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Morphometry, productivity and bromatological analisis of purple elephant grass according to nitrogen fertilization

João Paulo Farias Ramos[1*], José Thyago Aires Souza[3], Rubens Fernandes Costa[1], Raimundo Ribeiro Ferreira[2], Iara Tamires Rodrigues Cavalcante[2], Ricardo Miranda Leite[2], Selma Soares Santos[2] and Valdemir Ribeiro Cavalcante[2]

[1]Empresa Estadual de Pesquisa Agropecuária da Paraíba, Rodovia Ministro Abelardo Jurema, PB-008, Km 7, Cx. Postal 4140, 58045-970, Jacarapé III, João Pessoa, Paraíba, Brazil. [2]Programa de Pós-Graduação Integrado em Zootecnia, Centro De Ciências Agrárias, Universidade Federal da Paraíba, Areia, Paraíba, Brazil. [3]Instituto Nacional do Semiárido, Campina Grande, Paraíba, Brazil. *Author for correspondence. E-mail: jpemepapb@yahoo.com.br

ABSTRACT. The objective was to evaluate the morphometric, productive and chemical aspects of purple elephant grass as a function of nitrogen fertilization. The treatments consisted of applying 0, 20, 40, 60, and 80 kg ha^{-1} of N, using a randomized block design, with five treatments and four replications. The following were evaluated: plant height, number, length and leaf mass, stem diameter and mass, leaf/stem ratio, production of green and dry mass, support capacity for dairy cows, crude protein, neutral detergent fiber and mineral matter. The data were submitted to analysis of variance and Tukey's test at 5% probability. The increase in N doses did not affect ($p < 0.05$) the morphometry of the purple elephant grass, however it positively stimulated the productivity, the animal support capacity and the bromatological components of the harvested material. The lack of response to nitrogen fertilization may be related to the edaphocilimatic conditions during the experiment and efficiency in the use of N of the variety used. The results demonstrate the high demand of the cultivar for N, actively interfering in the forage yield.

Keywords: forage yield; growth; nitrogen; *Pennisetum purpureum* Schum.

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Introduction

Livestock farming, specifically dairy cattle, stands out as one of the main income generators in small rural properties in Northeast of Brazil, however, for the maintenance of animal productive potential, food production and storage are essential,

In this sense, the formation of cutting weeds stands out for their high forage yield and the lower need for cultivation area compared to trampling weeds. Among the different species of cut grasses used in animal feed, elephant grass (*Pennisetum purpureum* Schum.), has a prominent role, as it is recognized as a forage with high potential for dry matter production and high nutritional value (Paciullo et al., 2015).

Despite being incorporated into the landscape of most rural properties of Agreste Paraibano in Brazil, management, mainly of fertilization of the weeds of *Pennisetum purpureum* Schum. is often performed incorrectly. Costa, Paulino, Magalhães, Rodrigues, and Seixas Santos (2016) point out that the nutritional aspects of forage plants are affected by several factors, such as: age, height of cut or grazing, morphological, anatomical characteristics, climatic factors and by fertilization.

Among the nutrients necessary for the good growth and development of forage grasses, nitrogen has a fundamental role because it is an essential constituent of proteins, directly interfering in the photosynthetic process, due to its participation in the chlorophyll molecule, becoming, therefore, limiting in intensive cultivation (Porto, 2017).

The deficiency of this macronutrient can influence not only the photosynthetic capacity (Živčák et al., 2014), but also acts in decreasing the number of cells in division and consequently affecting the cell elongation and growth rate of the plant, constituting one of the factors that most affect elephant grass productivity (Martuscello, Majerowicz, Cunha, Amorim, & Braz, 2016). In this context, the objective was to evaluate the morphometric, productive and bromatological components of elephant grass cv. purple as a function of nitrogen fertilization doses.

