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Nitrogen doses for common beans crop in the Cerrado region in the State of Bahia

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Abstract
Common beans crop is very demanding in nutrients, where nitrogen is the most required by the crop. The nitrogen fertilization recommendations for the Cerrado in Western Bahia are based on recommendations elaborated for the Cerrado conditions in the Brazilian Central-West region, and such recommendations may not be adequate, as the Cerrado in the state of Bahia is predominantly characterized by sandy soils and little rainfall than the other areas of this biome, showing peculiar characteristics regarding the behavior of nitrogen in the soil. Thus, the objective of this study was to evaluate the effect of nitrogen doses on the morphological characteristics, yield and quality of beans in the common beans crop in the Cerrado in the State of Bahia. The experiment was conducted in the municipality of Barreiras, State of Bahia (BA), in a randomized block design, consisting of five nitrogen doses (0, 60, 120, 180 and 240 kg ha^{-1}) and four replications. The morphological attributes, grain yield and dry biomass and the physical and chemical quality of the grains were evaluated. The data were subjected to analysis of variance and the means were compared by the test of Tukey at 5% and regression analysis was performed to assess the effects of N doses on the variables. Regarding morphology, the highest nitrogen doses had a positive influence on stem diameter and number of leaves. The maximum efficiency dose was 63 kg ha^{-1} with productivity of 2,889.6 kg ha^{-1} of grains, while the maximum dose of 240 kg ha^{-1} increased the protein content in grains by 46% in relation to the absence of nitrogen fertilization.
Keywords: nitrogen fertilization; *Phaseolus vulgaris*; Western Bahia.

Doses de nitrogênio para a cultura do feijão na região do Cerrado baiano.

Resumo
O feijoeiro é bastante exigente em nutrientes, sendo o nitrogênio o mais requerido pela cultura. As recomendações de adubação nitrogenada para o Cerrado do Oeste da Bahia são baseadas em recomendações elaboradas no Cerrado do Centro-Oeste do país, assim, tais recomendações podem não ser adequadas, pois o Cerrado baiano é caracterizado por solos predominantemente arenosos e precipitação pluviométrica inferior as demais áreas deste bioma, tendo características peculiares quanto ao comportamento do nitrogênio no solo. Assim, objetivou-se avaliar o efeito de doses de nitrogênio nas características morfológicas, produtividade e qualidade dos grãos da cultura do feijão no Cerrado baiano. O experimento foi realizado no município de Barreiras, BA, com delineamento em blocos casualizados, constituído por cinco doses de nitrogênio (0, 60, 120, 180 e 240 kg ha^{-1}) e quatro repetições. Foram avaliados os atributos morfológicos, produtividade de grãos e de biomassa seca e qualidade física e química dos grãos. Os dados foram submetidos a análise de variância e as médias comparadas pelo teste de Tukey a 5% e feita análise de regressão para avaliar os efeitos das doses de N nas variáveis. Em relação à morfologia, as maiores doses de nitrogênio influenciaram positivamente no diâmetro do colmo e número de folhas. A dose de eficiência máxima foi de 63 kg ha^{-1} com produtividade de 2.889,6 kg ha^{-1} de grãos, enquanto a dose máxima de 240 kg ha^{-1} aumentou em 46% os teores de proteínas nos grãos em relação à ausência de adubação nitrogenada.
Palavras chave: adubação nitrogenada, Oeste baiano, *Phaseolus vulgaris*.

Introduction

Common bean (*Phaseolus vulgaris* L.) is one of the most important leguminous plants for human diets, especially in developing countries, such as Brazil. This legume stands out with a high social significance in human diets since its nutritional properties are based on fact that they are a rich source of protein and are poor in fat (AFONSO *et al*., 2011; CATUCHI *et al*., 2019). Bahia is the fifth national producer and the largest produced in the Northeast regions, with 281,6 thousand tons of bean. In this context, Western regions of Bahia accounts for 78 thousand tons of grains, where the municipalities of Barreiras, Correntina, Jaborandi, Luís Eduardo Magalhães and São Desidério, stand out totaling more than 70% of all production (SILVA, 2015; AIBA, 2019).

