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Grain yield and quality of common bean cultivars in response to nitrogen

Produtividade e qualidade de grãos de cultivares de feijão comum em resposta ao nitrogênio

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Abstract

Nitrogen (N) is the nutrient most required by common bean, and the response to N fertilization may be variable among genotypes. The objective of this work was to evaluate the N nutrition, grain yield, grain size, and crude protein concentration of common bean cultivars in response to topdressing N rates. Two experiments were conducted on a Typic Rodudalf, under two growth conditions ("dry" and "rainy" seasons). A randomized complete block design with a 7 × 4 factorial arrangement and four replicates was used. The treatments consisted of seven cultivars (Pérola, BRS Ametista, BRS Notável, IPR Campos Gerais, IPR Tangará, IAC Formoso, and IAC Imperador) and four N rates (0, 35, 70, and 140 kg ha^{-1}). The experiments were analyzed jointly. The application of N did not affect the cycle, plant population, and number of grains per pod, but increased the leaf N concentration, number of pods per plant, grain size, and grain yield, regardless of the cultivar. The responses of common bean cultivars to N rates varied according to the growth condition, with response to N only in the "rainy" season experiment, under conditions of lower N and higher C/N ratio in the straw of the preceding crop. The crude protein concentration in the grains was influenced in an inconsistent manner by the factors studied.

Additional keywords: genotype; grain size; nitrogen fertilization; *Phaseolus vulgaris*; protein.

Resumo

O nitrogênio (N) é o nutriente mais exigido pelo feijoeiro comum, e a resposta à adubação nitrogenada pode ser variável entre os genótipos. O objetivo deste trabalho foi avaliar a nutrição nitrogenada, a produtividade de grãos, o tamanho dos grãos e o teor de proteína bruta nos grãos de cultivares de feijão comum em resposta a doses de N em cobertura. Foram conduzidos dois experimentos em um Nitossolo Vermelho, porém sob duas condições de cultivo (safras "da seca" e "das águas"). Adotou-se o delineamento em blocos casualizados, com fatorial 7 × 4 e quatro repetições. Os tratamentos foram constituídos por sete cultivares (Pérola, BRS Ametista, BRS Notável, IPR Campos Gerais, IPR Tangará, IAC Formoso e IAC Imperador) e quatro doses de N (0, 35, 70 e 140 kg ha^{-1}). Procedeu-se à análise conjunta dos experimentos. A aplicação de N não afetou o ciclo, a população de plantas e o número de grãos por vagem, mas incrementou o teor de N na folha, o número de vagens por planta, o tamanho dos grãos e a produtividade de grãos, independentemente da cultivar. As respostas das cultivares do feijoeiro comum às doses de N variaram em função da condição de cultivo, com resposta ao N apenas no experimento "das águas", sob condições de menor quantidade de N e maior relação C/N na palhada da cultura precedente. O teor de proteína bruta nos grãos foi influenciado de maneira pouco consistente pelos fatores estudados.

Palavras-chave adicionais: adubação nitrogenada; genótipo; *Phaseolus vulgaris*; proteína; tamanho do grão.

Introduction

The total bean cultivation area in Brazil is approximately 3.2 million ha, with a production of 3.4 million tons of grains, where common bean (*Phaseolus vulgaris* L.) is the main cultivated species (CONAB, 2018). In the last decades, Brazilian breeding programs in common bean have given greater emphasis on obtaining cultivars with carioca-type grains (Lemos et al., 2015). Currently, 65-70% of the total common bean produced and consumed in Brazil has carioca-type grains (Lemos et al., 2015; CONAB, 2018). Cultivar Pérola, with carioca-type grain, stood out as one of the most cultivated cultivars until very recently, having a significant planted area in some regions; however, several other cultivars have been constantly released to the market (Lemos et al., 2015).

