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Topdressing N fertilization on productivity and nutritional status of common bean crop

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Abstract

The present study aimed to compare sources and doses of N on productivity, nutritional status and commercial quality of bean (*Phaseolus vulgaris*) crop. The treatments consisted of the following N doses: 60, 90 and 110 kg N/ha. The sources were YaraLiva Nitrabor (390, 585 and 715 kg ha^{-1}) and Urea (130, 195 and 240 kg ha^{-1}). Both sources and doses were applied before or after 15 mm irrigation. In case of fertilizers application after 15 mm irrigation, 1 mm of water was applied after application only to lightly soak granules, which was called “drizzle”, simulating a low-intensity rain after fertilizer application. The experiment was designed as randomized block with four replications in a factorial scheme (2x3x2) + 1, during 113 days with sowing on 06/25/2018 and harvest on 10/18/2018. BRS Estilo was the cultivar used in this study. Application of calcium nitrate in moist soil followed by drizzle provide gains around 5.48 kg of bean/kg of topdressing N, while urea provides gains of 2.22 kg of bean/kg of topdressing N.

Keywords: *Phaseolus vulgaris*, nutrition, nitrogen, yield, nutrients.

Introduction

Common bean is the most important legume for human consumption and the main source of protein for many populations in Latin America, Caribbean, Asia and Africa. Brazil is the world's largest producer of common beans (*Phaseolus vulgaris* L.), and its areas are spread to tropical and subtropical regions. However, the average bean yield in Brazil is still low. Low fertility and high acidity of soil are among factors that contribute to the low yield. Rational use of fertilizers and soil correctives are very important factors in modern agriculture, because, in addition for contributing to the productivity and reduced production costs, they reduce the risk of environmental pollution (Fageria et al., 2015).

Among the nutrients required by bean crop, the present study highlights nitrogen (N), calcium (Ca) and boron (B). N is the nutrient required in greater amount by crop, around 36.5 kg of N/ton of grain produced. N influences leaf growth and duration of leaf area and, thus, the size of carbohydrate source and photosynthetic rate per unit leaf area. Therefore, deficient plants will have low accumulation of dry matter and productivity.

Ca takes the third position among the nutrients with the greatest requirement which are 8 kg of Ca/ton of grain produced. Among functions of Ca in plants, the ones that stand out are the strengthening of plant structure, participation in nitrate reduction, activation of several enzymes to neutralize organic acids and maintenance of plant's turgescence.

B is the third nutrient required in greater quantity among micronutrients. B participates actively in several biochemical and physiological processes, including maintaining membrane integrity, cell wall synthesis, in addition to respiration and lignification.

N fertilization is a management technique necessary to achieve high productive potential in agricultural systems. However, several factors affect the efficiency of topdressing N fertilization, but three are considered important for the growers: N source, quantity and method of application. The source and dose are extremely important to obtain maximum economic return.

The comparison between the efficiency of each fertilizer is important to obtain more information about the crop's response to the use of different N sources and, therefore, to improve the management of N fertilization of bean crop. The use efficiency of N fertilizer in tropical agro-ecosystems is commonly low (Dourado-Neto et al., 2010) and N losses by $N\text{-}NH_3$ volatilization may reach up to 40% of total N applied to crops depending on the type of source (Cantarella et al., 2007; Mazzetto et al., 2020). Crusciol et al., (2019) in an attempt to evaluate the efficiency of N-based sources in common bean, observed that urea-based fertilizers are highly prompt to losses of ammonia (NH_3) volatilization (up to 15.5 kg ha^{-1} $N\text{-}NH_3$) compared to other sources such as ammonium-nitrate (< 1 kg $N\text{-}NH_3$/ha) in fine-textured soil and under field conditions. Such losses may reflect, along the years, in increases on yield components.

The objective of the study was to compare sources and doses of N on productivity, nutritional status and commercial quality of bean crop.

Results

Content and accumulation of N

Sources of N influenced N content in diagnostic leaf (Table 5). Statistical difference was observed among doses only for calcium nitrate. 60 kg/ha of N via urea resulted in higher N content in leaf, which may be attributed to concentration effect.

Drizzle and drizzle x dose interaction influenced N accumulation (extraction) (Table 8). N extraction reduced in presence of drizzle with 110 kg/ha of N via urea. Also, in presence of drizzle, for N doses, urea provided less N extraction than calcium nitrate. These results are due to volatilization loss that can be accelerated with low intensity precipitation (drizzle) after N application.

Content and accumulation of Ca

Treatments did not affect the Ca content in leaves (Table 6). Ca availability in soil was equivalent to 1,650 kg ha^{-1} of Ca at 0 - 30 cm depth. 110 kg/ha of calcium nitrate carried 191 kg ha^{-1} of Ca, that far exceeds the amount applied via calcium nitrate and the crop demand, justifying the lack of response of treatments for Ca content in leaves.

Drizzle, source and dose influenced Ca accumulation (extraction) (Table 9). Ca extraction reduced in response to N doses via calcium nitrate associated to 15 mm of water. Such effect was also observed for urea, however, associated to drizzle after application. Drizzle application led to low Ca extraction depending on the dose and source of N. It may be associated to low N use with drizzle and possible low expansion of leaf area, which compromises the mass flow of Ca in soil.