The significant increase in the use of nitrogen fertilizers is one of the factors responsible for the high productivity of the bean crop. According to Aires *et al*. (2019), nitrogen (N) is one of the elements mostly demanded by the bean crops, absorbed in higher quantities. However, although this crop can fix atmospheric N through symbiosis with bacteria of the Rhizobium genus, its quantity is not sufficient to meet the requirements of the crop (RABELO *et al*., 2017), even when nitrogen fertilization is carried out, because, a great part of the nitrogen applied to the soil is not used by the crop due to possible losses from erosion, leaching, denitrification and volatilization, as well as the great interaction that this nutrient suffers with the soil. Therefore, its management is essential because it considers the high environmental risks, in addition to identifying adequate nitrogen doses for the crop as it can improve its assimilation for the plant.

Nitrogen fertilization is considered one of the principal steps in the agricultural production process, as the management of this nutrient is one of the most difficult. In the case of beans, the supply of N at sowing and in topdressing is essential for the adequate development of seedlings (GOMES JUNIOR; SÁ, 2010; KOTZ-GURGACZ *et al*., 2018). When applied in the recommended dose, it promotes a rapid growth, increase the number of leaves and the protein content in the seeds, feeds soil microorganisms that decompose the organic matter, in addition to increasing the dry matter content and radiation efficiency, reflecting in greater nutritional value (KANEKO *et al*., 2010). In addition, nitrogen fertilization is considered essential for the achievement of high yields of common beans, especially when grown in areas with high technology use (as is the case of Cerrado in the State of Bahia), in which, in common beans cultivars the N is the nutrient most extracted by the plant and the second most exported by the grains (SORATTO *et al*., 2013; GUIDORIZZI, 2019).

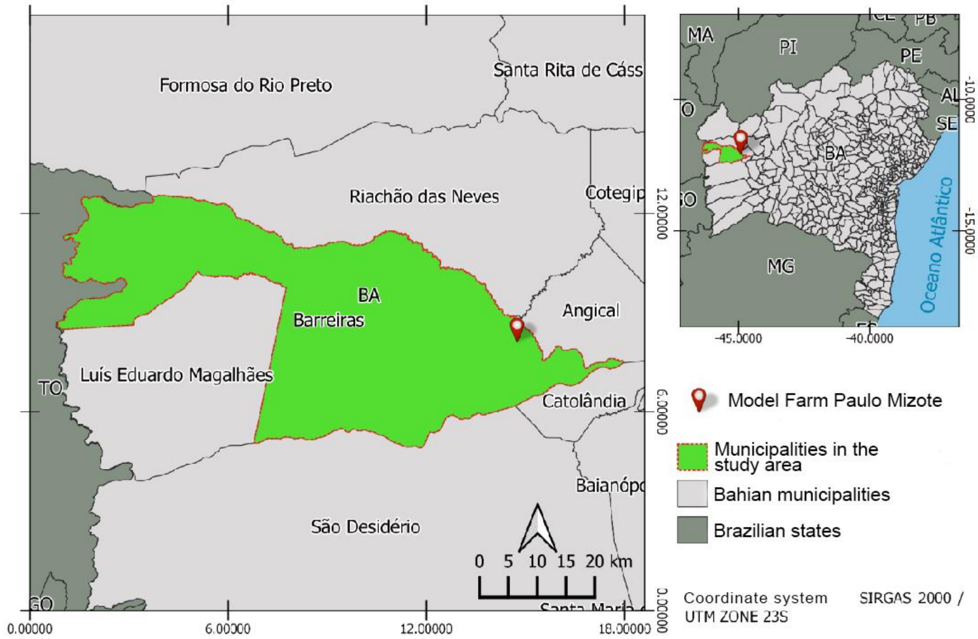
The nitrogen fertilization recommendations for the Cerrado in Western Bahia are based on recommendations elaborated for the Cerrado region located in the Brazilian Central-West; however, due to the diversity of the soil and climate in the Cerrado biome, which covers a vast area and wide diversity, this recommendation may differ in some regions. Therefore, it is necessary to study nitrogen management, aiming to reduce losses both in terms of productivity, a variable directly linked to the use of such nutrient, and to avoid its excessive or unnecessary use.

