



Nitrogen efficiency in marandu palisadegrass pastures under increasing nitrogen levels

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ABSTRACT: The use of nitrogen (N) in pastoral ecosystems leads to increased productivity, as it allows the plant to elongate its leaves and, therefore, grazing herbivores harvest the green leaves. However, there are very volatile N sources, which can be replaced by ammonium nitrate, which is less volatile and less dependent on the application in rainy days. The treatments are compound of Marandu palisade grass pastures managed under continuous stocking at a canopy height of 25 cm, with different levels of N fertilizer: 0, 75, and 150 kg ha⁻¹ year⁻¹, as ammonium nitrate (32% of N), with four replicates (pastures) in a completely randomized design. Nitrogen uptake (54.9, 96.5, 113.8 kg N ha⁻¹) and N nutrition index (0.67, 0.98, 1.15) were different between N level, respectively, 0, 75 and 150 kg ha⁻¹ year⁻¹. The N recovery (58.3, 40.9 %) differed between 75 and 150 kg ha⁻¹ year⁻¹, respectively. The dose of 75 kg N kg ha⁻¹ year⁻¹ results in better N utilization, while the dose of 150 kg N ha⁻¹ year⁻¹ enables greater stocking rate; therefore, requiring less grazing area.

Key words: nitrogen nutrition index, *Urochloa*, canopy, beef cattle, nitrogen recovery, sustainability.

Eficiência do nitrogênio em pastagens de capim-marandu adubadas com doses crescentes de nitrogênio

RESUMO: O uso de nitrogênio (N) em ecossistemas pastoris leva ao aumento da produtividade, pois permite que a planta alongue suas folhas e, portanto, os herbívoros colham as folhas verdes. Porém, existem fontes de nitrogênio muito voláteis, que devem ser substituídas por nitrato de amônio, que é menos volátil e menos dependente da aplicação em dias chuvosos. Os tratamentos foram compostos por pastagens de capim-marandu, manejadas sob lotação contínua, na altura do dossel a 25 cm, com diferentes doses de N: 0, 75 e 150 kg ha⁻¹ ano⁻¹, na forma de nitrato de amônio (32% de N), com quatro repetições (piquetes), em delineamento inteiramente casualizado. A absorção de nitrogênio (54,9; 96,5; 113,8 kg N ha⁻¹) e o índice nutricional de N (0,67; 0,98; 1,15) foram diferentes entre as doses de N, respectivamente, 0, 75 e 150 kg ha⁻¹ ano⁻¹. A recuperação de N (58,3; 40,9%) diferiu entre 75 e 150 kg ha⁻¹ ano⁻¹, respectivamente. A dose de 75 kg N kg ha⁻¹ ano⁻¹ resultou em melhor aproveitamento do N, enquanto a dose de 150 kg N ha⁻¹ ano⁻¹ possibilita maior taxa de lotação; portanto, exigindo menos área de pastagem.

Palavras-chave: índice nutricional de nitrogênio, *Urochloa*, cobertura, bovinos de corte, recuperação de nitrogênio, sustentabilidade.

INTRODUCTION

The nitrogen fertilization increases productivity in pastoral ecosystems since the canopy of Marandu palisadegrass (*Urochloa brizantha* cv. 'Marandu') respond to N fertilization by emitting new leaves and decreasing leaf lifespan. These responses effectively contribute to an increase in stocking rate (SR) as the canopy leaf blades grow rapidly and are quickly utilized, thereby preventing stem elongation and senescence (ONGARATTO et al., 2021). In addition, N fertilization, by increasing

animal productivity, can decrease the GHG emission intensity of the system, reducing the environmental impacts of the beef cattle chain. DALLANTONIA et al. (2021) observed greater productivity and lower carbon footprint (10.5 kg CO₂eq kg⁻¹ carcass) in *brizantha* palisadegrass pastures fertilized with 150 kg N ha⁻¹ (urea) and grazed by F1 bulls, Aberdeen Angus x Nelore. Besides the beneficial effects of N fertilizers, in tropical pastures, the ammonia (NH₃) volatilization is one of the main loss pathways, mainly when urea is applied at the end of the rainy season, decreasing the N available

for forage growth. CORRÊA et al. (2021) found that the loss of N from urea, in the form of volatilized ammonia, can reach 47% at the dose of 270 kg of N ha⁻¹. However, considering the cost-benefit aspect, urea is the primary N source utilized in Brazilian livestock systems (ROMANZINI et al., 2020).