Content and accumulation of B

Source x dose interaction and triple interaction (at 25% of probability) influenced B content, increasing in response to N doses only with urea and when application was carried out before 15 mm of water (Table 7). Greater vegetative growth may contribute to the mass flow and increase B content in the shoot.

B accumulation responded to source and dose of N (Table 10). Calcium nitrate provided greater B accumulation, regardless drizzle, or 15 mm of water after application. This effect results from presence of 0.3% soluble B in commercial calcium nitrate (YaraLiva Nitrabor).

SPAD index

Drizzle and drizzle x dose interaction influenced SPAD index at flowering stage (Table 3). SPAD index was lower in the simulation of low-intensity irrigation after application of 60 kg/ha of N via urea. N source and drizzle x dose interaction influenced SPAD index at grain filling stage (Table 4). For the average N doses, urea in presence of drizzle presented lower SPAD index than application followed by 15 mm of water.

Number of pods, number of grains per pod and 1000 grains mass

The number of pods was lower with drizzle and 110 kg/ha of N via urea compared to the application of urea plus 15 mm of water (Table 11).

Drizzle x source interaction influenced the number of grains per pod (Table 12). Presence of drizzle provided greater number of grains per pod than application of 15 mm of irrigation at 120 kg ha^{-1} of N via calcium nitrate. Such result, in principle, is not reported in the literature.

The 1000 grains mass was not influenced by treatments (Table 13). This variable has high genetic control and low influence of environmental factors.

Productivity

Productivity was influenced by source, dose, and drizzle x dose interaction (Table 14). There was no difference between N sources when 15 mm of water were applied after N sources. Calcium nitrate provided greater productivity when N was applied followed by drizzle (only 1 mm of water). This is due to volatilization loss of urea, which is accelerated when moisture is enough for dissolution, but not for soil incorporation. Increasing productivity provided by N doses was significant, but the magnitude was below expectations (variable from 4.2 to 15.4 bags/ha).

Productivity x N doses

Linear models fitted to productivity data in response to N doses, regardless source and whether before 15 mm of irrigation or with wet soil plus drizzle (Figure 1). When sources were applied before 15 mm of water (ideal condition) the gains provided by sources were similar (similar slope of models). However, when sources were applied in humid soil followed by drizzle, calcium nitrate provided greater gain per kg of N applied than urea. Urea provided a gain of 0.03706 bags of 60 kg per kg of N applied (2.2236 kg of beans per kg of N applied), calcium nitrate provided gains of 0.09141 bags of 60 kg per kg of N applied (5.4846 kg of beans per kg of N applied). Greater gain of calcium nitrate when applied with drizzle can be attributed to the nitric source that does not loss by volatilization.

Commercial quality of beans was not influenced by treatments (data not show).

Discussion

SPAD index

Urea is an amidic source and subjected to volatilization loss, especially when dissolved without immediate soil incorporation, justifying the effect of drizzle only for urea, not for calcium nitrate. Furlani Júnior et al., (1996) obtained good correlation between chlorophyll meter readings and N application rates (R = 0.86) and leaf N concentration (R = 0.75) indicating that chlorophyll meter is a useful device to detect N deficiency in bean plants.

According to Barbosa et al., (2008) the relative chlorophyll indices increase over time, stabilizing after full flowering (49 DAE) indicating that after this stage, the crop response to N is low, due to the lower demand, and that chlorophyll content in leaves stabilizes, making the use of the device ineffective to indicate the need to apply N as topdressing from this stage.

High SPAD index indicates that irrigation was needed to incorporate N urea-based fertilizer to prevent losses due to urea volatilization. Calcium nitrate, a nitric source, is not sensitive to volatilization losses, which justifies the non-effect of 15 mm of water.

Table 1. Soil chemical analysis before the installation of the experiment.

$pH_{(H2O)}$	P	K	S	Ca^{2+}	Mg^{2+}	CEC	B	Cu	Fe	Mn	Zn	P-rem	OM
	----- mg/dm³ -----			----- $cmol_c/dm^3$ ------			--------------- mg/dm³ ---------------					mg/L	dag/kg
5.4	1.5	25.0	16.0	2.1	0.9	7.77	0.60	4.4	164	13.2	0.7	14.4	2.6

Extractors: P, K, Cu, Fe, Mn and Zn - Mehlich-1; S - monocalcium phosphate in acetic acid; B - hot water. _P-rem = remaining P when agitated with 0.010 mol/L $CaCl_2$ containing 60 mg/L of P; OM = soil organic matter determined by oxidation with potassium dichromate. Sampling depth: 0 to 30 cm.