Therefore, the objective of this study was to evaluate the effect of nitrogen doses on the morphological characteristics, productivity and quality of beans in the bean crop in the Western region of Bahia.

Material and Methods

The experiment was conducted on the model farm Paulo Mizote, located in the municipality of Barreiras, state of Bahia (latitude 12°05’17.7” S, longitude 44°55’16.7” W), as shown in Figure 1, in a Sandy-loam soil, in the period from May to August 2019. The region is in the *Cerrado* biome and the climate, according to the classification of Koppen, is classified as Aw.

Figure 1. Location of Paulo Mizote model farm, located in the municipality of Barreiras, Western Bahia.



Prior to the experiment setting up, 15 simple soil samples were collected at a depth of 0-20 cm to make a composite sample, for the characterization of chemical and physical properties (EMBRAPA, 2018), whose results were: pH in water = 6.35; P (Mehlich) = 27.05 mg/dm^3; K^+ = 54.41 mg/dm^3; Ca^{2+} = 2.70 $cmolc/dm^3$; Ca^{2+} + Mg^{2+} = 3.60 $cmolc/dm^3$; Al^{3+} + H^+ = 1.65 $cmolc/dm^3$, T = 5.42 $cmolc/dm^3$, V = 69.54 %, O.M. = 1.05 dag/kg and particle size composition of 80.88%, 9.83% and 9.29% of sand, silt and clay, respectively. Soil correction was not necessary, as according to Sousa and Lobato (2004) the ideal base saturation for bean crop is from 60%

The experimental design used in the experiment was the randomized blocks, with five treatments and four replicates. The treatments were composed of five nitrogen doses (0, 60, 120, 180 and 240 kg ha^{-1}). The dose of 60 kg of N ha^{-1} was considered as standard, as it is recommended for the Cerrado region, according to Sousa and Lobato (2004). The other doses were established according to the standard dose.

The plots consisted of 5 m in length and 1.20 m in width (6 m^2). Sowing was carried out in furrows, manually, using 0.4 m spacing between lines, 0.07 m between plants and depth from 0.01 to 0.02 m and 14 days after emergence. Thinning was carried out to obtain 14 plants per linear meter.

As it is a soil with less than 15% clay, the nitrogen doses were split as it follows: 50% at 10 days after seedling emergence and 50% at the beginning of flower buds, according to Sousa and Lobato (2004), distributed in the form of urea on the soil surface next to the rows of plants. Regarding the application of potassium, a maintenance fertilization was applied, corresponding to 36 kg ha^{-1} of K_2O in the form of potassium chloride. Irrigation was carried out by conventional spraying, and weeds were controlled by manual weeding.

The sampling of the bean plants was performed after physiological maturation (approximately 90 days after sowing) and for that, four bean plants were collected in the two central lines, dispensing the first two lines with border plants (useful area of 4 m^2 of each plot).

The variables analyzed in this experiment in relation to morphology were: plant height (cm), obtained by measuring, with the help of a measuring tape, from the ground to the apex of the plant; stem diameter (cm), determined using a digital caliper, 5 cm above the ground; leaf length (cm), defined as the distance between the insertion point of the petiole in the leaf blade and the leaf apex; leaf width (cm), obtained by the largest dimension perpendicular to the length axis; number of leaves per plant, determined by counting the total leaves per plant; number of pods per plant, also obtained by counting the total pods per plant.

Grain yield was determined by manual harvesting of all plants in the useful area. After harvesting, the total grain mass was weighed on a digital scale. After, the productivity was corrected to a standard moisture of 13% and the results were expressed in kg ha^{-1}.

The dry biomass (BS) was determined by collecting a sample of plant material at grain harvesting the grains and conducted to the greenhouse at a temperature of 65 °C, for 72 hours, where it the constant weight was obtained. After this process, the material was weighed to obtain dry biomass, the results of which were expressed in kg ha^{-1}.

The determination of the physical and chemical quality of the grains was initially carried out by weighing of a thousand grains (PMG), according to Brasil (2009), and then, the protein contents in the grains were determined according to AOAC (2005). To calculate the protein content, the conversion factor equivalent to 6.25 was used.