In Marandu palisadegrass, the apparent N recovery (REC), efficiency of N usage (NUE) and nitrogen nutrition index (NNI) have already been determined in a continuous stocking method. The study conducted by DELEVATTI et al. (2019) found that the apparent N recovery (REC) exhibited a linear increase, while the N nutrition index (NNI) showed a linear decrease with increasing levels of urea as the N source. However, the behavior of these variables in Marandu palisadegrass fertilized with ammonium nitrate, which is known to be a less volatile and more environmentally friendly N source, has yet to be observed.

Few studies have evaluated the use of ammonium nitrate, in the fertilization of the pastoral ecosystem. It has already been published research with ammonium nitrate fertilization in pastures of Coastcross (*Cynodon dactylon*; SILVEIRA et al., 2007; PRIMAVESI et al., 2006), Pensacola (*Paspalum notatum* Flügge; SILVEIRA et al., 2015), Sudan grass (*Sudanese Sorghum*; ABO-ZEID et al., 2017), Tifton 85 (*Cynodon* spp.; BORGES et al., 2017).

However, studies from *Urochloa* grass, the most used warm-season grass in the world, are lacking. CORRÊA et al. (2021) evaluated the Marandu grass canopy with different levels (90, 180 and 270 kg ha⁻¹) and N sources (urea, nitrate and ammonium sulfate), but without the animal component. These authors concluded that ammonium nitrate and sulfate, when used as a N source, is an efficient strategy to increase forage accumulation and reduce NH₃ volatilization losses. Therefore, to comprehensively assess the impact of ammonium nitrate on Marandu grass canopies, this study was designed to quantify the recovery, utilization efficiency, NNI of pastures grazed by Nellore young bulls under varying levels of ammonium nitrate fertilization. The underlying hypothesis was that an increase in N doses would result in a decline in NUE. The primary objective of this study was to evaluate the effects of different N levels, specifically focusing on ammonium nitrate, on the recovery, efficiency, and NNI of Marandu palisadegrass, and consequently provide valuable recommendations for its optimal use.

MATERIALS AND METHODS

The experiment was conducted at the Beef Cattle Unit of Sao Paulo State University “Julio de

Mesquita Filho” (UNESP), Jaboticabal, Sao Paulo, Brazil (21° 15' 22" S, 48°18' 08" W; 595m altitude). According to Köppen's classification the climate is humid and subtropical, with dry winters and warm summers (Aw). Soil at the site is categorized as a typical Hapludox with a clayey texture (STAFF, 1999). Soil samples (0–20 cm) from each pasture were collected at the beginning of the experimental period in each year. The average soil chemical composition was pH (CaCl₂) 5.0, organic matter 23.6 g dm⁻³, P-resin 7.4 mg dm⁻³, K⁺ 1.9 mmolc dm⁻³; Ca²⁺ 19.9 mmolc dm⁻³; Mg²⁺ 10.2 mmolc dm⁻³; H+Al 24.7 mmolc dm⁻³; sum of bases 31.9 mmolc dm⁻³; cation exchange capacity 56.7 mmolc dm⁻³; and base saturation 55.8%.

The pastures were settled in 2005 with a monoculture of Marandu palisadegrass. The experimental area comprised 24 ha, divided into 12 pastures of approximately 2 ha each. The experimental period was composed of two experimental cycles. First cycle from December to April of 2018/2019 and second cycle from December to April 2019/2020.

The evaluations initiated when the canopy height reached 25 cm, and the initial herbage mass did not differ among treatments ($p > 0.05$). Before the beginning of the first experimental period, all pastures were grazed to reach the target canopy height of 25 cm, in November of 2018, and similar initial herbage mass. Between the end of the first cycle and the beginning of the second cycle (i.e., from April to December 2019), all pastures were monitored and sporadically grazed so that all pastures reached the target canopy height of 25 cm, and similar initial herbage mass before the beginning of the second experimental period.

The treatments consisted of pastures receiving different levels of N: 0 (0N), 75 (75N), and 150 (150N) kg N ha⁻¹ of ammonium nitrate (32% N) in a completely randomized design, with four replicates (pastures). According to the occurrence of rainfall, N was fractioned in three levels of the same amount per year, on the following dates: 19 December 2018; 23 January 2019; 23 February 2019; 10 December 2019; 30 January 2019; and 20 March 2020. The pastures were managed using the put-and-take methodology under continuous grazing (MOTT & LUCAS, 1952) to maintain a canopy height of 25 cm, on average. The control of the stocking rate in each paddock was measured weekly, considering the maximum amplitude of 8% variation on canopy height (23–27 cm). The canopy height was also measured weekly by using a centimeter-graduated ruler, at the curvature of the upper leaves, at 80 random points per pasture.