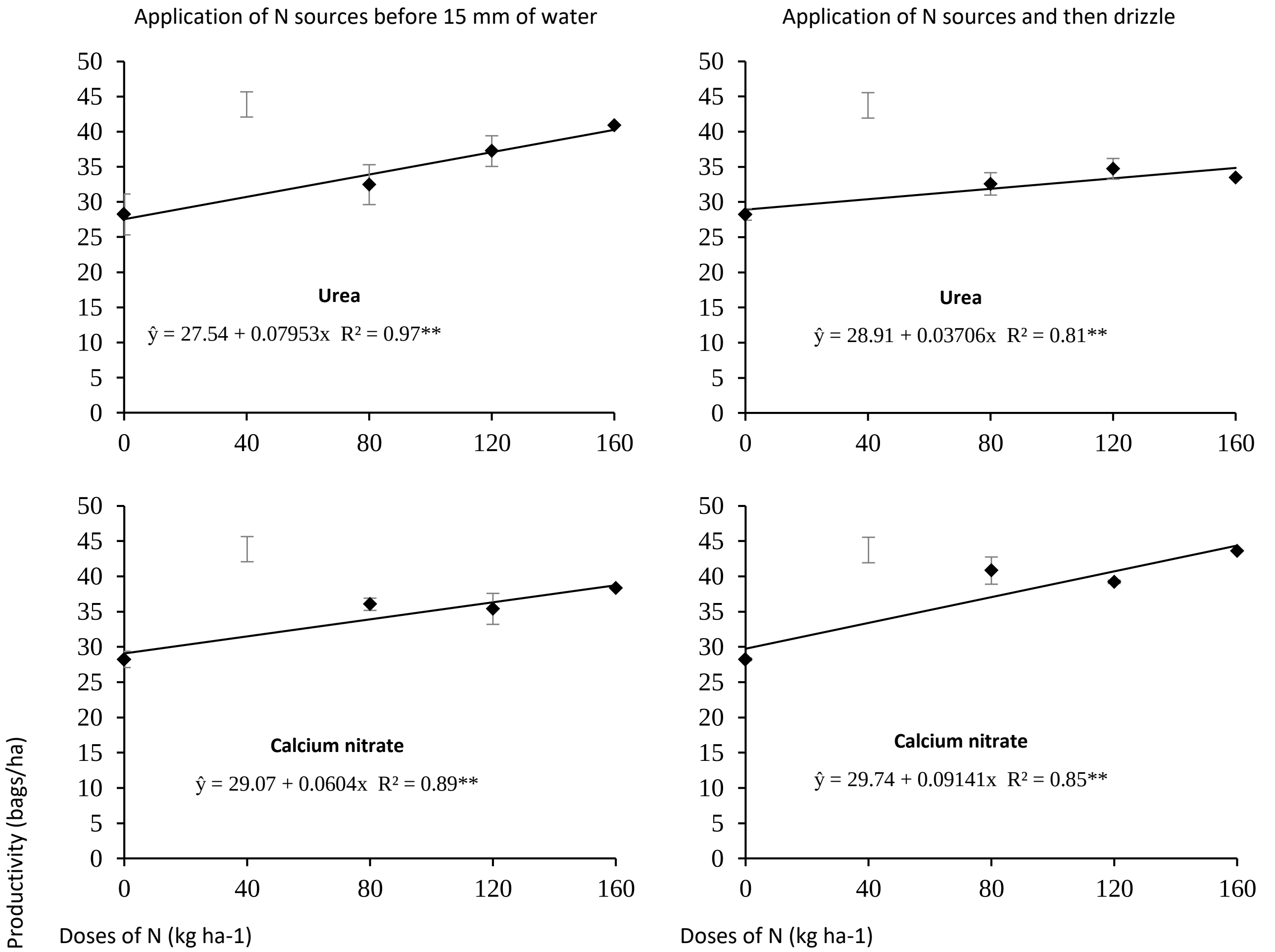

Figure 1. Productivity (bags/ha) of bean in response to sources, doses, and presence of drizzle after N application. IPACER, Rio Paranaíba – MG (2018). [1]Drizzle consisted of applying the N sources in moist soil and then carrying out irrigation of 1 mm aiming only dissolution without incorporating the fertilizers.

Table 2. Nutrient content applied in different treatments.

Treatments	Products	Dose of product (kg ha^{-1})	Dose of N* (kg ha^{-1})	Dose of Ca (kg ha^{-1})	Dose of B (kg ha^{-1})
1	Control	0	17.5	0	0
2	Nitrabor**	390	60	71.4	1.17
3	Nitrabor**	585	90	107	1.76
4	Nitrabor**	715	110	130.8	2.15
5	Urea***	130	60	0	0
6	Urea***	195	90	0	0
7	Urea***	240	110	0	0

* sowing + topdressing. In sowing, 17,5 kg ha-1 of N were applied (350 kg ha^{-1} of the fertilizer 05-37-00); ** Nitrabor (15 00 00) with 15.5% N, 19% Ca and 0.3% B, applied as topdressing without incorporation; *** Urea (46 00 00) without treatment, applied as topdressing without incorporation.

Table 3. SPAD of the central leaflet from third trefoil at full flowering of bean in response to sources, doses and presence of drizzle after N application. IPACER, Rio Paranaíba – MG (2018).