The data obtained were submitted to analysis of variance by the F test and, subsequently, the means were compared by the test of Tukey at 5%. To perform the analysis of variance and Tukey's test, the Sisvar® software was selected (FERREIRA, 2019). To evaluate the effects of N doses, regression analysis was performed, and the polynomial models were chosen according to the significance of the coefficients and with the best adjustment of the coefficient of determination (R^2).

Results and Discussion

Table 1 shows the morphological characterization of the bean crop. It can be seen the effect of the doses only for the variables related to stem diameter and number of leaves with an increase of 23.3% and 8.6%, respectively, with the dose of 240 kg ha^{-1} in comparison to the control (without application of N).

It was not observed any effect of nitrogen fertilization for the other variables such as plant height, leaf length and width and number of pods, which shows that nitrogen mainly affects the vegetative growth aspects of the crop. Similar results were found by Barbosa (2010), where there was no difference in plant height and number of pods with the application of increasing doses of nitrogen.

The increment in the number of pods may be closely related to the height of the plants and the higher emission of productive branches. According to results, the plant height variable did not show any significant values, thus, it may also have influenced the behavior of the number of pods, regardless of the dose applied. Another factor may be related to the nutritional requirement of beans, where the crop may have already supplied its demand, indicating, in this case, a trend in consumption beyond its need.

Table 1. Mean values of the plant height (cm), stem diameter (cm), leaf length (cm), leaf width (cm), number of the leaves and number of pods per plant according to the N doses (kg ha^{-1}).

Dose	Height	Diameter	Leaf			Pods
			Length	Width	Number	
0	77.4 a ± 3.3	4.3 b ± 0.1	9.0 a ± 0.2	6.01 a ± 0.2	10.7 b ± 0.8	4.2 a ± 0.3
60	90.0 a ± 6.2	5.2 ab ± 0.1	9.8 a ± 0.1	6.67 a ± 0.1	13.0 ab ± 0.3	6.0 a ± 0.3
120	95.7 a ± 5.5	4.8 ab ± 0.2	8.9 a ± 0.2	5.80 a ± 0.1	11.2 ab ± 0.4	5.5 a ± 0.4
180	97.5 a ± 2.2	5.0 ab ± 0.1	9.7 a ± 0.1	6.47 a ± 0.2	13.7 ab ± 0.5	6.5 a ± 0.5
240	100.7 a ± 3.3	5.7 a ± 0.1	9.0 a ± 0.2	6.09 a ± 0.2	17.0 a ± 0.9	7.0 a ± 0.5
CV (%)	13.96	9.64	9.6	11.31	20.98	30.02
LSD	29.07	1.09	2.02	1.58	6.21	3.95

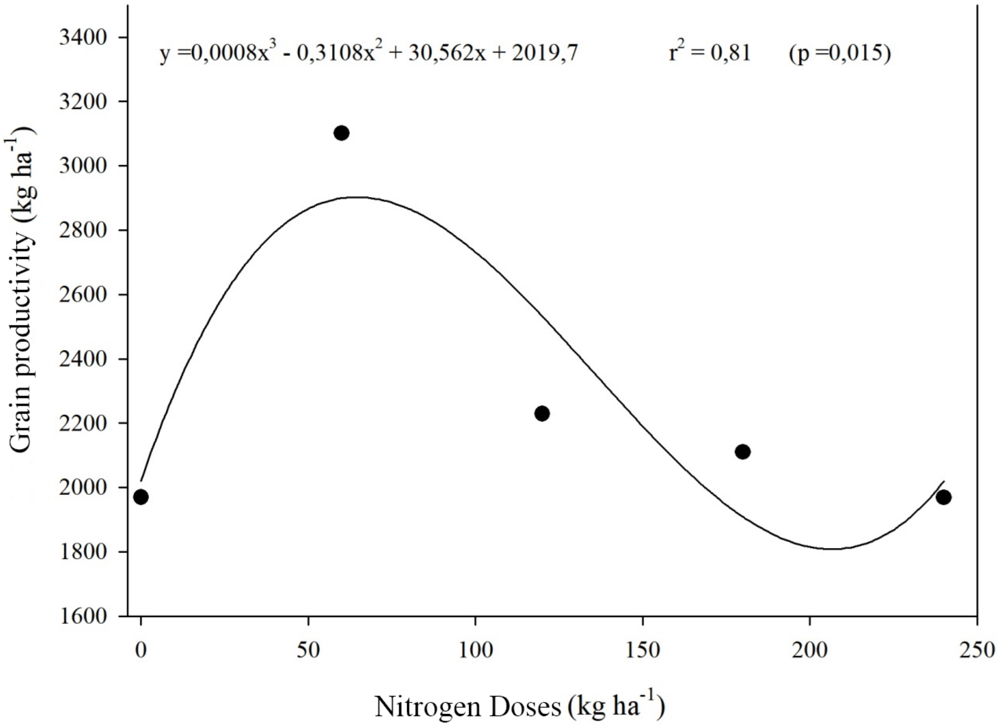
Means followed by the same letter in the columns are not different from each other by the test of Tukey, at the level of 5% of probability. CV (coefficient of variations); LSD (least significant difference); mean standard deviation.

