



Morphogenetic, structural and production traits of marandu grass under nitrogen rates in Neo soil

[Características morfológicas, estruturais e produtivas do capim-marandu sob doses de nitrogênio em Neossolo]

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ABSTRACT

Most sandy soils have low natural fertility and low levels of organic matter, making nitrogen (N) fertilization essential. Thus, five doses of N were applied (0, 75, 125, 175 and 225mg dm⁻³) in a randomized block design to evaluate the effects of nitrogen fertilization on the morphogenetic, structural and production characteristics of *Brachiaria brizantha* cv. Marandu in a Quartzarenic neosoil. The doses of N did not affect the height of the canopy. The leaf elongation rate, final leaf length and number of live leaves increased linearly at the doses of N. Leaf appearance rate, stem elongation rate, leaf lifespan, phyllochron, leaf senescence rate and tiller density showed a quadratic response to the rates. There was also an effect of N rates in herbage mass, leaf mass, stem mass, which increased linearly. *Brachiaria brizantha* cv. Marandu cultivated in Quartzarenic neosoil requires higher doses of N, 175 and 225mg dm⁻³. Under these conditions, increases in its morphogenetic, structural and productive characteristics are observed. These findings may not be repeated in the most fertile soils with the greatest capacity to supply N.

Keywords: fertilization, *Brachiaria brizantha*, forage, Quartzarenic Neosol, urea

RESUMO

A maioria dos solos arenosos tem baixa fertilidade natural e baixos teores de matéria orgânica, tornando a adubação com nitrogênio (N) essencial. Assim, foram aplicadas cinco doses de N (0, 75, 125, 175 e 225mg dm⁻³) em delineamento de blocos ao acaso, para se avaliarem os efeitos da adubação com nitrogênio nas características morfológicas, estruturais e produtivas da *Brachiaria brizantha* cv. Marandu, em um Neossolo Quartzarênico. As doses de N não afetaram a altura do dossel. A taxa de alongamento foliar, o comprimento final da folha e o número de folhas vivas aumentaram linearmente em função das doses de N. A taxa de aparecimento de folhas, a taxa de alongamento do caule, o tempo de vida da folha, o filocrono, a taxa de senescência foliar e a densidade de perfilhos apresentaram resposta quadrática às doses de N. A massa da forragem, a massa foliar e a massa do caule aumentaram linearmente. *Brachiaria brizantha* cv. Marandu cultivada em Neossolo Quartzarênico requer maiores doses de N, 175 e 225mg dm⁻³. Nessas condições, são observados aumentos em suas características morfológicas, estruturais e produtivas. Esses achados podem não se repetir nos solos mais férteis e com maior capacidade de suprir N.

Palavras-chave: adubação, *Brachiaria brizantha*, forragem, Neossolo Quartzarênico, ureia

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INTRODUCTION

Cultivars of the species *Brachiaria brizantha* stand out for their persistence and high herbage production capacity (Calvano *et al.*, 2011; Euclides *et al.*, 2019) as well as high phenotypic plasticity in sandy soils and in semiarid environments (Veras *et al.*, 2020). However, for these plants to persist in sandy soils, fertilization management is necessary due to their lower natural fertility (Bezerra *et al.*, 2017). Quartzarenic Neosoils (Quartzipsamments) are very sandy (Freitas *et al.*, 2012), naturally less fertile (Soratto *et al.*, 2011) soils with low water-holding capacity, high erodibility (Zuo *et al.*, 2008), high acidity and low nutrient availability (Silva *et al.*, 2011). Plants grown in this soil type have their nutrient absorption capacity reduced due to rapid leaching and low cation-exchange capacity, which renders Quartzarenic Neosoils less productive (Moura *et al.*, 2017).

Knowledge of the limiting nutritional factors is essential for plants to be able to achieve optimal production capacity (Megda and Monteiro, 2010). In this respect, adequate soil fertility and the maintenance of its chemical attributes are the factors responsible for the formation and development of plants (Aquino *et al.*, 2014). To express their maximum production potential, plants must be adequately supplied with nutrients, mainly nitrogen (N). However, the fraction of N in the soil resulting from the mineralization of organic matter is not sufficient to meet the requirements of plants in tropical sandy soils (Fagundes *et al.*, 2012; Campos *et al.*, 2020; Clément *et al.*, 2020). Thus, a low supply of N can compromise the appearance of new tissues (Farias *et al.*, 2019).