Source of N	Doses of N (kg ha^{-1})						Mean of N sources	
	80		120		160			
Application of N sources before 15 mm								
Urea	43.1	aAα	44.0	aAα	44.3	aAα	43.8	Aα
Calcium nitrate	44.0	aAα	42.7	aAα	43.8	aAα	43.5	Aα
Application of N sources and then drizzle /1								
Urea	39.9	aAβ	42.4	aAα	42.1	aAα	41.5	Bβ
Calcium nitrate	42.4	aAα	43.3	aAα	43.3	aAα	43.0	Aα
Control							41.2≠	
Values of F and CV								
Drizzle =	7.4^{*}	Drizzle x Source =	1.11^{Ns}	Triple interaction =	0.03^{Ns}			
Source =	1.48^{Ns}	Drizzle x Dose =	3.03^{o}	Treatments =	1.9^{Ns}			
Dose =	1.52^{Ns}	Source x Dose =	1.1^{Ns}	C.V. (%) =	3.63			

/1 Drizzle consisted of applying the sources of N in moist soil and then carrying out irrigation of 1 mm aiming only dissolution without incorporating the fertilizers; **, *, ^{o}, ^{Ns} - significant at 1, 5 and 10% or not significant by F test, respectively; ≠ average of the control treatment differs from the average of the factorial by F test at 5%. Means followed by same letter, uppercase in the columns, lowercase in rows and Greek in the comparison with and without drizzle, do not differ by SNK test at 5%.

Table 4. SPAD of the central leaflet from third trefoil at bean pod filling in response to sources, doses and presence of drizzle after N application. IPACER, Rio Paranaíba – MG (2018).

Sources of N	Doses of N (kg ha^{-1})						Mean of N sources	
	80		120		160			
Application of N sources before 15 mm								
Urea	39.5	aAα	41.6	aAα	41.7	aAα	40.9	Aα
Calcium nitrate	40.6	aAα	40.5	aAα	40.1	aAα	40.4	Aα
Application of N sources and then drizzle /1								
Urea	37.3	aAα	39.0	aAα	40.2	aAα	38.8	Aβ
Calcium nitrate	38.7	aAα	40.6	aAα	41.4	aAα	40.2	Aα
Control							34.5≠	
Values of F and CV								
Drizzle =	4.01^{Ns}	Drizzle x Source =	1.06^{Ns}	Triple interaction =	0.52^{Ns}			
Source =	3.89*	Drizzle x Dose =	2.84^{Ns}	Treatments =	4.21**			
Dose =	0.57^{Ns}	Source x Dose =	0.58^{Ns}	C.V. (%) =	4.24			

/1 Drizzle consisted of applying the N sources in moist soil and then carrying out irrigation of 1 mm aiming only dissolution without incorporating the fertilizers; **, *, ^{Ns} - significant at 1 and 5% or not significant by F test, respectively; ≠ average of the control treatment differs from the average of the factorial by F test at 5%. Means followed by same letter, uppercase in columns, lowercase in rows and Greek in the comparison with and without drizzle, do not differ by SNK test at 5%.

Table 5. N content in the bean diagnostic leaf (g/kg) in response to sources, doses and presence of drizzle after N application. IPACER, Rio Paranaíba – MG (2018).

Sources of N	Doses of N (kg ha^{-1})						Mean of N sources	
	80		120		160			
Application of N sources before 15 mm								
Urea	41.9	aAβ	48.9	aAα	48.0	aAα	46.3	Aα
Calcium nitrate	40.3	bAα	37.8	bBβ	49.8	aAα	42.6	Aα
Application of N sources and then drizzle /1								
Urea	50.5	aAα	44.8	aAα	45.2	aAα	46.8	Aα
Calcium nitrate	37.1	bBα	48.7	aAα	45.9	aAα	43.9	Aα
Control							43.2≠	
Values of F and CV								
Drizzle =	0.38^{Ns}	Drizzle x Source =	$2,00^{Ns}$	Triple interaction =	6.59**			
Source =	3.39^{Ns}	Drizzle x Dose =	0.06^{Ns}	Treatments =	2.93*			
Dose =	4.76*	Source x Dose =	2.81^{o}	C.V. (%) =	10.1			

/1 Drizzle consisted of applying the N sources in moist soil and then carrying out irrigation of 1 mm aiming only dissolution without incorporating the fertilizers; **, *, ^{Ns} - significant at 1 and 5% or not significant by F test, respectively; ≠ average of the control treatment differs from the average of the factorial by F test at 5%. Means followed by same letter, uppercase in columns, lowercase in rows and Greek in the comparison with and without drizzle, do not differ by SNK test at 5%.

Table 6. Ca content in the bean diagnostic leaf (g/kg) in response to sources, doses and presence of drizzle after N application. IPACER, Rio Paranaíba – MG (2018).

Sources of N	Doses of N (kg ha^{-1})						Mean of N sources	
	80		120		160			
			Application of N sources before 15 mm					
Urea	14.8	aAα	10.3	aBβ	14.0	aAα	13.0	Aα
Calcium nitrate	14.2	aAα	15.7	aAα	14.4	aAα	14.8	Aα
			Application of N sources and then drizzle /1					
Urea	14.8	aAα	15.6	aAα	15.1	aAα	15.2	Aα
Calcium nitrate	14.2	aAα	16.5	aAα	13.3	aAα	14.7	Aα
Control							13.8	
			Values of F and CV					
Drizzle =	1.39^{Ns}	Drizzle x Source =	1.35^{Ns}		Triple interaction =	0.6^{Ns}		
Source =	0.05^{Ns}	Drizzle x Dose =	1.64^{Ns}		Treatments =	1^{Ns}		
Dose =	0.53^{Ns}	Source x Dose =	2.13^{Ns}		C.V. (%) =	18.1		

/1 Drizzle consisted of applying the N sources in moist soil and then carrying out irrigation of 1 mm aiming only dissolution without incorporating the fertilizers; **, *, ^{Ns} - significant at 1 and 5% or not significant by F test, respectively; $^{\neq}$ average of the control treatment differs from the average of the factorial by F test at 5%. Means followed by same letter, uppercase in columns, lowercase in rows and Greek in the comparison with and without drizzle, do not differ by SNK test at 5%.

