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COMMON BEAN YIELD AS AFFECTED BY IN FURROW FILLER LIMING AND NITROGEN TOPDRESSING[1]

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ABSTRACT - The use of filler liming in the sowing furrow can improve the chemical characteristics of the soil and, together with nitrogen fertilization, increase common bean yield. The objective of this study was to determine the effect of filler liming of the sowing furrow along with nitrogen topdressing fertilization on the yield of common bean, cultivar Pérola, irrigated by central pivot, in the Cerrado Region. The field experiments were conducted for three consecutive cropping years, in a randomized block design with four replications, in a 2x4 factorial scheme, consisting of two doses of nitrogen topdressing fertilization (zero and 60 kg ha^{-1} of N) and four doses of filler liming application in the sowing furrow (0, 200, 400 and 600 kg ha^{-1} of $CaCO_3$). The plant density (PD), number of pods (NP), number of grains (NG), mass of 100 grains (M100) and, grain yield (GY) were evaluated. The use of 60 kg ha^{-1} of N provided greater M100 and GY. The increase of the filler liming doses in the sowing furrow led to a reduction of the NP. The filler liming dose of 200 kg ha^{-1} provided higher values of NG and M100, and when combined with the nitrogen topdressing fertilization, improved the GY of the common bean.

Keywords: *Phaseolus vulgaris.* Soil correction. Nitrogen fertilization. Calcium carbonate. Cerrado.

EFEITO DA APLICAÇÃO DE CALCÁRIO FILLER NO SULCO DE SEMEADURA E NITROGÊNIO EM COBERTURA NA PRODUTIVIDADE DO FEIJÃO-COMUM

RESUMO - O uso de calcário filler no sulco de semeadura, aliada à adubação nitrogenada em cobertura, é uma prática pouco utilizada e seus efeitos sobre os atributos químicos do solo e produtividade do feijão comum necessitam ser estudados. O objetivo deste estudo foi determinar o efeito da aplicação de calcário filler no sulco de semeadura, juntamente com a adubação nitrogenada de cobertura, na produtividade do feijão-comum, cultivar Pérola, irrigado por pivô-central, cultivado no Cerrado. Os experimentos de campo foram conduzidos por três safras consecutivas, em delineamento de blocos ao acaso com quatro repetições, no esquema fatorial 2x4, sendo duas doses de nitrogênio em cobertura (zero e 60 kg ha^{-1} de N) e quatro doses de cálcario filler no sulco de semeadura (0; 200; 400 e 600 kg ha^{-1} de $CaCO_3$). Foram avaliados o número de plantas (NP), número de vagens (NV), número de grãos (NG), massa de 100 grãos (M100) e a produção de grãos (PG). O uso de 60 kg ha^{-1} de N proporcionou maior M100 e GY. O incremento nas doses de calcário filler no sulco de semeadura proporcionou redução no NV. A aplicação de 200 kg ha^{-1} de calcário filler proporcionou os maiores valores de NG e M100 e, quando combinada com a adubação nitrogenada em cobertura, proporcionou maior PG do feijão-comum.

Palavras-chave: *Phaseolus vulgaris*. Correção do solo. Adubação nitrogenada. Carbonato de cálcio. Cerrado.

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INTRODUCTION

The common bean has great economic importance for Brazil. In the 2018 harvest, the cultivated area was 3.2 million hectares, with a grain production of 3.1 million tons (CNPAF, 2020). In Brazil, the crop is grown in three different cropping seasons: rainy season (September to December), dry season (January to March) and winter season (May to July). However, despite its importance, there is still low productivity, mainly in the rainy (1,225 kg ha^{-1}) and dry (842 kg ha^{-1}) seasons, due to the low use of technology (CNPAF, 2020).

The winter season can be described as more technologically intensive, characterized by a huge use of industrial products (NASCENTE et al., 2012) and normally has a higher average grain yield, with about 2,596 kg ha^{-1} (CNPAF, 2020). These data indicate that the use of technology leads to significant increases in grain yield of the common bean. Among the aspects that must be improved, aiming to achieve high productivity levels, acidity correction and fertility management of the soil are crucial (CARVALHO et al., 2018; DIDA; ETISA, 2019). Thus, the adequate and balanced supply of nutrients to the common bean crop by liming and fertilizer use provides significant increases in crop productivity (KIPNGETICH; MWONGA; OJIEM, 2021).