In this respect, it is possible that for sandy soils and of low natural fertility, it would be necessary to use higher doses of N for the plants to express the greatest genetic potential. In this study, we tested the hypothesis that high levels of N fertilization are required to enhance the agronomic characteristics of *Brachiaria brizantha* cv. Marandu (marandu grass) in Quartzarenic Neosoils. Therefore, the objective was to examine the effect of N fertilization rates on the morphogenetic, structural and production traits of marandu grass in a Quartzarenic Neosoil.

MATERIAL AND METHODS

The experiment was carried out in the experimental area of the Forage Crops Research Group at the Federal University of Rio Grande do Norte (GEFOR-UFRN), located in Macaíba campus - RN, Brazil (5°89'25.78" S; 35°36'37.05" W, 50 m above sea level). The experimental period was from September 17 (sowing) to December 17, 2018. The climate of the region is dry and sub-humid, with water surplus occurring from May to August (Thornthwaite, 1948). The monthly average precipitation during the experimental period was 35.94mm and the minimum, average and maximum temperatures were 24.22°C, 26.88°C and 29.66°C, respectively, data were obtained from the database of the National Institute of Meteorology (Climatologia..., 2020). To ensure its establishment, the crop was irrigated when more than two days passed without rain. The experiment was installed in a randomized block design with five treatments, which consisted of N doses: 0, 75, 125, 175 and 225mg dm⁻³, which corresponds to 0, 150, 250, 350 and 450kg ha⁻¹ of N, respectively. Applied as urea, and four replications.

Urea was applied with the aid of a pipette in the form of a nutrient solution. The pots were kept in an open environment and used as experimental units. Each pot received 8 dm³ of soil, which corresponded 11.52kg of soil. The amount of soil in each pot was calculated based on the soil density (1.44kg dm⁻³) and the volume of the pot (8 dm³). The soil, which was classified as a Quartzarenic Neosoil (Teixeira *et al.*, 2018), was collected in the experimental area at a depth of 0 to 20cm for analysis. The soil had 91.4% sand; 4.1% silt and 4.0% clay. The soil had 91.4% sand; 4.1% silt and 4.0% clay.

Soil analyzes were performed as described in Teixeira *et al.* (2018). The pH was measured in water using the CaCl₂ method (Teixeira *et al.*, 2018). The soil showed the following chemical characteristics: pH - 5.37; phosphorus - 6.0mg dm⁻³; potassium - 41.0mg dm⁻³; sodium - 11.0mg dm⁻³; calcium - 0.53cmolc dm⁻³; magnesium - 0.48cmolc dm⁻³; aluminum - 0.16cmolc dm⁻³; Cation exchange capacity - 4.0cmolc dm⁻³. Based on the results of the analysis, time-of-planting fertilization was carried out using 50mg dm⁻³ P₂O₅ (single superphosphate) and 50mg dm⁻³

³ KCl (potassium chloride). This fertilization procedure also included 10mg dm⁻³ of micronutrients in the form of FTE-BR12 at 10%, which was later continued in three applications of 30% performed 30, 45 and 60 days after sowing.

Brachiaria brizantha cv. Marandu was sown at a depth of 2 to 3cm, using 15 seeds per pot. Thinning was carried out on the tenth day after sowing, leaving five plants per experimental unit. The morphogenetic traits were evaluated weekly, starting 15 days after sowing, in three tillers per experimental unit that were chosen at random and identified with colored threads. The following variables were measured: total leaf length (expanded and expanding), number of live leaves (NLL, leaves/tiller) and pseudo stem length (distance from the base of the tiller to the last exposed ligula). With these results, the following variables were determined: final leaf length (FLL, cm tiller⁻¹), phyllochron (days), leaf appearance rate (LAR, leaves/tiller day), leaf elongation rate (LER, cm/tiller day), stem elongation rate (SER, cm/tiller day), leaf senescence rate (LSR, cm/tiller day) and leaf lifespan (LLS, days) (Chapman and Lemaire, 1993).