Table 7. B content in the bean diagnostic leaf (mg/kg) in response to sources, doses and presence of drizzle after N application. IPACER, Rio Paranaíba – MG (2018).

Sources of N	Doses de N (kg ha^{-1})						Mean of N sources	
	80		120		160			
			Application of N sources before 15 mm					
Urea	43.7	bAα	60.6	aAα	63.9	aAα	56.1	Aα
Calcium nitrate	51.1	aAα	50.6	aAα	45.8	aBα	49.2	Aα
			Application of N sources and then drizzle /1					
Urea	51.3	aAα	60.3	aAα	48.7	aAα	53.4	Aα
Calcium nitrate	49.5	aAα	49.7	aAα	52.4	aAα	50.5	Aα
Control							48.8	
			Values of F and CV					
Drizzle =	0^{Ns}	Drizzle x Source =	0.11^{Ns}		Triple interaction =	2.08^{Ns}		
Source =	2.06^{Ns}	Drizzle x Dose =	0.93^{Ns}		Treatments =	1.39^{Ns}		
Dose =	0.84^{Ns}	Source x Dose =	2.86^{o}		C.V. (%) =	13.7		

/1 Drizzle consisted of applying the N sources in moist soil and then carrying out irrigation of 1 mm aiming only dissolution without incorporating the fertilizers; **, *, ^{0}, ^{Ns} - significant at 1, 5 and 10% or not significant by F test, respectively; $^{\neq}$ average of the control treatment differs from the average of the factorial by F test at 5%. Means followed by same letter, uppercase in columns, lowercase in rows and Greek in the comparison with and without drizzle, do not differ by SNK test at 5%. B content data were transformed by Box-Cox to meet assumptions of variance analysis.

Table 8. N accumulation (shoot + grains – kg ha^{-1}) by bean crop in response to sources, doses and presence of drizzle after N application. IPACER, Rio Paranaíba – MG (2018).

Sources of N	Doses of N (kg ha^{-1})						Mean of N sources	
	80		120		160			
			Application of N sources before 15 mm					
Urea	146.4	aAα	161.9	aAα	155.5	aAα	154.6	Aα
Calcium nitrate	156.4	aAα	151.8	aAα	152.8	aAα	153.7	Aα
			Application of N sources and then drizzle /1					
Urea	129.4	aAα	143.6	aAα	126.9	aBβ	133.3	Bβ
Calcium nitrate	147.9	aAα	156.6	aAα	153.9	aAα	152.8	Aα
Control							$114.0^{\neq}$	
			Values of F and CV					
Drizzle =	4.61^{*}	Drizzle x Source =	0.18^{Ns}		Triple interaction =	0.37^{Ns}		
Source =	0.97^{Ns}	Drizzle x Dose =	3.92^{o}		Treatments =	2.48^{*}		
Dose =	3.23^{Ns}	Source x Dose =	0.59^{Ns}		C.V.(%) =	10.6		

/1 Drizzle consisted of applying the N sources in moist soil and then carrying out irrigation of 1 mm aiming only dissolution without incorporating the fertilizers; **, *, ^{0}, ^{Ns} - significant at 1, 5 and 10% or not significant by F test, respectively; $^{\neq}$ average of the control treatment differs from the average of the factorial by F test at 5%. Means followed by same letter, uppercase in columns, lowercase in rows and Greek in the comparison with and without drizzle, do not differ by SNK test at 5%.

Table 9. Ca accumulation (shoot + grains, in kg ha^{-1}) by bean crop in response to sources, doses and presence of drizzle after N application. IPACER, Rio Paranaíba – MG (2018).

Sources of N	Doses of N (kg ha^{-1})						Mean of N sources	
	80		120		160			
Application of N sources before 15 mm								
Urea	45.1	aBα	44.3	aAα	43.4	aAα	44.2	Aα
Calcium nitrate	61.7	aAα	48.4	bAα	41.7	bAα	50.6	Aα
Application of N sources and then drizzle [/1]								
Urea	51.0	aAα	33.0	bAα	30.4	bAβ	38.2	Aα
Calcium nitrate	45.6	aAβ	39.7	aAα	40.1	aAα	41.8	Aβ
Control							$34.2^{\neq}$	
Values of F and CV								
Drizzle =	10.58**	Drizzle x Source =	0.38^{Ns}	Triple interaction =	4.78*			
Source =	10.16**	Drizzle x Dose =	0.35^{Ns}	Treatments =	4.31**			
Dose =	4.79*	Source x Dose =	0.05^{Ns}	C.V. (%) =	16.0			

/[1] Drizzle consisted of applying the N sources in moist soil and then carrying out irrigation of 1 mm aiming only dissolution without incorporating the fertilizers; **, *, ^{Ns} - significant at 1 and 5% or not significant by F test, respectively; $^{\neq}$ average of the control treatment differs from the average of the factorial by F test at 5%. Means followed by same letter, uppercase in columns, lowercase in rows and Greek in the comparison with and without drizzle, do not differ by SNK test at 5%.

