, respectively of 2,391.94 and 2,045.60 kg of DM ha^{-1}.

Table 2: Forage mass and volumetric density in Xaraés grass pastures in response to N application under pre and post grazing conditions

Source	Rates (kg N ha^{-1} yr^{-1})				Effect	
	0	**80**	**160**	**240**	***L***	***Q***
	Forage mass of 0–30 cm (kg DM ha^{-1})					
Urea	3325.0	4093.3	3702.4	3891.6	0.0017[1]	0.1816
NBPT	3325.0	3450.4	3459.7	3911.6	0.0172[2]	0.3521
P-value	1.0000	0.0006	0.1690	0.9052		
	Post-grazing forage (kg DM ha^{-1})					
Urea	2106.3	2391.9	2321.0	2188.8	0.7046	0.2139
NBPT	2106.3	2045.6	2185.5	2329.4	0.0358[3]	0.0534
P-value	1.0000	0.0042	0.2439	0.2268		
	Forage volumetric density (kg DM ha^{-1} cm^{-1})					
Urea	110.8	136.4	123.4	129.7	0.0017[4]	0.1816
NBPT	110.8	115.0	115.3	130.4	0.0173[5]	0.3520
P-value	1.0000	0.0006	0.1689	0.9049		

L= linear; Q= quadratic; N= nitrogen; DM= Dry matter; NBPT= N-(*n-butyl*) thiophosphoric triamide. Regression equations: [1]$\hat{Y} = 1.6363x + 3556.7$ $R^2 = 0.27$; [2]$\hat{Y} = 2.2112x + 3271.3$ $R^2 = 0.79$; [3]$\hat{Y} = 1.0115x + 2045.3$ $R^2 = 0.73$; [4]$\hat{Y} = 0.0546x + 118.55$ $R^2 = 0.27$; [5]$\hat{Y} = 0.0737x + 109.04$ $R^2 = 0.79$

For volumetric density (0–30 cm), under pre-grazing conditions, there were significant differences (P≤0.05) for source, period of the year (P=0.0231), N rates (P<0.0001), source × N rates interaction (P=0.0305), and period × N rates interaction (P<0.0020). In the interaction, a positive linear effect (P≤0.05) was observed during the wet season and the transition; plants that had more water were able to respond to the N added. In the dry season, they were not influenced (P>0.05) by the N rates when they adjusted to a linear and quadratic (Table 3).

Table 3: Forage volumetric density in Xaraés grass pastures in response to N doses during periods of the year (wet season, dry season, and the transition)

Period of year	Rates (kg N ha year) 0	80	160	240	Effect *L*	*Q*
Forage volumetric density (kg DM $ha^{-1}cm^{-1}$)						
Wet	104.5 [a]	125.5 [a]	129.2 [a]	134.1 [a]	<0.0001[2]	0.2535
Dry	115.9 [a]	124.4 [a]	111.3 [b]	111.7 [b]	0.2392	0.4206
Transition	112.0 [a]	127.3 [a]	117.6 [ab]	144.4 [a]	<0.0001[1]	0.1022
P-value	0.2456	0.9174	0.0372	<0.0001		
Volumetric density in the grazing stratum (kg DM ha^{-1} cm^{-1})						
Wet	67.1 [a]	76.8 [a]	77.6 [a]	84.0 [a]	<0.0001[4]	0.4760
Dry	68.1 [a]	60.3[b]	69.9 [a]	66.1[b]	0.8304	0.5493
Transition	63.1 [a]	74.8 [a]	73.7 [a]	89.2 [a]	<0.0001[3]	0.5231
P-value	0.4946	0.0001	0.1357	<0.0001		

L= linear; Q= quadratic; N= nitrogen; DM= Dry matter.