Material and methods

The research was carried out at the Experimental Station of Alagoinha, belonging to the State Agricultural Research Corporation of Paraíba S.A. - EMEPA-PB, located in the mesoregion of agreste Paraíba, in Alagoinha, Paraíba State, Brazil. (6°57'00'' S and 35°32'42'' W, 154 masl). The climate of the region, according to the Köppen classification, is of the As' type, hot and humid (Alvares et al., 2013), with the rainy season starting between the months of February and March, extending until July or August. The precipitation that occurred during the experimental period (300.3 mm) is shown in Table 1, the soil in the area was classified as Abrupt Pálico Chromic Luvisolo (EMBRAPA, 2013).

Table 1. Dynamics of rainfall occurred during the experimental period.

Trial Period (days)	Days without rain	Days with rain	Days with rain >10 mm	%
62	28	34	7	20.6
Days with rain between 5-10 mm	%	Days with rain <5 mm	%	Total Precipitation (mm)
8	23.5	19	55.9	300.3

The experiment was carried out in random blocks with five treatments and four replications, totaling 20 plots, which were dimensioned with an area of 25 m². The *Pennisetum purpureum* Schum. cv. Purple (elephant grass cv. Purple) was grown at a spacing of 1 x 0.2 m between rows and plants, respectively, corresponding to a density of 50,000 plants ha^{-1} and 125 plants per plot. Urea (45% N) was used as a nitrogen source, so the treatments consisted of fertilizing with 0, 20, 40, 60, and 80 kg ha^{-1} of N, that is, 0, 44.5, 89, 133.5, and 178 kg of urea ha^{-1}, calculated based on the recommendation of Cavalcanti (1998). Fertilization was carried out in two equal plots, the first after uniform weeding and the second after 30 days. In each fertilization, doses of 0, 10, 20, 30, and 40 kg ha^{-1} per treatment were applied, respectively.

Before planting, 15 simple soil samples were collected at a depth of 0 – 40 cm from the experimental area, then transformed into a composite sample sent to the soil laboratory of the Rural Engineering Department of the Agricultural Sciences Center, Federal University of Paraíba in Areia, Paraíba State, Brazil, to characterize fertility, the results are shown in Table 2.

Table 2. Chemical soil attributes for fertility in the 0-20 cm layer of soil.

pH		K^+	Na^+	$H^+ + Al^{+3}$	Al^{+3}	Ca^{+2}	Mg^{+2}	V%	CTC	OM g kg^{-1}
H_2O (1:2.5)	P mg dm^{-3}		------------------	------------------	cmol$_c$ dm^{-3}	------------------	------------------			
5.85	5.62	171	0.40	5.25	0.5	3.55	1.70	55.12	11.03	18.68

P, K, Na: Mehlich Extractor 1; H + Al: 0.5 M Calcium Acetate Extractor, pH 7.0; H+Al: 0.5 M Calcium Acetate Extractor, pH 7.0; Al, Ca, Mg: 1 M KCl Extractor; OM: Organic Matter - Walkley-Black; V%: base saturation.

The variables evaluated were plant height (PH), number of leaves (LN), leaf length (LL), stem diameter (SD), leaf mass (LM), stem mass (SM), leaf/stem ratio (L/SR), green mass productivity (GMP), dry mass productivity (PMS), support capacity for dairy cows (CS), crude protein (CP), neutral detergent fiber (NDF), and mineral matter (MM).

The plant height and leaf length were measured with the aid of a tape measure, while the stem diameter was quantified by a digital caliper model Digimess®. The leaf and stem mass, and leaf/stem ratio were obtained by weighing of materials on a digital scale with a capacity of 15 kg. The green mass productivity (GMP) in mg ha^{-1} was determined by cutting the plants 60 days after the uniform cut, considering the average weight of the plot and then multiplied by the plant population per hectare. Then, a sub-sample was taken from each treatment for pre-drying in an oven at 65°C for 72 hours, in order to quantify the dry matter (DM) content according to the methodology recommended by AOAC (1990), then the dry mass productivity (DMP) also in mg ha^{-1} was obtained by the product of the multiplication of GMP and the levels of DM.