Herbage mass, crude protein and N efficiency evaluations

Herbage mass and herbage accumulation were estimated using the methodology of ONGARATTO et al. (2021). Samples of hand-plucked forage were dried at 55 °C for 72 h in a forced-air oven for dry matter (DM) determination and ground in a knife mill (Arthur H. Thomas Co., Philadelphia, PA, USA) 1-mm screens, to determine crude protein (FP, Leco Instruments Inc., St. Joseph, Michigan, USA). The indices related to N efficiency were calculated by the following equations (LEMAIRE et al., 2008). Apparent N recovery (REC) by forage was estimated based on the N uptake of fertilized and unfertilized pastures as:

$$N \text{ uptake (kg N ha}^{-1}\text{)} = \{(TFL + AcF) \times \% N \text{ forage}\}$$

Where:

TFL is the total forage leaf dry mass of the treatment in kg ha⁻¹;

AcF is the cumulative forage dry mass.

$$REC (\%) = \left(\frac{U_f - U_o}{N_f} \right)$$

Where:

REC is the apparent N recovery of fertilized pastures,

N_f is the rate of N fertilization (kg ha⁻¹);

U_f is the N uptake for a given N_f (kg ha⁻¹);

U_o is the N uptake of unfertilized pastures.

Efficiency of N usage (NUE) by the plants was estimated by:

Nitrogen nutrition index (NNI) was estimated as follows:

$$NNI = \frac{N_a}{N_c}$$

Where:

N_a is the actual N concentration;

N_c is the critical N concentration using the formula:

$$N_c = aW^{b};$$

W is the forage dry matter yield (mg ha⁻¹);

a and b are species-specific constants for C4 perennial grasses (3.6 and 0.34, respectively);

Luxury N consumption was assumed for NNI values > 1 (LEMAIRE & MEYNARD, 1997; LEMAIRES et al., 2008).

This weather data was obtained from the Agrometeorological Station of the Department of Engineering and Math Sciences at UNESP, located 500 m from the experimental area.

Data analysis

The variables of this experiment were analyzed in two consecutive years and within five periods of each year (28-day period, repeated measure), according to a randomized complete block design (block = year), with three treatments (levels of

N) and four replicates (pastures). All variables were analyzed as repeated measures in time (periods). Data were tested for normality and equal variance using the Shapiro–Wilk normality test and the Bartlett test of homogeneity of variances, respectively. The best covariance structure used for repeated-measures analyses was chosen as the one that achieved the lowest corrected Akaike information criterion. Comparisons between treatments were performed using Tukey's test, and significance was set at $P < 0.05$. Data were analyzed using the MIXED procedure of SAS (version 9.3; SAS Institute, Cary, NC, USA).

RESULTS

The mean values of temperature, rainfall, and number of rainy days in 2018/2019 and 2019/2020 were 24.8 °C and 24.5 °C, 731.7 mm and 798 mm, and 62 days and 58 days, respectively (Table 1). The analysis of variance comparing these weather variables for the 2018/2019 and 2019/2020 cycles was similar, regarding mean temperature ($P = 0.56$), rainfall ($P = 0.93$), and number of rainy days ($P = 0.99$).

The stocking rate differed ($P < 0.05$; SEM = < 0.01) among the levels of N, increasing from 1.9 AU (animal unit = 450 kg of live weight) to 2.8 AU and 3.8 AU for 0N, 75N, 150N, respectively.

The canopy heights and herbage mass among the levels of N were similar (25.3 cm; $P > 0.12$; SEM = ± 3.7; 5.400 kg DM ha⁻¹; $P = 0.07$; SEM = ± 0.44). The herbage accumulation rate was similar between 75N and 150N (110.9 kg DM ha⁻¹ day⁻¹; $P < 0.0001$; SEM = < 0.01) and lower in 0N (76.1 kg DM ha⁻¹ day⁻¹).

The crude protein differed among the levels of N ($P < 0.0001$; SEM = < 0.0002), increasing 10.1, 13.6 and 15.8 CP for 0N, 75 and 150N, respectively.

N uptake (SEM = 0.003) and NNI (SEM = 0.010) were different ($P < 0.001$) in the three N levels, while the REC only differed ($P < 0.01$; SEM = 0.104) between 75N and 150N level (Table 2).