Nitrogen (N) is the nutrient most extracted by the common bean plant and removed by its grains (Soratto et al., 2013b). It is a constituent of many components of plant cells, such as amino acids, proteins, and nucleic acids, giving the plants greater vegetative development and, consequently, greater photoassimilate production and yield (Malavolta et al., 1997; Soratto et al., 2004; Maia et al., 2017). However, the N cycle in the soil-plant system is complex, and factors such as climatic conditions, soil type and management, preceding crops, among others, affect the response of crops to N fertilization (Cantarella, 2007; Soratto et al., 2013a; Soratto et al., 2014, Maia et al., 2017). Thus, adequate N management is considered one of the main practices to obtain high yields in common bean crop, especially when cultivated in areas with high technology use (Santos & Fageria, 2007; Soratto et al., 2004; Soratto et al., 2013a, Soratto et al., 2014; Amaral et al., 2016; Maia et al., 2017).

Nitrogen fertilization recommendations for common bean vary according to the area history and the expected grain yield considering the technological level, with rates varying from 40 to 110 kg ha^{-1} N (Ambrosano et al., 1997; Chagas et al., 1999; Sousa & Lobato, 2004). However, according to Santos & Fageria (2007) and Salgado et al. (2012), common bean cultivars differ in response to N management. Fornasieri Filho et al. (2007) observed that cultivar Pérola showed higher grain yield in response to N fertilization and higher N-use efficiency than cultivar IAC Una; however, both cultivars showed increased grain yield up to the highest rate studied (150 kg ha^{-1}) in the first year, and up to the 100 kg ha^{-1} rate in the second year. Guimarães et al. (2017) verified that cultivar Jalo Precoce presented higher grain yield with the rate of 40 kg ha^{-1} of topdressing N fertilization, while for cultivar BRS Estilo, the highest grain yield was obtained with 80 kg ha^{-1} of topdressing N fertilization. On the other hand, Soratto et al. (2017) obtained a linear increase in grain yield for cultivars IPR 139 and Pérola up to the rate of 180 kg ha^{-1} N. Hence, it was considered the hypothesis that there is a difference between currently used common bean cultivars for grain yield and quality in response to topdressing N fertilization.

The objective of this work was to evaluate the N nutrition, grain yield, grain size, and crude protein concentration of common bean cultivars in response to topdressing N rates.

Materials and methods

Two experiments (two growth conditions) were carried out in the municipality of Botucatu, São Paulo State, Brazil (22º51' S; 48º26' W, and 740 m altitude). According to the Köppen classification, the predominant climate in the region is type Cwa. The climatic data recorded during the experimental periods are presented in Figure 1.