Table 10. B accumulation (shoot + grains, in kg ha^{-1}) by bean crop in response to sources, doses and presence of drizzle after N application. IPACER, Rio Paranaíba – MG (2018).

Sources of N	Doses de N (kg ha^{-1})						Mean of N sources	
	80		120		160			
Application of N sources before 15 mm								
Urea	183.7	aBα	151.0	aAα	182.3	aBα	172.4	Bα
Calcium nitrate	235.8	aAα	179.4	bAα	233.0	aAα	216.1	Aα
Application of N sources and then drizzle [/1]								
Urea	207.2	aAα	155.9	aAα	176.7	aAα	180.0	Bα
Calcium nitrate	235.6	aAα	184.0	aAα	197.9	aAα	205.9	Aα
Control							$133.4^{\neq}$	
Values of F and CV								
Drizzle =	0.02^{Ns}	Drizzle x Source =	1.22^{Ns}	Triple interaction =	0.26^{Ns}			
Source =	10.12**	Drizzle x Dose =	1.03^{Ns}	Treatments =	4.56**			
Dose =	15.68**	Source x Dose =	0.16^{Ns}	C.V. (%) =	14.0			

/[1] Drizzle consisted of applying the N sources in moist soil and then carrying out irrigation of 1 mm aiming only dissolution without incorporating the fertilizers; **, *, ^{Ns} - significant at 1 and 5% or not significant by F test, respectively; $^{\neq}$ average of the control treatment differs from the average of the factorial by F test at 5%. Means followed by same letter, uppercase in columns, lowercase in rows and Greek in the comparison with and without drizzle, do not differ by SNK test at 5%. B content data were transformed by Box-Cox to meet assumptions of variance analysis.

Table 11. Number of pods per plant in response to sources, doses and presence of drizzle after N application. IPACER, Rio Paranaíba – MG (2018).

Sources of N	Doses of N (kg ha^{-1})						Mean of N sources	
	80		120		160			
Application of N sources before 15 mm								
Urea	14.3	aAα	14.8	aAα	15.1	aAα	14.7	Aα
Calcium nitrate	10.8	aAα	11.0	aAβ	15.3	aAα	12.4	Aα
Application of N sources and then drizzle [/1]								
Urea	13.6	aAα	12.9	aAα	12.7	aAα	13.0	Aα
Calcium nitrate	12.7	abAα	16.4	aAα	11.1	bAβ	13.4	Aα
Control							$8.0^{\neq}$	
Values of F and CV								
Drizzle =	0.17^{Ns}	Drizzle x Source =	3.42*	Triple interaction =	2.63^{o}			
Source =	0.47^{Ns}	Drizzle x Dose =	2.78^{Ns}	Treatments =	2.66*			
Dose =	1.49^{Ns}	Source x Dose =	0.55^{Ns}	C.V.(%) =	18.9			

/[1] Drizzle consisted of applying the N sources in moist soil and then carrying out irrigation of 1 mm aiming only dissolution without incorporating the fertilizers; **, *, ^{0}, ^{Ns} - significant at 1, 5 and 10% or not significant by F test, respectively; $^{\neq}$ average of the control treatment differs from the average of the factorial by F test at 5%. Means followed by same letter, uppercase in columns, lowercase in rows and Greek in the comparison with and without drizzle, do not differ by SNK test at 5%.

Table 12. Number of grains per bean pod in response to sources, doses and presence of drizzle after N application. IPACER, Rio Paranaíba – MG (2018).

Sources of N	Doses of N (kg ha^{-1})						Mean of N sources	
	80		120		160			
			Application of N sources before 15 mm					
Urea	4.8	aAα	4.1	aAα	4.6	aAα	4.5	Aα
Calcium nitrate	4.6	aAα	3.9	aAβ	4.6	aAα	4.4	Aα
			Application of N sources and then drizzle /1					
Urea	4.5	aAα	4.2	aBα	4.1	aAα	4.3	Aα
Calcium nitrate	4.3	abAα	5.0	aAα	3.9	bAα	4.4	Aα
Control							4.2	
			Values of F and CV					
Drizzle =	0.38^{Ns}	Drizzle x Source =		6.00**	Triple interaction =		1.83^{Ns}	
Source =	1.05^{Ns}	Drizzle x Dose =		1.02^{Ns}	Treatments =		1.83^{Ns}	
Dose =	0.01^{Ns}	Source x Dose =		1.24^{Ns}	C.V.(%) =		10.1	

/1 Drizzle consisted of applying the N sources in moist soil and then carrying out irrigation of 1 mm aiming only dissolution without incorporating the fertilizers; **, *, ^{Ns} - significant at 1 and 5% or not significant by F test, respectively; $^{\neq}$ average of the control treatment differs from the average of the factorial by F test at 5%. Means followed by same letter, uppercase in columns, lowercase in rows and Greek in the comparison with and without drizzle, do not differ by SNK test at 5%.

Table 13. Mass of 1000 grains (g) of common bean in response to sources, doses and presence of drizzle after N application. IPACER, Rio Paranaíba – MG (2018).