In most grain producing areas under no-tillage system, the correction of the soil acidity has been carried out by applying lime on the soil surface, without incorporation (TIRITAN et al., 2016). With the application of lime, there is an increase in pH values, calcium and magnesium levels, base saturation and reduction of exchangeable aluminum levels in the soil (CAIRES et al., 2008; PAGANI; MALLARINO, 2012).

However, even in corrected soils, the application of small doses of lime (less than 1000 kg ha^{-1}) in the sowing furrow can provide benefits to the crop (NASCENTE; COBUCCI, 2015a). For example, the application of calcium carbonate solution in the sowing furrow in corrected soil increases the availability of phosphorus and the productivity of the common bean (NASCENTE; COBUCCI, 2015a).

Considering that in no-tillage system, limestone is applied on the soil surface, without incorporation into the soil profile, the use of filler limestone in the furrow can improve the environment for the development of crops by supplying nutrients and fast correction of soil acidity due to its high reactivity. While conventional limestone has particle sizes ranging from 50% <0.3 mm and 50%> 0.3 mm, with reactivity ranging from 75 to 100%, filler limestone has a much finer particle size, less than 0.30 mm, showing reactivity greater than 100% (PRIMAVESI; PRIMAVESI, 2004).

Besides, among fertilizers, N-fertilizers are of great importance because they provide nitrogen (N), one of the most absorbed and most influential nutrient on crop growth (NASCENTE et al., 2017), which when applied as a topdressing after sowing can significantly affect the crop yield (SOUSA et al., 2020).

Although the combined use of filler liming in the sowing furrow and nitrogen topdressing fertilization can have a beneficial effect on the common bean yield, studies in Cerrado soils are still limited. Therefore, this work aimed at determining the effect of filler liming of the sowing furrow together with nitrogen topdressing on the yield components and grain yield of the common bean cultivar Pérola, irrigated by central pivot, in the Cerrado region.

MATERIAL AND METHODS

The experiments were carried out in the winter season of three different cropping years (2014, 2015 and 2016), in the experimental area of Embrapa Arroz e Feijão, located in the municipality of Santo Antonio de Goiás-GO, under the coordinates 16º28`00”S, 49º17`00”O and altitude of 823 m. According to Köppen’s classification the climate of the region is an Aw, tropical savanna, with dry season in winter and rainy in summer. The annual rainfall varies from 1.500 to 1.700 mm. The mean annual temperature is 22.7 °C, varying from 14.2 °C in the winter and 34.8 °C in the summer. Mean temperatures, rainfall distribution and irrigation events during the three experimental periods are presented in Figure 1.

The soil of the experimental areas is classified as an Oxisol (SOIL SURVEY STAFF, 2014). During the previous five years the experimental area was cropped with maize/soybean in the summer and with common bean in the winter under no-tillage. Before experiment settlement, 20 soil subsamples were taken at 0–20 cm depth to evaluate soil chemical properties. Chemical analysis followed basic procedures (DONAGENA et al., 2011). Before being analyzed, soil samples were dried (60 °C for 48 h) and sieved (2-mm). Soil pH was determined in 0.01 M $CaCl_2$ (1:2.5; soil/solution), after agitation for 1 h. Exchangeable Ca and Mg were determined in the extract obtained with 1 mol L^{-1} KCl (1:10; soil/solution) after agitation for 10 min. P and K contents were evaluated in the Mehlich-1 (0.05 mol L^{-1} HCl+0.0125 mol L^{-1} H_2SO_4) extract (1:10; soil/solution) after agitation for 10 min. Concentrations of Ca and Mg were determined in an atomic absorption spectrophotometer, K in a flame photometer and P by colorimetry, using the molybdenum-blue method and ascorbic acid as reducing agent. Organic matter was determined by Walkley & Black method. Soil characteristics before sowing at each site are shown in Table 1.