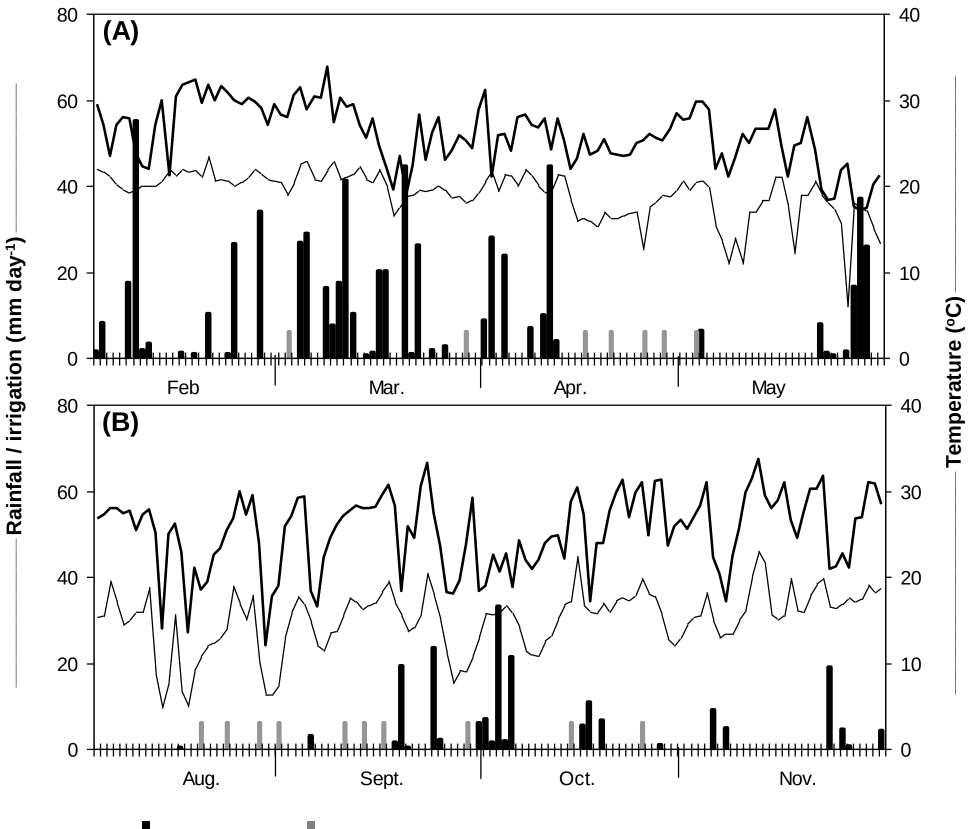

Figure 1 - Daily rainfall ( ), irrigation ( ), maximum temperature ( ), and minimum temperature ( ) recorded at the experimental area from during the periods (A) from February to May ("dry" season experiment) and (B) from August to November ("rainy" season experiment), in 2013. Botucatu-SP.

Experiments 1 and 2 corresponded, respectively, to the “dry” (February-May) and “rainy” (August-November) seasons; preceding crops were black oat/millet and maize, respectively. The soil of the areas used for the experiments was classified as a Nitossolo Vermelho distroférrico, i.e., a Typic Rodudalf, with 643 g kg^{-1} clay, 112 g kg^{-1} silt, and 245 g kg^{-1} sand. Before common bean was sown, soil samples were collected from the 0.0–0.20-m layer. In the area used in the “dry” season, the soil had the following characteristics: 30 g dm^{-3} organic matter; pH ($CaCl_2$) 5.8; 61 mg dm^{-3} P_{resin}; 5.1, 54, 27, and 27 $mmol_c$ dm^{-3} K, Ca, Mg, and H+Al, respectively; base saturation (BS) of 76%. In the “rainy” season, the soil characteristics were as follows: 25 g dm^{-3} organic matter; pH ($CaCl_2$) 4.8; 38 mg dm^{-3} P_{resin}; 6.2, 36, 11, and 45 $mmol_c$ dm^{-3} K, Ca, Mg, and H+Al, respectively; BS of 46%. The desiccation of plants present in the experimental areas was performed 15 days before sowing, using herbicide glyphosate at the rate of 2,160 g a.i. ha^{-1}. Ten days after desiccation, crop residues were managed with the use of a straw mower. Samples of the straw remaining on the soil were collected one day before sowing for both experiments, using a 0.25-m^2 area frame. These samples were dried at 65 ºC for 72 h, being subsequently weighed. We observed the equivalent of 3,882 kg ha^{-1} dry matter (DM) for the “dry” season, and 4,253 kg ha^{-1} DM for the “rainy” season. The dried material was ground and subjected to analysis of N and C concentrations (Malavolta et al., 1997). The amount of N in the remaining straw was obtained by multiplying the DM amount present at the soil surface by the N concentration at that straw. The C/N ratio was obtained by dividing the concentrations of these elements in the straw. Values of 61 and 46 kg ha^{-1} N were observed for the “dry” and “rainy” season experiments, respectively, with C/N ratios of 26 and 31.

In both experiments, the experimental design was randomized blocks in a 7 × 4 factorial scheme with four replicates. The treatments consisted of seven common bean cultivars of the commercial group Carioca (Pérola, BRS Ametista, BRS Notável, IPR Campos Gerais, IPR Tangará, IAC Formoso, and IAC Imperador) and four topdressing N rates (0, 35, 70, and 140 kg ha^{-1}). Each experimental unit consisted of four 6-m long rows, with spacing of 0.45 m between rows. The two central rows were considered for evaluations, excluding 0.5 m from the ends of each evaluation row.

