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# Agronomic performance and economic viability of early cycle common bean cultivars under nitrogen fertilization

**Neuza Helena Carvalho de Oliveira, Flávia Constantino Meirelles, Ancelmo Cazuza Neto, Anderson Prates Coelho, Leandro Borges Lemos**

Universidade Estadual Paulista "Júlio de Mesquita Filho", Câmpus de Jaboticabal, Jaboticabal, São Paulo, Brasil. E-mail: hcarvalhoagro@gmail.com, flavia.meirelles@unesp.br, cazuza.neto@unesp.br, anderson.coelho@unesp.br, leandro.lemos@unesp.br

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## ABSTRACT

Improving nitrogen fertilization practices in early cycle common bean crops, as well as offering insights into the efficiency of cultivars and the economic viability of nitrogen rates is essential to increase sustainability in agriculture. The aim of this study was to evaluate the agronomic attributes and economic viability of early cycle bean cultivars in response to applying varied nitrogen (N) rates in topdressing. The experiment was conducted in a eutrophic Red Latosol with a clayey texture implementing a randomized block experimental design in a split-plot scheme with 4 replications. The plots were composed of the IAC Nuance, IAC 1849 Polaco and IAC Veloz cultivars with rajado, carioca and black grains, respectively. The subplots were formed by varied N rates applied in topdressing: 0, 60, 120 and 180 kg ha$^{-1}$. IAC Veloz stood out in productivity, being classified as efficient and responsive to the use of N. The IAC Nuance cultivar obtained the highest yield for sieve 14, while IAC 1849 Polaco stood out for sieve 13 and IAC Veloz for sieve 12. The IAC Veloz cultivar obtained a greater relative economic return in relation to the others due to its greater productivity; however, rates of 60 and 120 kg ha$^{-1}$ were not economically viable for this cultivar. The rate of 180 kg ha$^{-1}$ was the only one considered economically viable for the three cultivars evaluated in the experiment. Therefore, nitrogen fertilization management in common bean crops should be genotype-dependent, aiming at greater economic viability.

**Keywords:** *Phaseolus vulgaris* L.; Genotypes; Relative economic return; Economically viable rate.

## Desempenho agronômico e viabilidade econômica de cultivares de feijoeiro de ciclo precoce à adubação nitrogenada

## RESUMO

Aprimorar as práticas de adubação nitrogenada no cultivo de feijoeiro de ciclo precoce, oferecendo insights sobre a eficiência das cultivares e a viabilidade econômica das doses de nitrogênio é essencial para aumentar a sustentabilidade na agricultura. Objetivou-se avaliar os atributos agronômicos e a viabilidade econômica de cultivares de feijoeiro de ciclo precoce em resposta à aplicação de doses de nitrogênio (N) em cobertura. O experimento foi realizado em Latossolo Vermelho eutroférrico de textura argilosa, utilizando delineamento experimental de blocos casualizados, em esquema de parcelas subdivididas, com 4 repetições. As parcelas foram constituídas pelas cultivares IAC Nuance, IAC 1849 Polaco e IAC Veloz, de grãos tipo rajado, carioca e preto, respectivamente. As subparcelas foram formadas por doses de N aplicadas em cobertura: 0, 60, 120 e 180 kg ha$^{-1}$. A IAC Veloz destacou na produtividade, sendo classificada como eficiente e responsiva ao uso de N. A cultivar IAC Nuance obteve maior rendimento para a peneira 14, enquanto a IAC 1849 Polaco se destacou na peneira 13 e IAC Veloz na peneira 12. A cultivar IAC Veloz obteve maior retorno econômico relativo, em relação às demais, devido à sua maior produtividade, porém, as doses de 60 e 120 kg ha$^{-1}$ não foram economicamente viáveis para essa cultivar. A dose de 180 kg ha$^{-1}$ foi a única considerada economicamente viável para as três cultivares avaliadas no experimento. Portanto, o manejo de adubação nitrogenada em cobertura no feijão-comum deve ser genótipo-dependente, visando maior viabilidade econômica.

**Palavras-chave**: *Phaseolus vulgaris* L.; Genótipos; Retorno econômico relativo; Dose economicamente viável.

## 1. Introduction

The common bean (*Phaseolus vulgaris* L.) is one of the most important legumes cultivated globally, playing a crucial role in nutrition, society, and the economy. Bean production in Brazil reaches approximately 3 million tons annually, of which 600,000 tons are black beans, 1.8 million tons are colored beans, such as carioca and specialty beans, and 600,000 tons are cowpeas (Conab, 2022). Beans are one of the main components in the diets of many Brazilians, with an average annual consumption of approximately 15 kg per person (Los et al., 2020). Nutrients present in beans include 18 to 25% crude protein, in addition to minerals such as phosphorus, calcium, and magnesium, with levels of 3.8, 2.3, and 1.3 g $kg^{-1}$, respectively. Beans are also a good source of micronutrients such as iron, zinc and copper, with concentrations of around 82, 36 and 10 mg $kg^{-1}$, respectively (Klasener et al., 2020).