Canopy height and tiller density (TD) were measured on the last day of assessment. Height was determined using a ruler graduated in centimeters; five points were measured per pot and the curvature of the leaves was considered as the point of the average height of the canopy. Tiller density was determined by counting all live tillers per pot. To estimate the variables of herbage mass (HM), leaf mass (LM), stem mass (SM) and dead material mass (DMM), the entire aerial part of the plants was cut 90 days after sowing. The samples were used for the separation of the morphological constituents into the following fractions: leaf blade, stem (stem + sheath) and dead material. These components were dried in a forced-air oven at 55°C for 72h to determine the dry matter.

The roots were washed with running water over 1- and 2-mm-mesh sieves until the adhered soil was removed. Next, they were dried in a forced-air oven at 55°C until reaching constant weight and weighed to determine the root DM. Root density was determined by dividing the root DM by the soil volume in each experimental unit.

Data were subjected to analysis of variance. The mathematical model used contained the fixed effect of N rates and the block. The effect of N rates was analyzed using regression equations. Linear quadratic models were tested, and the model was selected according to the significance of the regression coefficients, adopting the 5% probability level and the coefficient of determination (R²). The morphogenetic and structural trait data were analyzed by principal components. The data set was standardized, and thus each descriptor had zero mean and variation. This analysis allowed us to reduce the space of original variables into a smaller set and to preserve the maximum of the original variability of the data. All statistical analyses were performed using R software version 3.6.1.

RESULTS

There was no effect of N rates (P>0.05) on canopy height (Table 1). The N rates induced a linear response in LER, FLL and NLL, which increased by 0.006cm/tiller, 0.032cm and 0.010 leaves/tiller, respectively, with each milligram of N added (Table 1). The N rates had a quadratic effect on LAR, SER, LLS, phyllochron, LSR and TD. Based on the derivative of the equation, the highest LAR (0.09 leaves/tiller day) was estimated at the rate of 150.00mg dm⁻³; the highest SER (0.10cm/day) at 83.33mg dm⁻³; the highest LLS (110.94 days) at 148.33mg dm⁻³; and the highest LSR (1.43cm/day) at the rate of 160.71mg dm⁻³ (Table 1).

The N rates did not influence DMM (P>0.05, Table 2). In turn, there was a linear effect of N rates on hM, LM and SM, which increased by 0.188 g/pot, 0.154 g/pot and 0.073 g/pot with each milligram of N, respectively (Table 2). Root DM and RD responded quadratically to the increasing N rates. Five main components (PC) were generated. However, the first PC explained 93% of the studied variation, and there was an equal distribution between the levels of fertilization with N. CP1, showed that the N rate of 125mg dm⁻³ was neutral in relation to the others (Table 3). This component, also related, the phyllochron and the LLS with the N rate of 0mg dm⁻³. Tiller height, TD, LSR, LAR, LER, FLL, NLL and SER showed a higher correlation with the N rates of 175 and 225mg dm⁻³ (Table 3).

Morphogenetic, structural...

Table 1. Morphogenetic and structural traits of *Brachiaria brizantha* cv. Marandu under different nitrogen rates in Quartzarenic Neosol

Variable	N rate (mg dm ⁻³)					P	SEM	P value		R ²		Equation
	0	75	125	175	225			L	Q	L	Q	
Morphogenetic												
LAR (leaves/ tiller day)	0.06	0.10	0.09	0.10	0.10	0.005	0.005	0.001	0.047	0.57	0.73	Y = 0.072+0.0003x-0.000001x ²
LER (cm/ tiller day)	1.21	2.56	2.09	2.51	2.93	0.002	0.206	<0.001	0.228	72.22	76.20	Y = 1.492+0.006x
SER (cm/day)	0.05	0.19	0.14	0.21	0.16	0.001	0.014	<0.001	<0.001	44.44	76.22	Y = 0.060+0.001x-0.000006x ²
LLS (days)	133.27	107.14	117.77	114.37	114.62	0.005	3.487	0.010	0.008	31.60	65.04	Y = 130.747-0.267x+0.0009x ²
Structural												
PHY (days/ leaf tiller)	14.82	9.81	10.98	10.33	0.84	0.001	0.498	<0.001	0.002	58.94	80.70	Y = 14.400-0.054x+0.0001x ²
FLL (cm)	12.06	18.36	16.72	18.09	20.87	0.001	0.924	<0.001	0.274	77.04	79.71	Y = 13.300+0.032x
NLL(leaves/ tiller)	9.11	11.16	10.91	11.33	11.91	0.007	0.395	0.001	0.177	81.09	99.36	Y = 9.577+0.010x
LSR (cm/day)	0.67	1.41	1.40	1.48	1.51	<0.001	0.040	<0.001	<0.001	70.76	93.64	Y = 0.716+0.009x-0.00002x ²
TD (tillers/pot)	21.66	56.50	61.50	72.25	67.50	<0.001	3.111	<0.001	<0.001	79.17	98.19	Y = 22.262+0.525x-0.001x ²
Canopy height (cm)	12.46	23.67	22.65	24.35	24.50	0.079	2.812	0.013	0.102	67.04	91.07	Y = 21.52