The common bean sowing was performed mechanically with a seeder-fertilizer machine, model SPH 249, on 02/20/2013 in the “dry” season and on 08/15/2013 in the “rainy” season, distributing 16 seeds per meter of furrow. Seeds were treated with fungicide carboxin + thiram (60 + 60 g a.i. 100 kg $seed^{-1}$), insecticide thiamethoxan (100 g a.i. 100 kg $seed^{-1}$), and cobalt + molybdenum (4.5 + 45 g per 100 kg seeds). In both experiments, 150 kg ha^{-1} of the formulated fertilizer 08-28-16 of N-P_2O_5-K_2O was applied in sowing fertilization. Emergences occurred at 6 and 11 days after sowing in the “dry” and “rainy” seasons, respectively. Topdressing N fertilization (ammonium nitrate) was performed in the V_4 stage. Thus, in the “dry” season, N fertilization was carried out on 03/13/2013 (16 days after emergence - DAE) for cultivars IAC Imperador and BRS Notável, and on 03/18/2013 (21 DAE) for the other cultivars. In the “rainy” season, in turn, N fertilization was carried out on 09/12/2013 (17 DAE) for cultivars IAC Imperador and BRS Notável, and on 09/18/2013 (23 DAE) for the other cultivars.

Phytosanitary treatments were carried out throughout the development cycle of common bean using herbicides fluazifop-p-butyl + fomesafen (125 + + 250 g a.i. ha^{-1}), insecticides thiamethoxam + lambda-cyhalothrin (35.3 + 26.5 g a.i. ha^{-1}), acephate (450 g a.i. ha^{-1}), flubendiamide (34 g a.i. ha^{-1}), and methomyl (108 g a.i. ha^{-1}), and fungicides azoxystrobin (50 g a.i. ha^{-1}), fluzinam (750 g a.i. ha^{-1}), fentin hydroxide (280 g a.i. ha^{-1}), procymidone (750 g a.i. ha^{-1}), and thiophanate-methyl + chlorothalonil (400 + + 1000 g a.i. ha^{-1}). Water (supplementary irrigation) was supplied by a conventional sprinkler irrigation system, with a 6 mm depth applied in each irrigation, according to the crop need.

At the R_6 stage of each cultivar, 30 leaves (third fully-expanded leaf from the apex) were collected per plot (Ambrosano et al., 1997). The leaves were washed in distilled water and dried at 65 °C for 72 h. Subsequently, these leaves were ground and subjected to N concentration analysis (Malavolta et al., 1997). The cycle was determined as the number of days elapsed from sowing until the physiological maturity of 90% of the plants of the plot. At the time of physiological maturity, production components (number of pods per plant, number of grains per pod, and 100-grain weight) were evaluated in ten plants per plot. Plant population and grain yield (kg ha^{-1}) were evaluated in two 3-m long rows per plot. The data of 100-grain weight and grain yield were corrected to 13% water (wet basis).

The grains harvested in each plot were classified through sieves with oblong holes numbers 10 (3.97 × 19.05 mm), 11 (4.37 × 19.05 mm), 12 (4.76 × × 19.05 mm), 13 (5.16 × 19.05 mm), 14 (5.56 × × 19.05 mm), and 15 (5.95 × 19.05 mm). With the results, relative sieved grain yield (RSGY) and sieve yield (SY) were calculated according to Carbonell et al. (2010). Grain samples were oven dried at 65 ºC for 72 h, being then ground and subjected to N concentration analysis (Malavolta et al., 1997). The protein concentration in the grains was determined by multiplying the N concentration by the index 6.25.

The data obtained in the two experiments (growth conditions) were subjected to analysis of variance to verify if there was effect of the growth condition and the interactions between growth condition and the other factors studied. The means of the experiments and cultivars were compared by the Tukey test at 5% probability. Nitrogen rates were evaluated by regression analysis. The statistical program SISVAR was used.

Results and discussion

The final population of common bean plants was not affected by cultivars and N rates, varying only between the experiments (growth conditions). In the "dry" season experiment, 131,000 plants ha^{-1} were obtained, while in the "rainy" season experiment, the average population was 173,000 plants ha^{-1}. This result probably occurred due to the planting and soil moisture conditions in the germination and emergence phases.