Regarding grain yield, no significant differences were found in the linear and quadratic models of the regression analyses. The cubic model was used as it presents significance (Table 2).

Table 2. Model, equation, coefficient of determination (R^2) and significance level (P), for bean yield.

Model	Equation	R^2	(P)
Linear	$2474.18 - 1.65x$	10.93%	0.19
Quadratic	$2217.83 + 6.89x - 0.035x^2$	36.51%	0.053
Cubic	$2019.66 + 30.56x - 0.31x^2 + 0.0007x^3$	80.17%	0.015

Figure 2. Yield of bean plants according to the nitrogen doses in Western Bahia state.



The N dose variation factor significantly influenced grain yield, with a peak of 2,889.6 kg ha^{-1} with the dose of 63 kg ha^{-1} of N (Figure 2), thus an increase of 4.7% in relation to the recommended dose in the region. The dose with maximum productive efficiency was similar to the dose of 60 kg ha^{-1} recommended by Sousa and Lobato (2004). Similar results were found by Silveira *et al*. (2003), in studies carried out in the Cerrado of the Brazilian Central-West region, where they obtained maximum productivity of 2,449 kg ha^{-1} with the dose of 62 kg ha^{-1} of N in topdressing, which is close to the dose estimated in this experiment.

Beans yield is greatly influenced by nitrogen fertilization, since the application of high doses of N may not result in high production due the accumulation of nitrate in the plant, according to Calonego (2010), resulting from ammonium nitrification and insufficient synthesis of nitrate reductase.

Regarding the production of dry biomass, the nitrogen doses did not influence this variable (Table 3). This result can be attributed to the lack of significance in the morphological attributes, where some aspects such as plant height and leaf area can influence the increase in dry matter. Alvarez *et al*. (2005), when testing doses of N in beans for two consecutive years, observed that the dry matter contents of the plants were not influenced by the applied nitrogen doses.

Table 3. Means values of the dry matter production (kg ha^{-1}) and weight of one thousand grains (TGW) in grams as a function of N doses (kg ha^{-1}).

Dose (kg ha^{-1})	Dry matter	Weight of one-Thousand grains (g)
0	2249.33 a ± 398.17	234.02 a
60	2934.40 a ± 360.59	239.55 a
120	3847.87 a ± 434.98	242.47 a
180	4417.63 a ± 325.41	246.50 a
240	5584.69 a ± 816.85	250.77 a
CV (%)	32.36	6.00
LSD	3635.28	31.78