Through the dry mass productivity (DMP ha), a simulation of the support capacity (SC) of elephant grass (EG) was performed for lactating cows for a period of 180 days. Therefore, a cow with an average body weight (BW) of 400 kg, consuming 3% of BW and with an average production of 12-14 kg of milk was considered for the estimate.

For the analysis of the bromatological composition of the elephant grass biomass, after cutting, the material was weighed, chopped and placed separately in paper bags, for subsequent pre-drying in a forced circulation oven at 65°C for 72 hours. Soon after this process, the samples were weighed and ground in a Willey mill (knife mill) with 1 mm sieve and placed in an airtight container for later analysis. Samples of elephant grass were analyzed for dry matter (DM- Method 967.03 – AOAC, 1990), mineral matter (MM - Method 942.05 – AOAC, 1990), and crude protein (CP - Method 981.10 - AOAC, 1990) at the Laboratory of Animal Nutrition of the Department of Animal Sciences at UFPB. For the determination of neutral detergent fiber (NDF), a methodology was used according to Van Soest, Robertson, and Lewis (1991) with the aid of an ANKON® device, from Ankon technology Corporation.

For data analysis, an analysis of variance was initially carried out based on the average of the plots for each of the evaluated characteristics. For the characteristics presented a significant effect involving fertilization levels, Tukey's multiple comparison tests were used, at the 5% significance level and for the case of significant effect involving the variation of nitrogen doses, joint polynomial regression analysis was used for the 1st and 2nd degree linear models, with the respective regression analysis of variance, testing the significance of the sources of variation due regression and due to regression deviations.

Results and discussion

Although the morphometric characteristics of elephant grass cv. purple have been elevated, were not statistically influenced by the increase in nitrogen doses (Table 3), the plant height and the number of leaves ranged from 1.86 to 2.17 m and from 12.75 to 21.87 leaves, respectively. According to Menezes et al. (2015), this variable, the plant height, is positively correlated with dry matter yield.

Table 3. Morphometric characteristics of elephant grass cv. Purple submitted to different doses of nitrogen fertilization.

Variables	N doses (kg ha^{-1})					p-value	CV (%)
	0	20	40	60	80		
pH	1.86	1.94	1.89	2.13	2.17	0.3095^{ns}	13.37
LN	12.75	19.00	14.75	18.75	21.87	0.3397^{ns}	44.17
LL (cm)	64.50	73.75	74.87	78.87	75.00	0.0659^{ns}	12.00
SD (mm)	10.15	10.74	12.19	13.91	15.75	0.2575^{ns}	27.64
GLM (g)	52.88	63.00	63.63	70.00	73.00	0.3637^{ns}	29.28
GSM (g)	87.63	93.50	119.38	123.63	136.00	0.1497^{ns}	34.91
L/SR (%)	36.29	36.35	37.11	41.34	41.35	0.2445^{ns}	12.24

Means followed by different letters in the line differ ($p < 0.05$) from each other by the Tukey test. PH = plant height; LN = leaf numbers; LL = leaf length; SD= stem diameter; GLM = Green leaf mass; GSM = Green stem mass; L/SR = Leaf/stem ratio; ns = not significant levels of probability; CV = coefficients of variation.

Mota et al. (2011) evaluating the height of elephant grass plants in the rainy season in northern of Minas Gerais also did not obtain a significant effect when adding doses of 100, 300, 500, and 700 kg ha^{-1} of N. According to these authors, the rainfall distribution during the cultivation period can lead to a lack of significance between treatments, a relevant detail, considering that the presence of rain occurred in 55% of the entire experimental period of this work. Similar results were observed by Novo et al. (2016) when studying the influence of nitrogen and potassium fertilization in different genotypes of elephant grass in Rio de Janeiro, where the authors did not obtain differences in plant height, stem diameter and number of tillers even with high fertilization doses (100, 800, 1,500, and 2,200 kg ha^{-1} of N and 50, 400, 750, and 1,100 kg ha^{-1} of K_2O).