The cycle of cultivars was not affected by N rates. Cultivars BRS Notável and IAC Imperador showed a cycle of 78 days, on average 9 days shorter than the other cultivars (87 days). In the "dry" season experiment, the cycle of common bean cultivars averaged 8 days shorter than in the "rainy" season, which was due to higher temperatures, especially at the beginning of the cycle (Figure 1).

Regarding N concentration in the diagnostic leaf of common bean plants, there was only effect of the isolated factors (Table 1). Common bean cultivation during the "dry" season, in succession to black oat/millet, provided a higher leaf N concentration. This result may have occurred mainly due to the higher amount of N accumulated in the straw and lower C/N ratio of the preceding crop, which, together with higher water availability and temperature in early February, provided higher N uptake by bean plants (Figure 1).

Table 1 – Leaf N concentration (LNC), grain yield (GY), number of pods per plant (NPP), number of grains per pod (NGP), 100-grain weight (100W), relative grain yield retained in sieves (RYRS), sieve yield (SY), and crude protein concentration in grains (CPC) of common bean cultivars grown during "dry" and "rainy" season in response to topdressing N rates.

Treatments	LNC ($g\ kg^{-1}$)	GY ($kg\ ha^{-1}$)	NPP	NGP	W100 (g)	RYRS	SY (%)	CPC ($g\ kg^{-1}$)
Experiment (E)								
Dry season	44.6a	3,333b	21.5a	5.1a	27.4a	7.8b	86.5b	265a
Rainy season	40.7b	3,776a	20.0b	4.8b	27.4a	8.4a	92.1a	239b
Cultivar (C)								
Pérola	44.1ab	3,385b	18.3b	4.7cd	28.3b	8.2ab	89.5a	245b
BRS Ametista	42.5abc	3,533b	18.2b	4.9bcd	30.5a	8.0bc	89.7a	262a
BRS Notável	41.0bc	3,575b	21.9a	4.8bcd	25.6d	8.4ab	91.0a	256ab
IPR Campos Gerais	44.6a	3,573b	17.7b	5.2ab	28.0b	8.2ab	91.1a	254ab
IPR Tangará	44.0ab	4,054a	23.0a	5.3a	26.0cd	8.6a	92.7a	244b
IAC Formoso	42.9ab	3,363b	23.1a	5.0abc	26.9c	7.7c	85.2b	255ab
IAC Imperador	39.2c	3,397b	23.0a	4.6d	26.4cd	7.6c	86.2b	245b
Nitrogen ($kg\ ha^{-1}$)								
0	42.4	3,363	19.7	4.9	27.2	7.9	87.8	256
35	41.3	3,466	19.6	5.0	27.2	8.1	88.9	249
70	42.6	3,584	20.9	4.8	27.1	8.2	89.8	246
140	44.1	3,819	22.7	5.0	28.0	8.3	90.7	256
Regression	L(1)	L(2)	L(3)	ns	Q(4)	L(5)	L(6)	Q(7)
E × C	ns	<0.001	<0.001	ns	<0.001	<0.001	<0.001	0.018
E × N	ns	0.004	ns	ns	0.002	ns	ns	<0.001
C × N	ns	ns	ns	ns	<0.001	ns	ns	0.003
E × C × N	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)	10.8	16.6	20.9	10.7	4.7	6.9	4.9	6.4

Means followed by equal letters, in the columns within each factor (experiment/growth condition and cultivar), do not differ by Tukey's test, at 5% probability. (1)$y = 41.66 + 0.0157^{**}x$ $R^2 = 0.66$; (2)$y = 3349.08 + 3.3581^{**}x$ $R^2 = 0.98$; (3)$y = 19.34 + 0.0230^{**}x$ $R^2 = 0.93$; (4)$y = 27.28 - 0.0082^{**}x + 0.0001^{**}x^2$ $R^2 = 0.94$; (5)$y = 7.96 + 0.0025^{**}x$ $R^2 = 0.98$; (6)$y = 88.09 + 0.0204^{**}x$ $R^2 = 0.94$; (7)$y = 256.43 - 0{,}2805^{**}x + 0.0020^{**}x^2$ $R^2 = 0.99$. ns Nonsignificant; * and ** Significant by the t-test at 5 and 1% probability, respectively.