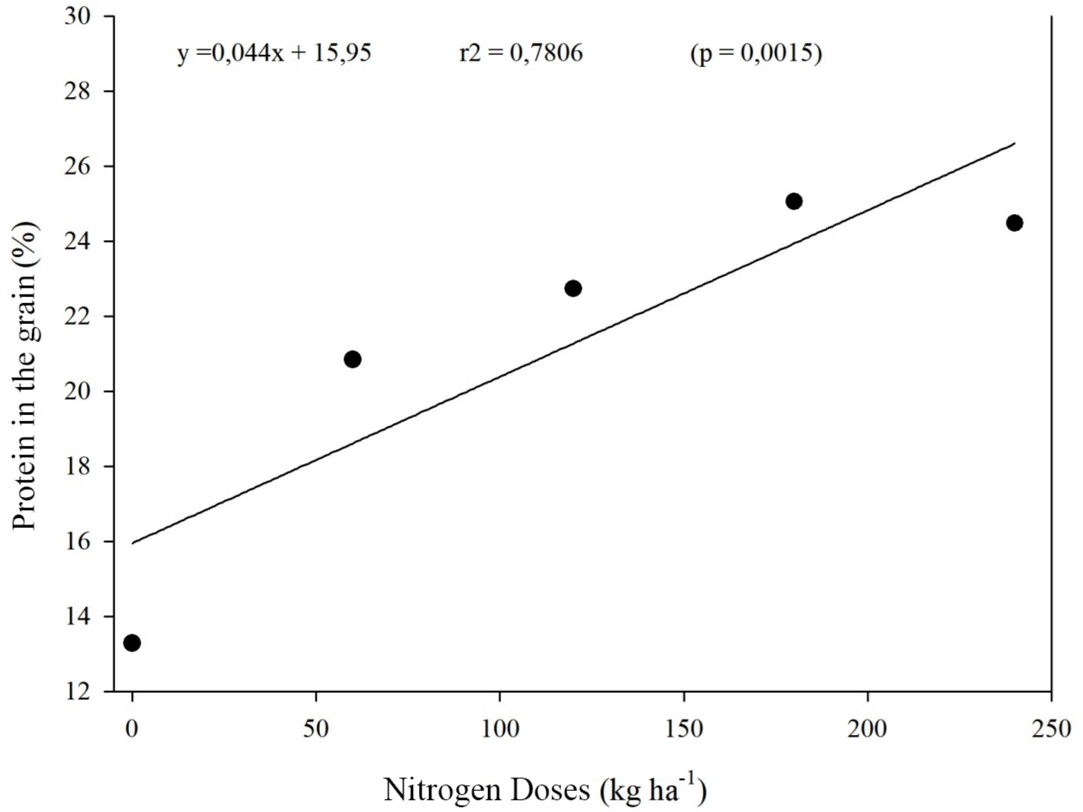
Means followed by the same letter in the columns are not different from each other by the test of Tukey, at the level of 5% of probability. CV (coefficient of variations); LSD (least significant difference); mean standard deviation.

The application of increasing doses of N also did not influence the weight of a thousand grains (Table 3). Similar results were found by Moreira *et al*. (2013), where this variable was also not affected by the applied doses, therefore ensuring that the application of N does not cause great variation in the number of grains per pod nether in the mass of 100 grains. A similar result was also found by Souza *et al*. (2014), which did not show a significant difference in the variable in question.

The nitrogen doses influenced the protein content of the bean grains, adjusting to a linear regression (Figure 3). It is observed an increasing trend in the crude protein content as the doses are incremented with a variation of 15.9% in the absence of fertilizer (0 kg ha^{-1}) to 26.6% with the dose of 240 kg ha $^{-1}$, with an increase of approximately 10%. In some situations, a positive relationship has been observed between nitrogen fertilization and the accumulation of proteins in the bean seed. An effect is also observed through seed inoculation and co-inoculation (YADEGARI; RAHMANI, 2010) and when high doses of nitrogen are provided increasing leaf nitrogen content, grain yield, sieve yield and crude protein content in the grain (D'AMICO-DAMIÃO *et al.* 2020).

A similar behavior was observed by Gomes Junior and Sá (2010), stating that there are several factors that can influence the accumulation of protein in the seeds, ranging from intrinsic characteristics of the cultivar to edaphic variations of the cultivation area and performance of environmental factors. However, the efficiency of the use of N can be determined by the relationship between the levels of soluble protein and crude protein in the seed, since part of the N may be in the form of free amino acids or peptides that are not part of the composition of the proteins.

Figure 3. Protein production in the beans grain according to the nitrogen doses in Western Bahia State.



Conclusion

- The different nitrogen doses influenced the bean yield.
- The recommendation used, according to the fertilization manual for the Cerrado region, was also suitable for the Cerrado region of the State of Bahia, as the dose that obtained maximum efficiency (2,889.6 kg ha^{-1}) was only 4% higher than the recommended dose.
- The dose of 240 kg ha^{-1} of nitrogen increased by up to 46% the protein content in beans.

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