Although nitrogen doses did not have a significant effect on leaf length (LL) and stem diameter (SD), these varied by 22.3 and 54.7%, respectively, Bastos et al. (2017) point out that the absence of difference for LL may occur due to the end of the crop cycle, in this period the plant possibly directs its nutritional reserves primarily to the development of stems, not more to the leaves as at the beginning and middle of the cycle.

Araújo, Vitorino, and Mercante (2016) when studying the effect of N on the diameter of corn stem (*Zea mays* L.) noticed that the crop did not respond to nitrogen fertilization. According to Schultz, Reis, and Urquiaga (2015), divergences in results related to nitrogen fertilization are quite common, given that the dynamics of this nutrient in the soil is easily affected by factors such as: environmental conditions, edaphic pH, form of application and absorption capacity by the plant.

The green leaf mass, stem and leaf/stem ratio were increased by 38, 55.2, and 14%, respectively with the increase of the N dose from 0 to 80 kg ha^{-1} of N, however, there was no statistical difference. These results differ from those obtained by Nirmal et al. (2016), who evaluated the growth of cultivars of forage sorghum (*Sorghum bicolor* L.) found positive linear due to the increase in nitrogen fertilization doses response.

Nitrogen is a nutrient of great production for the yield of forage production, as this is known to have great influence on, mainly, the aerial part of the plant, forage canopy, the part consumed by the animal. Although the importance of nutrients, such as nitrogen, to the morphological and physiological processes of plants is recognized, these depend on the turgidity of tissues, they are especially sensitive to factors such as the water available in the soil (Mota et al., 2011; Evangelista & Lima, 2014).

The increase in N doses applied to the soil provided positive linear response to the productivity of green and dry mass of the purple elephant grass (GMP and DMP), increasing them to 70.2 and 13.39 mg ha^{-1}, superiority of 85,4 and 138.1% compared to the productivity of plants without nitrogen fertilization via soil, 37.87 and 5.58 mg ha^{-1}, respectively (Table 4).

Table 4. Forage yield and support capacity of elephant grass as a function of nitrogen fertilization.

Variables	N doses (kg ha^{-1})					CV (%)
	0	20	40	60	80	
GMP (t ha^{-1})	37.87^b	39.95^b	42.57^{ab}	52.45^{ab}	70.2^a	35.1
DMP (t ha^{-1})	5.58^b	6.92^b	10.84^b	10.88^{ab}	13.39^a	23.5
SC (cow ha^{-1})	5.9^b	7.38^b	11.56^{ab}	11.61^{ab}	14.28^a	34.2

Means followed by distinct letters on the line differ ($p < 0.05$) from each other by the Tukey test; GMP = green mass productivity; DMP = dry mass productivity; SC = support capacity; CV = coefficients of variation; Regression Equations: (GMP) $\hat{Y} = 33.176 + 0.3086x$, $R^2 = 0.84$; (DMP) $\hat{Y} = 24.606 + 0.0783x$, $R^2 = 0.93$; (SC) $\hat{Y} = 5.948 + 0.094x$, $R^2 = 0.93$.

The results obtained demonstrate the high demand of purple elephant grass for N, acting as a stimulant and source of vigor, actively interfering in the forage yield of the crop. According to Mota et al. (2011), elephant grass productivity is highly conditioned, among other factors, to the increase in soil fertility, in which nitrogen performs a role in modulating responses to soil fertilization, because in conditions of deficiency or use of insufficient quantities, grass has limited growth, consequently less production.