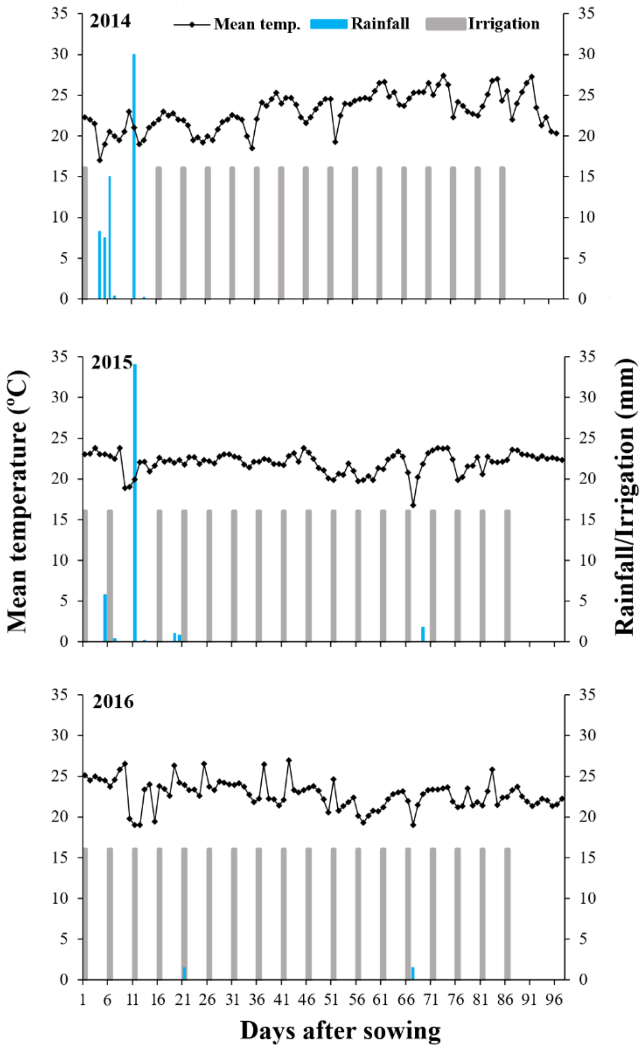

Figure 1. Mean temperatures, rainfall distribution and irrigation events at Santo Antônio de Goiás (Cerrado region, Brazil) during crop growing periods of the three experiments.

Table 1. Soil chemical analysis at different cropping years before field experiment implementation.

Cropping years	pH	Ca	Mg	P	K	SOM[1]
	in H_20	mmol$_c$ dm^{-3}		mg kg^{-1}		g kg^{-1}
2014	5.7	16.7	13.4	18.1	125	26.6
2015	5.4	26.0	10.1	12.4	92	34.3
2016	6.0	15.1	12.7	13.0	171	32.7

[1]Soil organic matter.

All experiments were assigned to a completely randomized block design, in a 2x4 factorial scheme, with four replications. The treatments consisted of the combination of two doses of nitrogen (N) (zero or 60 kg ha^{-1} of N) and four doses of filler limestone applied to the sowing furrow (0; 200; 400 and 600 kg ha^{-1}). The plots were composed of five rows with five meters in length and 0.45 m between rows. Plot size was 11.25 m^2 (5 rows X5 m X 0.45 m) and the plots were separated by rows of at least 0.9 m to prevent contamination by superficial run-off containing fertilizer. The useful area had 5.4 m^2, composed by the three central rows, discarding 0.50 m from each end.

The fertilization in the sowing furrow was 320 kg ha^{-1} of the formulated 5-30-15 (N-P_2O_5-K_2O). The filler limestone had 30% CaO and was mixed with the fertilizer. The volume was completed with sand to be applied at a dose of 920 kg ha^{-1} in the sowing furrow using a seeder-fertilizer machine with five sowing lines, spaced 0.45 m apart, and with double-sided fertilizer furrow and furrow seeder. The machine was set to operate at a speed of 4 km h^{-1}. Fifteen common bean seeds of the cultivar Pérola were distributed per meter. Urea was used as the N source and, was applied as a topdressing at the V4 vegetative stage (third trifoliolate leaf).

At each year of experimentation, trials were installed on the first half of June in areas with central pivot irrigation. Irrigation management was done according to the crop requirements with irrigations at each 2 days until germination and, at each 4 days afterwards, totaling an application of 325 mm.