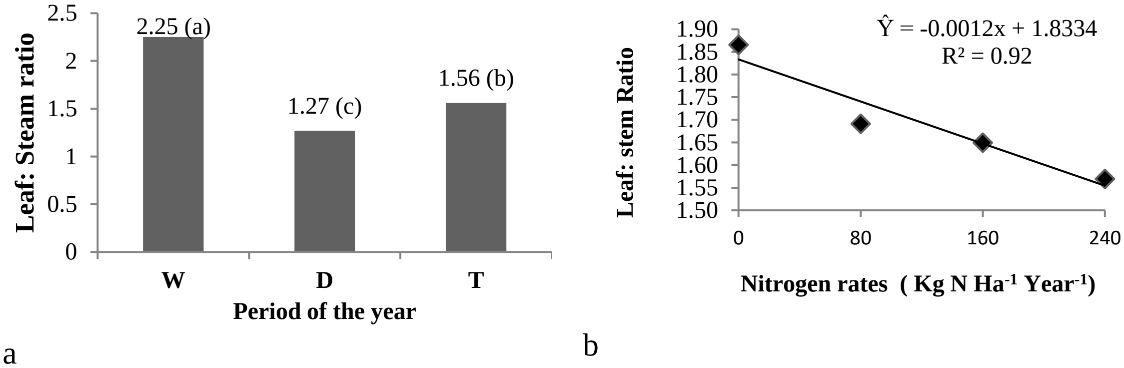
[ab] Mean values followed by different letters, in the same column, are significantly different at 5 % probability by Tukey's test.

Regression equations: [1]$\hat{Y}$= 0.1156x + 109.48 R^2 = 0.84; [2]$\hat{Y}$= 0.1091x + 112.24 R^2 = 0,63; [3]$\hat{Y}$= 0.0643x + 68.649 R^2 = 0.91 [4]$\hat{Y}$= 0.0964x + 63.648 R^2 = 0.87.

When evaluating the volumetric density in the grazing stratum, there was a significant effect (*P*<0.0025) in the period of year × N rates interaction. The interaction showed a positive linear effect was during the wet season and the transition, as there was an increase in N rates in the pastures. However, during the dry season, they were not influenced (*P*>0.05) by the rates when the adjusted function was linear and quadratic (Table 1).

The leaf:stem ratio was influenced (*P*≤0.05) by the periods of the year and N rates. Higher leaf:stem ratio was observed during the wet season and lower in the dry season (Figure 3a). The N sources did not influence the leaf:stem ratio (*P*>0.05). However, the increase in N rates in pastures reflected a linear reduction (*P*≤0.05) in the leaf:stem ratio (Figure 3b).

Figure 3: Leaf: stem ratio in Xaraés grass in response to N rates during periods of the year [wet season (W), dry season (D), and the transition (T)]



[abc] Means followed by the same letter in the column do not differ from each other by the Tukey test, at the 5% probability level.

Discussion

Nitrogen is an important constituent of proteins and the main nutrient for maintaining productivity[35]. When applied, it is assimilated by plants, promoting the increase of cellular constituents[1]. Furthermore, it strongly influences the appearance and elongation of leaves[36,37].Thus, N fertilization acts directly on the growth rate, which in turn affects the increase and availability of forage mass in the pasture.

The forage mass, characterized by the height of the canopy in the pre-grazing, was influenced by the rates of N, which promoted a positive linear effect in the wet season and the transition (Table 1), however in different magnitudes, according to the slope coefficient of the straight line. In the transition period for each kilogram of N applied, increases of 3.2719 kg DM ha^{-1}, and in the wet season values of 3.4671 kg DM ha^{-1} of available forage mass can be expected. These variations in the magnitude of responses to N fertilization can also be related to weather conditions throughout the year (Figure 1), with temperature and humidity in the favorable range for the development of Xaraés grass.