Sources of N	Doses of N (kg ha^{-1})						Mean of N sources	
	80		120		160			
			Application of N sources before 15 mm					
Urea	273.5	aAα	260.8	aAα	265.0	aAα	266.4	Aα
Calcium nitrate	266.1	aAα	250.5	aAα	257.4	aAα	258.0	Aα
			Application of N sources and then drizzle /1					
Urea	261.2	aAα	255.7	aAα	262.5	aAα	259.8	Aα
Calcium nitrate	255.0	aAα	261.2	aAα	255.2	aAα	257.1	Aα
Control							256.1	
			Values of F and CV					
Drizzle =	0.96^{Ns}	Drizzle x Source =		1.24^{Ns}	Triple interaction =		0.44^{Ns}	
Source =	1.1^{Ns}	Drizzle x Dose =		0.56^{Ns}	Treatments =		0.83^{Ns}	
Dose =	2.1^{Ns}	Source x Dose =		0.17^{Ns}	C.V.(%) =		4.4	

/1 Drizzle consisted of applying the N sources in moist soil and then carrying out irrigation of 1 mm aiming only dissolution without incorporating the fertilizers; **, *, ^{Ns} - significant at 1 and 5% or not significant by F test, respectively; $^{\neq}$ average of the control treatment differs from the average of the factorial by F test at 5%. Means followed by same letter, uppercase in columns, lowercase in rows and Greek in the comparison with and without drizzle, do not differ by SNK test at 5%.

Table 14. Productivity (bags/ha = 60 kg ha^{-1}) of bean crop in response to sources, doses and presence of drizzle after N application. IPACER, Rio Paranaíba – MG (2018).

Fontes de N	Doses de N (kg ha^{-1})						Mean of N sources	
	80		120		160			
			Application of N sources before 15 mm					
Urea	32.4	bAα	37.2	abAα	40.9	aAα	36.9	Aα
Calcium nitrate	36.1	aAα	35.4	aAα	38.4	aAβ	36.6	Aβ
			Application of N sources and then drizzle /1					
Urea	32.6	aBα	34.7	aAα	33.5	aBβ	33.6	Bβ
Calcium nitrate	40.8	aAα	39.2	aAα	43.6	aAα	41.2	Aα
Control							28.2$^{\neq}$	
			Values of F and CV					
Drizzle =	0.43^{Ns}	Drizzle x Source =		0.98^{Ns}	Triple interaction =		1.4^{Ns}	
Source =	4.28*	Drizzle x Dose =		14.72**	Treatments =		5.63**	
Dose =	12.92**	Source x Dose =		1.66~	C.V.(%) =		8.5	

/1 Drizzle consisted of applying the N sources in moist soil and then carrying out irrigation of 1 mm aiming only dissolution without incorporating the fertilizers; **, *, ^{Ns} - significant at 1 and 5% or not significant by F test, respectively; $^{\neq}$ average of the control treatment differs from the average of the factorial by F test at 5%. Means followed by same letter, uppercase in columns, lowercase in rows and Greek in the comparison with and without drizzle, do not differ by SNK test at 5%.

Content and accumulation of N

Andreotti et al., (2005) also observed higher leaf contents of N by incorporating urea, ammonium sulfate, ammonium nitrate to the soil, compared to the mode without incorporation because of volatilization.

Bernardes et al., (2014) observed that N sources (urea, urea + NBPT and N gradual release) in bean crop did not influence the total N content and N accumulation in leaves at flowering. However, increasing N doses (0, 50, 100 and 150 kg ha^{-1}) increased total N content and accumulation in leaves of common bean during flowering, up to the estimated dose of 120.7 kg ha^{-1}, reaching a maximum value of 47.2 g of N per kg of dry mass.

Valderrama et al., (2009) also tested N doses as topdressing in common bean and found that N content in leaves increased concomitantly with increasing N topdressing, and N contents of leaf varied from 31.5 g kg^{-1} (control) up to 39.25 g kg^{-1} (120 kg ha^{-1} of N) which are close from those found in the present study.

Productivity

Regarding productivity, limitations of other nutrients may be happened, especially P. To achieve the experimental objectives, an area of first cultivation was chosen and two crops were also grown with cover crops to reduce the N potential. However, high productivity is associated to soils with high nutrients contents, especially P and Ca in deeper soil layers. A cultivation environment with these characteristics with low N potential can result in greater productivity inputs.

Number of pods, number of grains per pod and 1000 grains mass

Bernardes et al., (2014) did not observe effect of N sources (urea, urea + NBPT and N gradual release), and interaction between sources and doses (0, 50, 100 and 150 kg ha^{-1} of N) on grain yield, number of pods per plant, number of grains per pod, mass of 100 grains and final plant stand. For this same author, the productivity increased with increasing N doses, and the maximum estimated yield was 2.876 kg ha^{-1}, with a dose of 133.6 kg ha^{-1} of N.

BRS Estilo cultivar has an average mass of 1000 grains between 240 and 260 g. Reduced number of pods per plant and grains per pod allowed that even control treatment had well-formed grains with mass characteristic of the variety used.

Maintenance of urea on surface contributes to the release of ammonia and significant losses of N in the soil-plant system. $N\text{-}NH_3$ emissions from urea-based fertilizers are higher than other fertilizers due to the rapid hydrolysis of urea which causes rise in pH in the direct vicinity of the application zone, especially in soils with high urease enzyme activity due to crop residues (Cantarella et al., 2018; Fontoura et al., 2010). Therefore, under favorable conditions to volatilization losses, calcium nitrate is more interesting than urea, as it was not dependent on timing and volume of precipitation after its distribution in soil (Mazzetto et al., 2020).