Weed plants can hinder crop development by competing for natural resources such as water and nutrients. Its control was done by applying Fomesafen (1.0 L ha^{-1}) at V_2 stage and Fluasifop-p-butil (1.0 L ha^{-1}) at V_3 stage. Fungicides Chlorothalonil, 900 g a.i. ha^{-1} (against anthracnose=*Colletotrichum lindemuthianum*), *thiophanate-methyl*, 450 g a.i. ha^{-1} (against angular leaf spot=*Phaeoisariopsis griseola*) and Trifloxystrobin+Propiconazole, 130 g a.i. ha^{-1} (against powdery mildew=*Erysiphe polygoni*) were applied after flowering. Insecticides (*thiamethoxam*, 0.1 kg ha^{-1}; Imidacloprid, 0.5 L ha^{-1} and Chlorpyrifos chlorpyrifos, 1.0 L ha^{-1}) were applied against *Bemisia tabaci*, *Heliothis zea* and *Etiella zinckenella*, respectively.

At the R9 phenological stage, the plant density (PD) was determined by counting the number of plants per meter. For the yield components evaluation 10 plants were randomly collected per plot to determine the number of pods (NP) per plant and the number of grains (NG) per pod. From each sample 100 grains were weighted to determine the mass of 100 grains (M100). To determine grain yield (GY), the useful plot was collected. The grains were weighed, and the moisture corrected to 13% and GY expressed in kg ha^{-1}.

The data obtained in the experiments were grouped and the analysis by experiment group was performed. When the differences were significant ($p<0.05$, teste “t”), the results of each cropping year were analyzed separately. The data was submitted to analysis of variance and upon confirmation of a statistically significant value in the F test ($p\leq0.05$), regression analysis at 5% significance was applied for the filler liming doses, since N application was evaluated only for 0 and 60 kg ha^{-1}. Statistical analysis was performed using the software Sisvar (FERREIRA, 2011).

RESULTS AND DISCUSSION

The evaluation of the effects of filler liming doses and the topdressing applications of N on common bean revealed that the plant density (PD), the number of pods per plant (NP), the number of grains (NG), the mass of 100 grains (M100) and the grain yield (GY) differed between the evaluated cropping years (Table 2). Cropping years 2014 and 2015 had the highest grain yield and differed from 2016 cropping year. This was because 2016 witnessed the lowest pod numbers and mass of 100 grains. According to Fageria and Santos (2008), number of pods per plant, number of grains per pod and mass of 100 grains are the main yield components of the common bean and directly affect grain yield.

Significant effects of N doses and filler liming doses were observed for some of the evaluated parameters. However, none significant interaction was observed between N and filler liming doses (Table 3).

Table 2. Joint analysis of the experiments carried out in the 2014, 2015 and 2016 cropping years, with topdressing N-fertilization and filler liming of the sowing furrow. Plant density (PD- nº m^{-1}), number of pods (NP- nº $plant^{-1}$), number of grains (NG- nº pod^{-1}), mass of 100 grains (M100- g) and grain yield (GY- kg ha^{-1}) of common bean.

Cropping year (CY)	PD	NP	NG	M100	GY
2014	8.78 c	12.92 b	3.90 b	23,43 b	2,235.59 a
2015	10.15 b	14.07 a	3,30 c	28.95 a	2,371.22 a
2016	11.70 a	11.76 c	4.52 a	20.09 c	1,694.88 b
F_{CY}	*71.02***	*14.00***	*116.77***	*645.97***	*52.15***
CV (%)	9.62	13.49	8.18	4.12	13.34

CV= Coefficient of variation; *significant ($p<0.05$, “F” test), **significant ($p<0.01$, “F” test), ^{ns}non significant ($p>0.05$, “F” test). Mean values followed by different letters within each column are statistically different ($p<0.05$, teste “t”).

Table 3. F values and its significance for plant density (PD- nº m^{-1}), number of pods (NP- nº $plant^{-1}$), number of grains (NG- nº pod^{-1}), mass of 100 grains (M100- g) and grain yield (GY- kg ha^{-1}) of the common bean as affected by filler liming and topdressing application of N.