LAR: leaf appearance rate; LER: leaf elongation rate; SER: stem elongation rate; LLS: leaf lifespan; PHY: phyllochron; FLL: final leaf length; NLL: number of live leaves; LSR: leaf senescence rate; TD: tiller density. SEM: standard error of the mean.

Table 2. Production variables in *Brachiaria brizantha* cv. Marandu under different nitrogen rates in Quartzarenic Neosol

Variable	N rate (mg dm ⁻³)					P	SEM	P value		R ²		Equation
	0	75	125	175	225			L	Q	L	Q	
HM (g/pot)	18.99	55.75	58.75	63.50	79.25	0.019	7.205	0.002	0.774	93.51	94.00	Y = 35.318+0.188x
LM (g/pot)	10.66	32.50	35.50	39.00	48.75	0.003	3.525	<0.001	0.169	91.75	95.17	Y = 14.796+0.154x
SM (g/pot)	5.00	16.75	16.75	18.75	23.50	0.001	2.083	<0.001	0.204	87.64	91.91	Y = 7.381+0.073x
DMM (g/pot)	3.33	6.50	6.50	5.75	7.00	0.141	0.922	0.033	0.204	59.01	77.27	Y = 5.82
Root DM (g/pot)	25.33	67.25	64.50	77.25	78.25	0.0003	5.326	<0.001	0.011	79.06	93.29	Y = 27.548+0.520x-0.001x ²
RD (g/kg soil)	2.19	5.83	5.59	6.70	6.79	0.0003	0.462	<0.001	0.011	79.06	93.29	Y = 2.391+0.045x-0.0001x ²

HM: herbage mass; LM: leaf mass; SM: stem mass; DMM: dead material mass; root DM: root mass; RD: root density. SEM: standard error of the mean.

Table 3. Principal components (PC) analysis for marandu grass under nitrogen fertilization

	PC1	PC2	PC3	PC4	PC5
Standard deviation	3.05	0.573	0.536	0.234	<0.001
Proportion of Variance	0.930	0.030	0.029	0.005	<0.001
Variable					
FLL	0.315	-0.438	-0.200	0.053	0.514
PHY	-0.326	-0.019	-0.124	0.311	-0.436
LAR	0.313	-0.386	0.354	0.195	0.040
LER	0.319	-0.364	-0.062	0.350	-0.214
NLL	0.322	-0.188	-0.289	-0.046	-0.643
LSR	0.322	0.198	-0.222	-0.385	0.016
LLS	-0.306	-0.104	-0.635	0.331	0.275
SER	0.305	0.528	0.245	0.628	0.095
TD	0.310	0.356	-0.459	0.141	0.020
Height	0.324	0.190	-0.095	-0.257	0.008

Leaf length (FLL), phyllochron (PHY), leaf appearance rate (LAR), leaf elongation rate (LER), number of live leaves (NLL), leaf senescence rate (LSR), leaf lifespan (LLS), stem elongation rate (SER), tiller density (TD) and height.

DISCUSSION

Despite the lack of effect for the height of the canopy, the pastures that did not receive fertilization with N, presented height almost 100% lower than the fertilized pastures, which denotes a positive effect of N in this variable. In fact, N promotes an increase in the stalk elongation rate (Table 1), which leads to greater height. The availability of N for plants is one of the main factors influencing their morphogenetic traits (Bezerra *et al.*, 2020). Leaf appearance rate is highly responsive to N fertilization, with the absence of this nutrient preventing the appearance of new tillers (Pereira *et al.*, 2010).