According to Minson[38], the availability of forage mass must be greater than 2,000 kg of DM ha^{-1}, as lower values, promote longer grazing time and reduced pasture consumption by the animals. It is noteworthy that pastures that did not receive N fertilization presented values higher than the above, with averages of 3,360.9; 3,477.9, and 3,136.2 kg MS ha^{-1} in the transition season, dry, and the wet season, respectively (Table 1). This situation can be attributed to defoliation management, with a height goal established respecting the ecophysiological limits of the forage plant.

The grazing strategy was defined according to the recommendations of Pedreira *et al*(39) and Sousa *et al*(40) for the cultivar Xaraés, under intermittent stocking, with the entry of animals to pasture occurring with a pre-grazing height of 30 cm, corresponding to 95 % of light interception (IL), and exit when lowered to 15 cm. Thus, the range of 15–30 cm in height was considered to determine the forage mass available in the grazing stratum (Table 1), which responded to N rates with a pattern similar to the forage mass of 0–30 cm. However, the forage mass in the grazing stratum, in theory, is what will be consumed by the animal during the time of occupation of the paddock. Thus, this stratum will directly influence the animal response, since, in practice, the availability of forage mass is associated with individual consumption by the animals and, consequently, greater performance(41). However, the responses of plants and animals under grazing are conditioned by the structure of the forage canopy(42), which has been characterized by variables such as canopy light interception, sward height, forage mass, and volumetric density. Considering that the pre-grazing height of the pastures was the same for all treatments, fixed at 30 cm. Thus, the variations obtained in the structure of pastures throughout the experimental period were results isolated and/or from the interaction of the sources of variations, of the periods of the year (wet season, dry season, and the transition), of the rates (0, 80, 160, and 240 kg of N ha^{-1} yr^{-1}) and sources N (conventional urea and NBPT-treated).

The forage volumetric density (Tables 2 and 3) and the leaf:stem ratio (Figure 3), evaluated in this study add to the results obtained for forage mass, since they are the relevant components in the structure of the pasture that influence behavior ingestive of the grazing animals(43).

A linear increasing effect was observed for the forage volumetric density and the volumetric density of the grazing stratum during the transition season, and the wet season (Table 3). The forage volumetric density, for each kilogram of N, applied, corresponded to the averages of 0.1091 and 0.1156 kg DM $ha^{-1}cm^{-1}$ for the wet season and the transition, respectively. However, for the volumetric density of the grazing stratum, these increases were 0.0964 and 0.0643 kg DM $ha^{-1}cm^{-1}$ respectively. Increases in forage volumetric density favor the apprehension by the animals during grazing(44), preferably with a greater proportion of leaf blades. The main plant structures that make up the forage volumetric density in the pasture are the leaf blade, stalk, and the ratio (leaf blade/stem), which constitute a relevant tool for the management of forage plants. In the critical limit condition, since a leaf/stem ratio less than 1 means greater production of stems, and these increase biomass production, implying a reduction in the quality of forage produced(45).

The leaf:stem ratio had a negative linear effect, with reductions of 0.0012 points for each kg of N applied to pastures (Figure 3b). However, despite the decreasing slope coefficient, the lowest value of this relationship was above the recommended limit, with a ratio of 1.55 points for rates of 240 kg of N ha^{-1} yr^{-1}(Figure 3b). This decrease can be explained by greater plant growth, but particularly the higher growth of the stems, with higher rates associated with temperature and rainfall conditions during the wet season, and the transition. Increases in the levels of N available to the plant cause an increase in tiller density(46), followed by an increase in the plant growth rate, which can promote early competition for light in the canopy, favoring elongation of the pseudostem(47-50), thus resulting in a reduction in the leaf:stem ratio. Nonetheless, the adopted pasture management strategy avoided excessive culm accumulation, and although present, they were of younger culms that were easily harvested by the animal, that is, consisting basically of pseudostem(39), formed by leaf sheath invaginations.