Factors	PD			NP			NG		
	2014	2015	2016	2014	2015	2016	2014	2015	2016
N doses (N)	0.82^{ns}	0.93^{ns}	3.34^{ns}	0.18^{ns}	0.01^{ns}	0.64^{ns}	3.38^{ns}	4.76^{*}	0.36^{ns}
Filler doses (F)	0.44^{ns}	3.32^{**}	52.31^{**}	2.93^{*}	0.59^{ns}	7.90**	2.33^{ns}	0.58^{ns}	7.44**
Interaction (NxF)	0.66^{ns}	$1,84^{ns}$	0.48^{ns}	1.5^{ns}	2.76^{ns}	1.34^{ns}	3.57^{ns}	1.69^{ns}	3.17^{ns}
CV(%)	5.58	11.39	9.46	10.92	15.60	13.90	6.64	10.31	7.19

Factors	M100			GY		
	2014	2015	2016	2014	2015	2016
N doses (N)	7.16^{*}	0.03^{ns}	4.28^{ns}	11.29^{**}	0.90^{ns}	52.83^{**}
Filler doses (F)	5.80^{**}	3.13^{*}	4.51^{*}	3.52^{*}	0.64^{ns}	15.32^{**}
Interaction (NxF)	3.80^{ns}	0.23^{ns}	7.45^{ns}	2.38^{ns}	0.80^{ns}	1.95^{ns}
CV(%)	3.83	4.14	3.31	14.51	13.52	11.74

CV= Coefficient of variation; *significant (p≤0.05, "F" test), **significant (p≤0.01, "F" test), ^{ns}non significant (p≥0.05, "F" test).

The topdressing application of 60 kg ha^{-1} of N resulted in NG value of 3.17, decreasing the NG by about 8% as compared to the non-addition of nitrogen. However, the topdressing application of 60 kg ha^{-1} of N increased the M100 in 2014 to 26.86 g and the GY in 2014 to 2428.31 kg ha^{-1} and in 2015 to 1950.44 kg ha^{-1}, in comparison to the zero dose, representing an increase of about 3.7%, 18.9% and 35%, respectively. Nitrogen is one of the most required nutrients by the common bean and its proper supply significantly affects production components and grain yield, since nitrogen is a constituent of several molecules that play important metabolic functions in plants (WANG et al., 2014). Additionally, Sorato; Perez and Fernandes (2014) and Lacerda; Nascente and Pereira (2019) also reported that increasing N rates provided increases in mass of 100 grains and in the grain yield of common bean.

Filler liming doses resulted in a significant effect on PD in 2015 and 2016, on NP in 2014 and 2016, on NG in 2016, on M100 in 2014, 2015 and 2016 and, on GY in 2014 and 2016 (Table 3). The regression analysis of the filler liming doses revealed a quadratic effect on the evaluated parameters (Figures 2, 3, 4, 5 and 6). Regarding PD, the adjustment coefficients (R^2) were 76% and 54% in 2015 and 2016, respectively, with the PD values being reduced as the filler liming doses increased (Figure 2). In 2015 the largest PD was observed without the addition of filler liming, while in 2016, the largest PD was observed with the addition of 200 kg ha^{-1} of filler liming (Figure 2).

The increase in the doses of filler liming can lead to changes in pH values in the rhizosphere, since the application of lime, even superficially, increases the soil pH (TOFFOLLI et al., 2014). Increased liming levels, which increase pH, can increase molybdenum availability (FAGERIA; BALIGAR; JONES, 2011), reduce the net photosynthesis rate, stomatal conductance and transpiration rate (QIN et al., 2017). Therefore, the higher filler liming rates evaluated in our study can be related to the reduction of the PD, although Silva et al. (2012) did not observe effects of conventional limestone doses on PD. However, the application of filler liming in furrow is a very little studied issue, with limited availability of published works.

The increase in filler liming doses in the sowing furrow increased the number of pods (NP), with a higher NP obtained at the doses of 600 and 400 kg ha^{-1} in 2014 and 2016, respectively (Figure 3). Although NP tended to increase as a resultant effect of increasing the filler liming dose, in 2016 a decrease in NP was observed in the highest dose of filler liming, corresponding to 600 kg ha^{-1}. Nascente and Cobucci (2015b) also reported a reduction in the number of pods per plant due to the increase in limestone doses, which could be a result of the decrease in the availability of phosphorus in the soil that occurs at high pH levels (PENN; CAMBERATO, 2019.).