According to Cantarella (2007), C/N ratio values between 12 and 25 favor N mineralization of the remaining straw and, consequently, greater availability of N for the subsequent crop. Cultivar IPR Campos Gerais presented the highest leaf N concentration, differing from BRS Notável and IAC Imperador, which may have occurred, among other factors, due to the difference in the nutritional requirement of each cultivar (Table 1). Topdressing N fertilization linearly increased the N concentration, regardless of the cultivar. Increases in leaf N concentrations in common bean plants as a function of N fertilization were reported by Soratto et al. (2004), Soratto et al. (2013a; 2017), Soratto et al. (2014), and Maia et al. (2017). However, in all treatments, leaf N concentrations were within the range considered suitable for common bean cultivation, which is between 30 and 50 g kg^{-1} (Ambrosano et al., 1997).

Grain yield was influenced by the experiment, cultivar, N rate, and by the interactions experiment × cultivar and experiment × N rate (Table 1). In the "dry" season, common bean cultivars showed no difference in grain yield (Table 2). In the "rainy" season, the highest grain yield was obtained with cv. IPR Tangará (4,498 kg ha^{-1}), which differed from cultivars IAC Formoso, Pérola, BRS Notável, and IAC Imperador. The highest grain yield obtained in cv. IPR Tangará was mainly due to the combination of the relatively high number of pods per plant and number of grains per pod (Tables 1 and 2). In the absence of topdressing N fertilization, the grain yield of common bean cultivars obtained in the "dry" and "rainy" season experiments did not differ statistically (Table 3). However, when topdressing N fertilization was applied, the highest grain yields were obtained in the "rainy" season experiment. In fact, this experiment was the only one in which grain yield was affected by N application, with linear adjustment, regardless of the cultivar. The higher response to N in the "rainy" season experiment is probably related to the lower amount of N and higher C/N ratio in the maize straw preceding common bean cultivation.

Table 2 - Experiment (growth condition) × cultivar interaction for grain yield, number of pods per plant, 100-grain weight, relative grain yield retained in sieves, sieve yield, and crude protein concentration in grains of common bean crop. Average of four topderssing N rates.

Exp.	Cultivar						
	Pérola	BRS Amestist	BRS Notável	IPR Campos Gerais	IPR Tangará	IAC Formoso	IAC Imperador
	Grain yield (kg ha^{-1})						
Dry	3,350aA	3,091bA	3,369aA	3,121bA	3,610bA	3,544aA	3,242aA
Rainy	3,419aBC	3,975aAB	3,781aBC	4,025aAB	4,498aA	3,182aC	3,552aBC
	Number of pods per plant						
Dry	19.3aB	18.4aB	22.4aAB	18.5aB	22.7aAB	22.1aB	26.9aA
Rainy	17.3aC	18.1aC	21.4aABC	16.9aC	23.4aAB	24.0aA	19.1bBC
	100-grain weight (g)						
Dry	29.0aB	30.1aA	25.1bCD	27.6bB	25.1bBC	28.4aD	25.8bBC
Rainy	27.7bAB	30.9aA	26.2aC	28.3aB	26.8aC	25.4bB	27.1aC
	Relative grain yield retained in sieves						
Dry	7.9bAB	7.8bABC	8.1bAB	7.5bBC	8.3bA	8.0aAB	7.3bC
Rainy	8.5aAB	8.3aAB	8.7aA	8.9aA	8.9aA	7.5bC	8.1aBC
	Sieve yield (%)						
Dry	86.0bAB	85.9bAB	88.4bA	86.0bAB	89.0bA	87.3aAB	83.2bB
Rainy	93.1aAB	93.6aAB	93.6aAB	96.2aA	96.4aA	83.1bC	89.2aB
	Crude protein concentration in grains (g kg^{-1})						
Dry	263aABC	279aA	265aABC	271aAB	256aBC	269aAB	251aC
Rainy	227bC	245bA	248bA	237bAB	233bAB	241bAB	239bAB

Means followed by equal lowercase letters in the columns (experiment/growth condition) and uppercase letters in the rows (cultivars) do not differ by Tukey's test, at 5% probability.