In case of rain or even excessive irrigation, it will be effective if the amount of water is sufficient to dilute the concentration of hydroxyls (OH^-) around the urea granules (Cabezas et al., 1997b). Incorporation of common urea or additive urea provides greater productivity regarding surface application because of volatilization losses (Cunha et al., 2011). Silva et al., (2004) studying topdressing N at 0, 25, 50, 75, and 100 kg ha^{-1} via urea observed that application of 75 to 100 kg N ha^{-1} provided considerable increases in grain yield in the three years of study.

Application of N with urea at 25, 50, 75, and 100 kg ha^{-1} together with increasing P_2O_5 doses (25, 50, 75, and 100 kg ha^{-1}) increased 100 grains mass, grain yield and contents of N and P in cowpea leaf (Júnior et al., 2015). Alvarez et al., (2005) did not observe difference in bean productivity by using urea or ammonium nitrate as topdressing, however the productivity of irrigated common bean cultivated in winter season can be increased by adding N as topdressing, as the crop responds to N application with doses above to 100 kg ha^{-1}. Afonso et al., (2011) concluded that N supply, regardless source used, provided an increase in grain yield. No difference was observed, concerning the nitrogenous fertilizer incorporated or not to the soil with irrigation water.

Materials and Methods

The experimental site, environmental and soil conditions

The experiment was carried out at IPACER Experimental Station, Rio Paranaíba (MG), Brazil (19º10'35" S and 46º06'21" W), with sowing on 06/25/2018 in conventional tillage system, desiccation on 10/11/2018 and harvest on 10/18/2018. The soil of the experimental area is Red Yellow Latosol with clay texture.

The soil chemistry analysis in the experimental area, before establishing the trial, is shown in Table 1. In order to reduce the potential of N mineralization from soil, millet followed by oat were cultivated in the experimental area before sowing. Millet plants were cut and manually removed from the area, whereas oat plants were cut and removed using a hydraulic blade positioned approximately 3 cm from soil surface.

BRS Estilo was the cultivar used. Currently BRS Estilo is one of the most planted in the Midwest Brazil. It has an average cycle of 90 days, indeterminate growth (type II/III) and semi-erect habit.

Experimental design and treatments

The experiment was designed as randomized block in a factorial scheme with four replications and 13 treatments, as shown in the Table 2. The treatments consisted of the combination of treatments 2 to 7 applied before or after 15 mm irrigation depth. In case of applying the fertilizers after 15 mm irrigation, we still used 1 mm water blade over fertilizers to lightly soak the granules, which was called "drizzle", simulating a low-intensity rain after fertilizer application. Each experimental plot consisted of 6 lines per 5 m length.

Bean crop was sown with 12 seeds per linear meter and rows were spaced at 0.50 m from each other. The area was fertilized with 300 kg ha^{-1} of granulated MAP (11% N and 22.7% P) as broadcasting to increase P content before cover crops (millet and oat). All experimental plots received 350 kg ha^{-1} of 05.37.00 with 0.5% Zn at bean sowing in furrow.

The following products were included in the foliar treatment and all experimental plots: YaraTera Krista Map (5kg ha^{-1}) – vegetative stage (MAP Purified); YaraVita Folicare (5 kg ha^{-1}) – grain filling stage (Formulated product with N, K, Mg e S); YaraVita Phosamco Bio (1l kg ha^{-1}) – pre-flowering stage (Formulated product N, P K and Micros, with algae extract).

Potassium (90 kg ha^{-1} of K_2O) was applied as granulated potassium chloride, at pre-sowing by broadcasting in whole area without incorporation - a common practice used in the field by bean growers. N was applied at V4 stage by broadcasting without soil incorporation.

Growth, yield and nutritional analysis

Yield, number of pods per plant, number of grains per pod and mass of 1000 grains were evaluated. SPAD Index were evaluated at the second trefoil from the apex to the base at full flowering and beginning of pod filling. Samples were taken at flowering stage (3rd leaves with petiole from the middle third) to analyze leaf tissue. Leaves and grains were analyzed for macro and micronutrients according to Malavolta et al. (1997).

Plants were collected and analyzed at R8 stage (physiological maturity of grains) to evaluate the nutrients accumulation, mainly N, Ca and B, ie, tissue analyzes were performed and accumulated nutrients were calculated based on dry matter. After harvest, the samples of each treatment were submitted to commercial evaluation (color, sieve and grade) in a referenced buyer of the region.

Statistical analysis

The data were submitted to variance analysis and treatments compared using SNK - Student Newman Keuls test ($\alpha = 0.05$) using the Software SPEED Stat (Carvalho and Mendes, 2017).

Conclusion

Calcium nitrate (YaraLiva Nitrabor) is a better source of topdressing N when applied in moist soil with later small irrigation. However, they are similar when applied before irrigation. Calcium nitrate provides higher bean productivity when environmental conditions are favorable to ammonia volatilization (Urea) and there is possibility to B response.
Application of calcium nitrate in moist soil followed by drizzle provide gains around 5.48 kg of bean/kg of topdressing N, while urea provides gains of 2.22 kg of bean/kg of topdressing N.

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