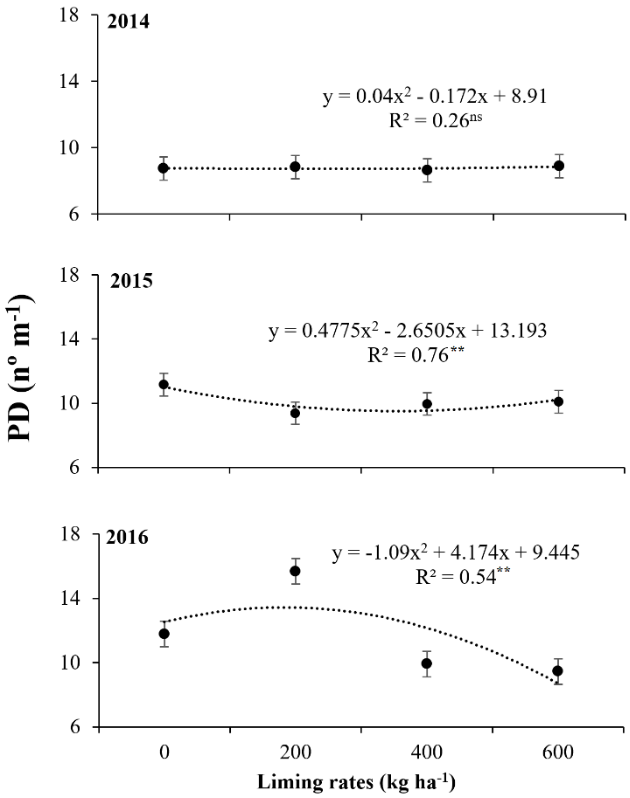

Figure 2. Regression analysis of filler liming doses effects on the plant density (PD) of the common bean in 2014, 2015 and 2016 cropping years.

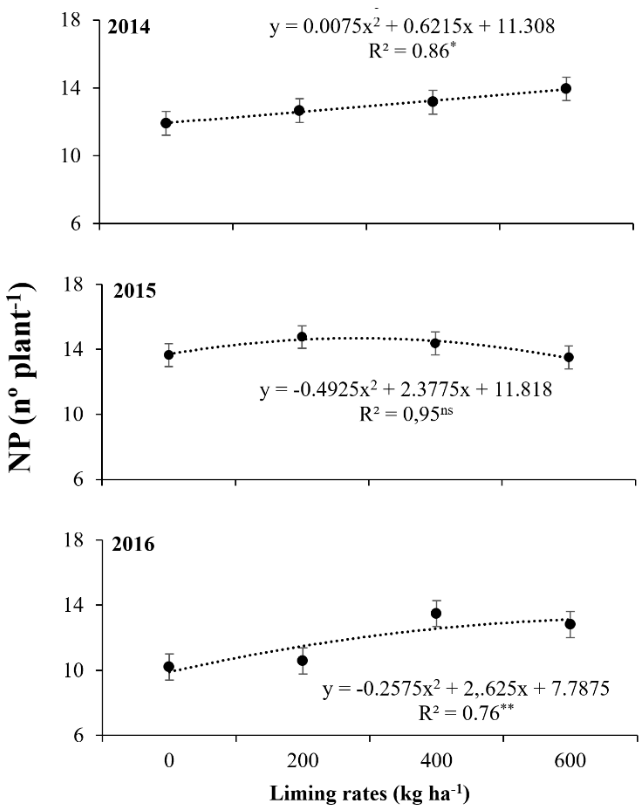

Figure 3. Regression analysis of filler liming doses effects on the number of pods (NP) of the common bean in 2014, 2015 and 2016 cropping years.

In spite of NP and NG showing a high correlation coefficient (DALCHIAVON; CARVALHO, 2012; PERINI et al., 2012), in our study the NG was not affected in the same manner as NP. The effects of filler liming doses on NG showed inconclusive results, with significant effect only in one (2016) of the three evaluated cropping years (Table 2), where greater NG has been observed with the use of 200 and 600 kg ha^{-1} of filler liming, as compared to zero and 400 kg ha^{-1} (Figure 4).