Leaf appearance rate is considered the central trait of morphogenesis because it influences the structural components of the forage (Difante *et al.*, 2011). For each new leaf, a bud is formed with the potential to develop a new tiller (Gastal and Lemaire, 2015). Nitrogen increases the number of dividing cells in meristematic zones, stimulates the production of new cells and induces an increase in LER, NLL and FLL (Farias *et al.*, 2019; Martuscello *et al.*, 2019). Leaf elongation rate is of great relevance to the biomass flow of plants, as it is directly associated with the photosynthetic capacity of plants, having a direct impact on herbage production (Paciullo *et al.*, 2016).

Phyllochron is defined as the time for the appearance of two consecutive leaves on the tiller (Wilhelm and McMaster, 1995) corresponding to the inverse of LAR. Therefore, when the plant is fertilized with N, phyllochron is reduced due to the positive effect of N on LAR (Braz et al., 2010). Unfertilized plants keep their live leaves longer; that is, the increase in N rates accelerates the senescence process, thereby reducing LLS and increasing LSR (Silva et al., 2015). This explains the higher correlation between the N rate of 0 and LLS and phyllochron (Table 3).

The leaf development process associated with N causes the plant to start senescence due to the translocation of nutrients for the expansion of new leaf blades, which accelerates tissue flow (Lemaire et al., 2011; Farias et al., 2019). The response of LSR to N fertilization was generated by LAR. Number of live leaves is a genetic trait, and when the plant reaches its maximum value for this variable, older leaves begin to senesce to be replaced by new leaves. The increased availability of N in the soil and, consequently, in the plant cells, enhanced the photosynthetic process. This, in turn, leads to changes in the structural characteristics of the tillers, such as size, weight and appearance rate (Alencar et al., 2010; Gurgel et al., 2020a). These morphogenetic variables directly influence structural variables (Pontes et al., 2003) and promote positive responses in production traits. As a result of this enhancement, the plant will have more leaf area to absorb light, increasing its photosynthetic rate and consequently herbage production (Pilbeam, 2018).

There was no effect of N rates on DMM (Table 2), likely because there was no competition for light. In other words, at 90 days, the plants supposedly had not yet reached the maximum number of live leaves per tiller. That is the moment from which senescence rate could influence the structure and botanical composition of the forage canopy (Difante et al., 2011). *Brachiaria* cultivars exhibit high plasticity when subjected to stress environments. To ensure their longevity, when in an environment with low N supply, they prioritize root growth to establish themselves faster. In contrast, under high levels of N, they increase leaf production and tiller growth (Garcez and Monteiro, 2016). The highest root production was observed at the N

rate of 0 mg dm⁻³, and as the fertilization levels were increased, there was a reduction in root DM and an increase in LM. This compensatory mechanism explains the relationship between LM and root DM.

The linear effect observed for root DM and RD (Table 2) was due to the relationship between the shoots and the root system, since greater herbage production induces a modulation in the root system to support aerial growth (Bertol et al., 2000; Gurgel et al., 2020b). The remarkable initial rapid growth of the root system is believed to be a mechanism to increase the N absorbed by these plants (Liao et al., 2004; Noulas et al., 2010), which favors the persistence of grasses in a production system (Garcez and Monteiro, 2016). Therefore, our hypothesis that high levels of N fertilization are necessary to improve the agronomic characteristics of *Brachiaria brizantha* cv. Marandu (marandu grass) in quartzarenic neosol is supported by our data. Although the higher N rate can benefit the production of marandu grass, it can cause a higher rate of losses and environmental problems. Thus, that in future research the loss rates are quantified to find a balance point to offer suggestions for the use of N in sandy soils.

CONCLUSIONS

Brachiaria brizantha cv. Marandu cultivated in Quartzarenic neosol requires higher doses of N, 175 and 225 mg dm⁻³. Under these conditions, increases in its morphogenetic, structural and productive characteristics are observed. These findings may not be repeated in the most fertile soils with the greatest capacity to supply N.

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