The blade:stem ratio was influenced by the periods of the year (Figure 3a), with the highest ratio in the wet season (2.25) and the lowest (1.27) in the dry season. Regardless of the season, the blade:stem ratio found in this study are above the pre-established critical limit, configuring a smaller proportion of stalk and demonstrating that the grazing strategy was efficient in controlling stalk elongation, ensuring a better quality of available forage. However, it is important to note that during the dry season, the forage mass of 0–30 cm did not differ from the wet season and the transition in pastures without N fertilization and with 80 kg of N ha^{-1} yr^{-1} (Table 1). For forage mass in the grazing stratum, this condition too was observed in pastures fertilized with 80 and 160 kg of N ha^{-1} yr^{-1}. Considering the leaf:stem ratio in the period of the year (Figure 3b), this situation demonstrates that the predominance of the stalk proportion, which can affect forage quality, impacting in intake, and animal performance.

The available forage mass is the result of forage accumulation during the regrowth period, which in turn is influenced by the post-grazing residue. There was a positive linear effect in the wet season (P<0.0004) for post-grazing forage mass (Table 1), for every kilogram of N applied, approximately 2,1404 kg DM ha^{-1}. This condition provides vigorous regrowth after grazing since greater green leaf remnant can be translated as greater photosynthetic apparatus for the plant to initiate regrowth.

Regarding fast release sources (conventional urea) and slow release sources (urea treated with NBPT) of N, it was expected that the use of protected urea would promote higher production of forage mass in all treatments with NBPT; due to the slow release of the N, since it would have lower losses of NH_3 by volatilization with greater use of N by the plant. However, this did not occur, only at the rate of 80 kg of N ha^{-1} yr^{-1}, differences were verified for forage mass in the pre-and post-grazing, and consequently, in volumetric density, with higher values in pastures fertilized with conventional urea (Table 2).

These results can be attributed to the synergistic effect of some factors: such as crop residues[51,52] which in pastures would be the post grazing residue, concentration of NBPT-treated urea[6], and climatic conditions with high temperatures and soil moisture during the period of fertilizer application[51,52,53]. In the present study, efficient grazing management promoted adequate grazing residue (Table 1) and consequently increased soil vegetation cover, which possibly affected the efficiency of NBPT-treated urea, when applied superficially in systems with leftovers. crop or post-grazing residue, which provides greater ground cover, the efficiency of NBPT-treated urea may be low due to the high urease activity[51].

The source NBPT-treated urea used is a commercial product, which in Brazil is marketed at a concentration of 530 mg kg^{-1}[52]. In a work carried out by the same author, using NBPT-treated urea in sugarcane cultivation with green straw cover, the amount of straw in the soil affected the efficiency of NBPT-treated urea. In this case, the recommendation was to double the 530 mg kg^{-1} concentration of NBPT in urea, as a way to increase its efficiency. Possibly, associated with the post grazing residue at the time of fertilization, the concentration of NBPT-treated urea has contributed to the results found, being indicative of evaluations of the use of NBPT in pastures with higher concentrations.

In addition, fertilizer applications were preceded by rain (Figures 1 and 2) and with favorable temperature, both in the wet season and the transition, a situation that favors the acceleration of NBPT degradation and increased NH_3 volatilization[54,55].

The correct grazing management ensured adequate post-grazing residue, and the increase in N rates reflected in greater forage production, affecting the quantity and the leaf-stem ratio, that was an indirect way of inferring the quality of the forage, and efficiency in the use of the forage produced. However, it may have compromised the efficiency of slow-release urea (NBPT) in promoting an increase in forage mass productivity.

Conclusions and implications

Slow release nitrogen source in Xaráes grass pasture managed with pre- and post-grazing heights of 30 and 15 cm, has no effect on forage availability. Therefore, the application of N, regardless of the sources of slow or fast release, provides an increase in forage mass and volumetric density in pasture up to the rate of 240 kg N ha^{-1} $year^{-1}$, during the wet season and the transition. It is necessary to carry out research, evaluating the increase in the concentration of NBPT-treated urea in tropical grass pastures with different post-grazing height.

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