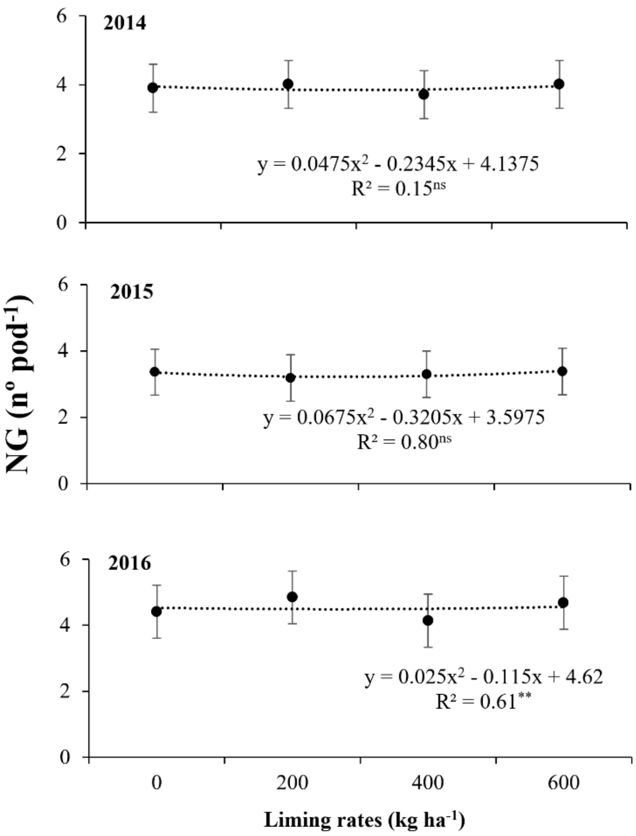

Figure 4. Regression analysis of filler liming doses effects on the number of grains (NG) of the common bean in 2014, 2015 and 2016 cropping years.

The mass of 100 grains (M100) varied significantly depending on the cropping year, with values inversely proportional to those observed for the NG, where the highest and lowest values of M100, observed in the 2015 and 2016 cropping years, respectively, corresponded to the smallest and highest NG values (Figure 4). According to Barili et al. (2011), the parameters grain mass and number of grains have an inverse correlation. Regarding the effect of the filler liming doses, the regression analysis revealed that the highest values of M100 were observed with the doses of 600, 200 and 400 kg ha^{-1}, in the 2014, 2015 and 2016 cropping years, respectively (Figure 5).

In 2014 and 2015 cropping years the grain yield (GY) values were higher than those obtained in 2016 (Table 2). However, significant effects of the filler liming doses were only observed in the cropping years 2014 and 2016 (Figure 6). The dose of 200 kg ha^{-1} of filler liming resulted in the highest GY, with subsequent decreases after this dose. According to Fageria, Baligar and Jones (2011), at high filler liming doses, a reduction in the availability of phosphorus and micronutrients occurs, leading to the decrease of the GY, since these nutrients can become unavailable to plants due to the increase in pH in the root region, as a result of filler limestone application in the sowing furrow.

Although a tendency to reduce GY was observed at filler liming doses greater than 200 kg ha^{-1}, it was found that in the two cropping years in which the study was conducted on soils with lower pH values (2014 = 5.7 and 2015 = 5.4) responses in the GY of common bean to filler liming were observed. These results indicate that, even in soils with adequate pH values, the application of small doses of filler limestone in the sowing furrow can provide significant increases in the grain yield of the crop (NASCENTE; COBUCCI, 2015a), since the use of lime provides better conditions for plant development (FAGERIA; BALIGAR; JONES, 2011; FAGERIA; NASCENTE, 2014).