The 100-grain weight was affected by the isolated factors and by the interactions experiment × cultivar, experiment × N rate, and cultivar × N rate (Table 1). However, in general, cv. BRS Ametista presented higher grain weight than the other cultivars, and there was no consistent effect of the experiment or N application on the grain weight of the cultivars (Tables 2 and 4). Considering the average of the cultivars, N application increased grain weight only in the "dry" season experiment (Table 3). The results indicate that the response to topdressing N fertilization was more related to environmental conditions than to the cultivar used, as reported by Soratto et al. (2004), Soratto et al. (2014), and Soratto et al. (2017). Differences in topdressing N rates to be applied in common bean crop may be related to growing seasons, remaining straw, grain yield (Ambrosano et al., 1997), soil management system (Soratto et al. 2004; Soratto et al., 2014), climatic conditions, N sources, N availability in the soil solution, and N dynamics in the soil-plant system (Soratto et al., 2004; Cantarella 2007).

Table 3 - Experiment (growth condition) × topdressing N rate interaction for grain yield, 100-grain weight, and crude protein concentration in grains of common bean crop. Average of seven cultivars.

Experiment	Nitrogen (kg ha^{-1})				Regression	R^2
	0	35	70	140		
	Grain yield (kg ha^{-1})					
Dry	3,330a	3,235b	3,365b	3,401b	ns	-
Rainy	3,396a	3,711a	3,725a	4,272a	y = 3412.89 + 5.9362**x	0.95
	100-grain weight (g)					
Dry	26.9b	27.0a	27.4a	28.3a	y = 26.71 + 0.0110**x	0.96
Rainy	27.6a	27.6a	26.7b	27.7a	ns	-
	Crude protein concentration in grains (g kg^{-1})					
Dry	264a	263a	270a	263a	ns	-
Rainy	248b	234b	223b	250b	y = 249.66 -0,6947**x + 0.0050**x^2	0.97

Means followed by equal letters in the columns (experiment/growth condition) do not differ by Tukey's test, at 5% probability. ^{ns} Nonsignificant. * and **Significant by the t-test, at 5 and 1% probability, respectively.

Relative sieved grain yield (RSGY) and sieve yield (SY) were influenced by experiment, cultivar, N rate, and by the interaction experiment × cultivar (Table 1). Cultivar IAC Formoso presented higher RSGY and SY values in the "dry" season experiment, in contrast to the other cultivars (Table 2). In general, in the "dry" season, the highest values of RSGY (8.3) and SY (89%) were obtained in cv. IPR Tangará, which differed statistically from cv. IAC Imperador. In the "rainy" season experiment, the highest values of RSGY were obtained in cultivars IPR Campos Gerais and IPR Tangará (8.9), which differed statistically from cultivars IAC Formoso and IAC Imperador. Still in this growing season, the highest SY value was observed in cv. IPR Tangará (96.4%), which differed statistically from cultivars IAC Formoso and IAC Imperador. Similar results were obtained in a study conducted by Carbonell et al. (2010), which evaluated SRGY and SY in 19 common bean genotypes grown during the "dry", "rainy", and "winter" seasons. The authors also observed differences between genotypes and growing seasons for both variables. According to these authors, the bean market has a greater demand for grains classified in sieves 13 and 14; therefore, these grains are more valued by the packaging industry. Regardless of cultivar and experiment, N application linearly increased RSGY and SY values (Table 1). These results corroborate those obtained by Soratto et al. (2011), who verified that N fertilization provided higher quality grains for cv. IAC Alvorada, indicated by the higher values of RSGY, in the absence of foliar N application or when it was only performed in the R_5 stage.