Silva, Enck, Martins, and Luz (2017) found that the productivity of green and dry mass of Marandu grass in two cycles increased by more than 100% due to the increase in N doses from 0 to 250 kg ha^{-1}.

Rocha et al. (2017) and Alexandrino, Vaz, and Santos (2010) point out that these effects reflect the essentiality of N to forage grasses, given that it is a structural constituent of protein molecules, amino acids, enzymes, coenzymes, vitamins and pigments, in addition to acting directly in the process of photosynthesis through participation in the chlorophyll molecule, making it indispensable for plant nutrition.

Intake of dry matter (DM) is the most important factor in nutrition, as it establishes the quantities of nutrients available for health and animal production. Estimates of consumption of lactating cows are vital for the prediction of milk production, as well as for establishing the nutritional requirements of the animals, necessary for the formulation of diets (NRC, 2007).

There was a linear growth ($p < 0.05$) of the support capacity of elephant grass for lactating cows as a function of nitrogen fertilization, an increase of 142% in relation to plants not fertilized (Table 4). The nitrogen fertilization at the highest level stimulated the yield of elephant grass, favoring the carrying capacity of the area, providing a marked increase in animal production per hectare.

The increasing of N fertilization resulted in a linear increase ($p < 0.05$) of crude protein (CP) and neutral detergent fiber (NDF) in elephant grass, however the mineral matter (MM) was not affected by the sources of variation (Table 5). There was an increase in the percentage of CP (18.37%) at the level 80 kg ha^{-1} of N compare to the control. Possibly, the supply of nitrogen in an adequate manner and in favorables conditions for the plant growth, favors the increase in protein content of the plants.

Table 5. Chemical composition of elephant grass subjected to different doses of nitrogen fertilization.

Variables (%)	N doses (kg ha^{-1})					p-value	CV (%)
	0	20	40	60	80		
CP	7.02^c	7.93^b	7.99^b	8.29^a	8.33^a	0.0001*	1.23
NDF	76.01^a	76.00^{ab}	75.95^{bc}	75.93^c	75.92^c	0.0043*	1.56
MM	2.4	2.5	2.1	2.4	2.2	0.0612^{ns}	2.1

Means followed by distinct letters on the line differ ($p < 0.05$) from each other by the Tukey test. CP = crude protein; NDF = neutral detergent fiber; MM = mineral matter; CV = coefficients of variation; p-value = Probability by regression model at 0.05*; ns = not significant levels of probability; Regression Equations: (CP) $\hat{Y} = 7.316 + 0.0119x$, $R^2 = 0.79$; (NDF) $\hat{Y} = 76.0012 - 0.0001x$, $R^2 = 0.93$.

In this work, it was observed that the NDF contents decreased from 76.01 to 75.92% due to the addition of 80 kg ha^{-1} of N, a similar result that also observed by Vitor et al. (2009) and Mota et al. (2010) working with the same forage species. According to these authors, nitrogen fertilization can reduce the percentage of NDF in plants by stimulating the growth of new tissues, which have lower levels of structural carbohydrates in dry matter.

The NDF content represents the chemical fraction of forage that has a close correlation with consumption and, according to Mertens (1987), NDF values above 60% negatively influence the forage intake by dairy cows. In this context, Van Soest (1994) reports that the fraction of neutral detergent fiber in dry matter directly interferes with the digestibility of feed in ruminant animals, that is, the higher, the lower the digestibility.

The supply of nitrogen in high doses, combined with favorable climatic conditions, can accelerate the maturity and senescence of the plant, limiting the beneficial effect of nitrogen fertilization on the NDF values. In this situation, possibly the material's precocity will be positively affected, influencing the management decision on the material's cutting time.

Conclusion

The morphometric characteristics of *Pennisetum purpureum* Schum. cv. Purple is not affected by nitrogen fertilization via urea. Nitrogen application results in a positive linear response in productivity, thus, support capacity. Also, nitrogen application increases crude protein and drecreases NDF levels on plant.

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