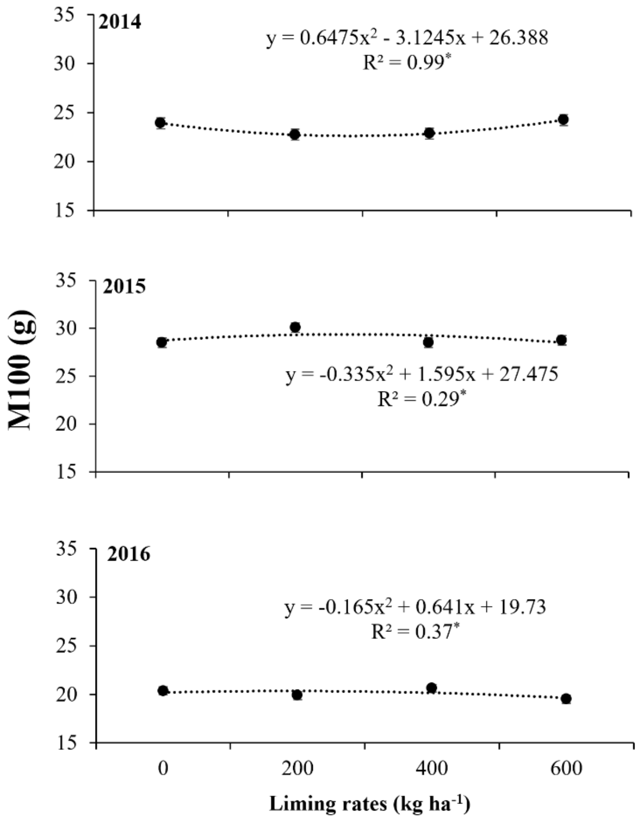

Figure 5. Regression analysis of filler liming doses effects on the mass of 100 grains (M100) of the common bean in 2014, 2015 and 2016 cropping years.

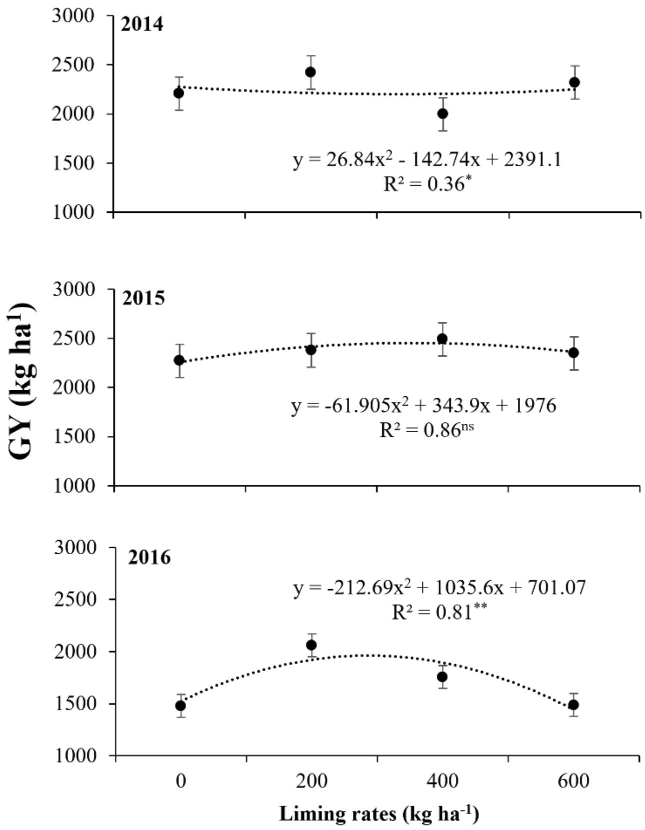

Figure 6. Regression analysis of filler liming doses effects on the grain yield (GY) of the common bean in 2014, 2015 and 2016 cropping years.

However, these responses to filler limestone use were not observed all over the evaluated parameters, nor all through the cropping years. Besides, interactions between filler liming and N doses were not observed. Thus, long term experiments under field conditions are needed for a better understanding of the filler liming and N application on the agronomical performance of the common bean.

CONCLUSIONS

The N and filler limestone application influenced the yield components and grain yield of the common bean cultivar, but there was no interaction among N and filler limestone application. N application increased the number of grains, the mass of 100 grains and the grain yield of the common bean. The application of 400 kg ha^{-1} of filler limestone increased the number of pods, while that of 200 kg ha^{-1} increased the pod density, the number of grains, the mass of 100 grains and the grain yield of the common bean.

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