DISCUSSION

The N uptake increased with increasing N level of ammonium nitrate. Similarly, DELEVATTI et al. (2019) reported that increasing level of N (90, 180, and 270 kg N ha⁻¹) resulted in increased N uptake from 110 to 175 kg N ha⁻¹, using urea as a source of N fertilizer. Although urea is known to produce greater losses by volatilization of N-NH₃ than ammonium nitrate, when applied with moderate rainfall, volatilization losses are markedly reduced, explaining

Table 1 - Temperature and total precipitation in 2018/19^a and 2019/20^b.

	T °C maximum*	T °C minimum*	T °C mean*	Total precipitation**	ND***
			2018		
December	30	20.2	25.2	88.2	16
			2019		
January	32.7	20.9	26.1	148.1	11
February	30.9	20.4	24.4	282.6	17
March	31	20.1	24.5	115.2	12
April	30.6	19.0	23.9	97.6	6
December	30.3	20.1	25.2	230	14
			2020		
January	30.9	20.1	25.1	266.3	19
February	29.2	19.9	24.5	185	18
March	31.2	18.1	24.7	84.1	6
April	29.4	16.5	22.9	32.6	1

^aDec 10, 2018 – Apr 29, 2019; ^bDec 09, 2019 – Apr 27, 2020; *degrees Celsius; **millimeters; *** number of rainy days; Agrometeorological Station of the Department of Engineering and Exact Sciences at UNESP.

the similarity between our results (DALLANTONIA et al., 2021; ROMANZINI et al., 2020; STOTT & GOURLEY, 2016).

The REC was higher in the 75N level suggesting that moderate level of N (± 75 kg of N ha⁻¹) was efficient in allowing tropical grasses to develop without impairing animal performance as suggested by CARDOSO et al. (2020) or damaging the environment by N leaching (DALLANTONIA et al., 2021).

The REC showed variation between the 75N and 150N systems, with higher REC observed at the 75N level (Table 2). In terms of the NNI values (Table 2), values above 1 indicate luxury consumption, values below 1 indicate deficiency, and an NNI value of 1 represents the critical level (LEMAIRE & MEYNARD, 1997; LEMAIRES et al., 2008). The NNI increased with higher levels of nitrogen ($P < 0.05$), and in the 150N system, we observed luxury consumption.

The NNI recorded in the 75N treatment approached 1, indicating that implementing a management strategy at 25 cm and adjusting the SR, along with a moderate N level (around 75 kg of N per hectare), are effective approaches to enhance the management of Marandu palisadegrass. This finding suggests that opting for a moderate N level in Brazilian pastures can lead to improved efficiency, resulting in cost savings and reduced environmental impact. Higher N levels lead to an increase SR, which can potentially result in reduced land area requirements per herd. Consequently, grassland areas play a crucial role in providing various ecosystem services, including provisioning, regulating, supporting, and cultural services.

CONCLUSION

The target NNI (i.e., NNI = 1) is observed in the 75N treatment, therefore, it should be used as

Table 2 - Efficiency of nitrogen usage of marandu palisade grass pastures under different levels of N.

Variable [‡]	-----Treatments [†] -----			P-value	SEM*
	0N	75N	150N		
N uptake, kg N ha ⁻¹	54.9 ^c	96.5 ^b	113.8 ^a	< 0.001	0.003
REC, %	-	58.3 ^a	40.9 ^b	< 0.012	0.104
NNI	0.67 ^c	0.98 ^b	1.15 ^a	< 0.001	0.010

[†] nitrogen (N) fertilization level at 0 (0N), 75 (75N), and 150 (150N) kg N ha⁻¹ of ammonium nitrate (32% N) kg N ha⁻¹, [‡] REC = apparent N recovery, NNI = nitrogen nutrition index, * standard error of the mean.

a management criterion for marandu palisadegrass pastures, as the highest REC is at this dose as well.

Under continuous stocking method and increasing nitrogen level, a dose of 75N is recommended based on nitrogen utilization variables. The 150N dose allows a greater animal stocking rate, with lower REC and luxury N consumption.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

Conceptualization, F.O., M.H.M.d.R.F., A.d.S.C., R.A.R. and F.L.F.d.Q.; data curation, M.H.M.d.R.F.; formal analysis, F.O. and E.B.M.; funding acquisition, M.H.M.d.R.F.; investigation, F.O., E.E.D., L.d.O.L. E.P.R., G.A.d.V., I.L.R., and I.d.M.V.; project administration, M.H.M.d.R.F.; supervision, M.H.M.d.R.F. and E.B.M.; writing original draft, F.O.; writing review and editing, F.O., M.H.M.d.R.F., A.d.S.C., R.A.R., F.L.F.Q., and E.B.M. All authors have read and agreed to the published version of the manuscript.

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Erratum

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