The crude protein concentration in the grains was influenced by the isolated factors and by the interactions experiment × cultivar, experiment × N rate, and cultivar × N rate (Table 1). All cultivars showed the highest grain protein concentration in the "dry" season experiment (Table 2), which was probably due to the higher amount of N accumulated in the straw and lower C/N ratio of the preceding crop. This may have provided greater N uptake by the common bean, as evidenced by the higher N concentration in the diagnostic leaf and by the absence of effect of N rates on the grain protein concentration of bean plants grown in the "dry" season (Tables 1 and 3). In the "dry" season experiment, there was a difference between cultivars regarding crude protein concentration in the grains. The highest values were observed in cultivar 'RS Amestita, which differed from IPR Tangará and IAC Imperador (Table 2). In the "rainy" season experiment, the highest protein concentrations were obtained in cultivars BRS Ametista and BRS Notável. The "rainy" season accounted for lower concentrations of crude protein in the grains with the application of intermediate N rates (35 and 70 kg ha^{-1}), probably due to the significant increase in grain yield, which was not accompanied by proportional increases in N uptake, causing a dilution effect. According to Soratto et al. (2013b), most of the N taken up by common bean (58-69%) is remobilized to the grains at the beginning of the reproductive phase, being especially a component of proteins

(Malavolta et al., 1997). The interaction cultivar × N rate showed a great variation between the cultivars within the different N rates, and inconsistent effects of N rates on the crude protein concentration of bean grains (Table 4). In general, the protein concentration ranged from 232 to 271 g kg^{-1}, and intermediate N rates provided lower values. These increases may be related to some increase in the crude protein concentration in the grains (Table 4), but mainly to the higher grain yields provided by N fertilization (Tables 1 and 3).

Table 4 - Cultivar × topdressing N rate interaction for 100-grain weight and crude protein concentration in grains of common bean crop. Average of two experiments (growth conditions).

Cultivar	Nitrogen (kg ha^{-1})				Regressão	R^2
	0	35	70	140		
	100-grain weight (g)					
Pérola	29.3a	27.2bc	28.0b	28.8ab	ns	-
BRS Ametista	29.2a	31.5a	30.7a	30.7a	ns	-
BRS Notável	25.7b	25.7cd	24.9d	26.3c	ns	-
IPR Campos Gerais	27.5ab	28.7b	27.9b	27.8bc	ns	-
IPR Tangará	26.0b	25.0d	25.1cd	27.8bc	$y = 25.98 - 0.0396^{**}x + 0.0004^{**}x^2$	0.99
IAC Formoso	26.7b	27.5bc	26.1bcd	27.4bc	ns	-
IAC Imperador	26.2b	25.2d	26.8cd	27.3bc	ns	-
	Crude protein concentration in grains (g kg^{-1})					
Pérola	252ab	241a	234ab	253ab	$y = 253.29 - 0.498^{**}x + 0.0036^{**}x^2$	0.98
BRS Ametista	268a	255a	256ab	271a	$y = 267.36 - 0.3928^{*}x + 0.0030^{*}x^2$	0.95
BRS Notável	271a	250a	244ab	260ab	$y = 270.97 - 0.717^{**}x + 0.0046^{**}x^2$	0.99
IPR Campos Gerais	263ab	255a	244ab	255ab	$y = 264.70 - 0.4498^{*}x + 0.0027^{*}x^2$	0.90
IPR Tangará	254ab	245a	232b	246b	$y = 255.72 - 0.5123^{*}x + 0.0032^{*}x^2$	0.90
IAC Formoso	242b	258a	256ab	266ab	$y = 246.43 + 0.1531^{**}x$	0.79
IAC Imperador	242b	237a	258a	243b	ns	-

Means followed by equal letters in the columns (cultivar) do not differ by Tukey's test, at 5% probability. [ns]Nonsignificant. * and **Significant by the t-test, at 5 and 1% probability, respectively.

Conclusions

Topdressing N application did not affect the cycle, plant population, and number of grains per pod, but increased the leaf N concentration, number of pods per plant, grain yield, relative sieved grain yield, and sieve yield of common bean plants, regardless of the cultivar.

The responses of common bean cultivars to topdressing N rates varied according to the growth condition. Nitrogen response was only observed in the "rainy" season experiment, under conditions of lower N and higher C/N ratio in the straw of the preceding crop.

The crude protein concentration in the grains was influenced in an inconsistent manner by the factors studied.

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