Several commercial types of beans are grown in Brazil, including carioca, black, and specialty beans, with a variety of cultivars available to producers. Carioca beans are the most widely cultivated, accounting for 70% of production (Pias et al., 2022), followed by black beans. However, Brazil is not self-sufficient in black bean production and needs to import beans to meet demand. These two types of beans are the most valued by consumers (Bento et al., 2020; Conab, 2022). Specialty beans have a range of colors in the seed coat, such as white, red, cream, and yellow, and may have streaks or marks of other colors. Although the production of these grains is still low in the country, their cultivation can be an interesting alternative for diversification and income stability for producers, with potential for commercialization in both the domestic and foreign markets due to their high added value (Ribeiro et al., 2014; Alves et al., 2020; Carbonell et al., 2020). The low production of black and special beans in São Paulo can represent a market opportunity for producers in the region.

It is important to consider several factors when choosing a bean cultivar, such as the type of grain, adaptability to the region, production potential, plant size, growth cycle, resistance to pests and diseases, tolerance to adverse weather conditions such as drought and high temperatures, in addition to efficiency in nutrient use (Lemos et al., 2015). Research on the efficiency of cultivars in nitrogen absorption and use is essential, since this is the nutrient most absorbed by the plant. The plant extracts approximately 40 kg of nitrogen per hectare for each ton of grains produced (Fageria et al., 2015; Leal et al., 2019; Perez et al., 2013).

Early maturity is an increasingly valued attribute by producers, as it facilitates integrating crops into crop rotation and intercropping systems, saves water and energy in irrigated systems, aligns cultivation with more favorable climate periods and provides a faster return on investment (Lemos et al., 2015; Bettiol et al., 2020).

Although the common bean establishes symbiosis with bacteria of the *Rhizobium* genus, biological nitrogen fixation is not sufficient to meet the plant's needs, requiring application of nitrogen fertilizers (Aragão et al., 2020; Bettiol et al., 2020; Dias et al., 2020). Studies indicate that the crop responds well to nitrogen application at rates higher than 180 kg $ha^{-1}$ (Soratto et al., 2017; Souza et al., 2019; Salvador Neto et al., 2022). A meta-analysis conducted by Pias et al. (2022) revealed that factors such as soil organic matter content, previous harvest and nitrogen rate applied affect bean grain productivity.

The nitrogen demand of the common bean varies widely due to factors such as climate, cultivar, soil type and production system, which influences the soil-plant-atmosphere dynamics. Therefore, determining ideal and economical nitrogen rates requires specific studies to guide nitrogen fertilization in different production systems (Aires, 2019; Leal, 2019). Producers and technicians should use the results of research conducted in similar conditions to their own to guide appropriate management of nitrogen fertilization.

Thus, the objective of this study was to evaluate the agronomic performance, relative economic return and economic viability of early-cycle common bean cultivars in response to applying different nitrogen rates as topdressing.

## 2. Material and Methods

The experiment was conducted at the São Paulo State University (Unesp), School of Agricultural and Veterinary Sciences, Jaboticabal, São Paulo, near the coordinates 21º 14' 59" S; 48º 17' 16" W and altitude of 570 m. The area was occupied by soybean crops (*Glycine max* L.) in the spring-summer harvest of 2018/2019, adopting conventional soil tillage using the Pioneer 95R95 IPRO cultivar, sown on 11/22/2018 and harvested on 03/22/2019, with a productivity of 4.5 t $ha^{-1}$.

The region's climate is characterized as Aw (humid tropical) according to the Koppen climate classification, with a rainy season in summer and dry winter, with an average annual precipitation of 1,425 mm. The soil is classified as eutroferric Red Latosol (Oxisol), with a clayey texture. The chemical analysis of the soil in the 0-20 cm layer presented the following result: pH ($CaCl_2$) = 5.9, OM = 19 g $dm^{-3}$, Presina = 52 mg $dm^{-3}$, K = 5.6 mmolc $dm^{-3}$, Ca = 41 mmolc $dm^{-3}$, Mg = 18 mmolc $dm^{-3}$, H+Al = 24 mmolc $dm^{-3}$, SB = 64.6 mmolc $dm^{-3}$, CEC = 89 mmolc $dm^{-3}$, V = 75%, B = 0.22 mg $dm^{-3}$, Cu = 0.6 mg $dm^{-3}$, Fe = 11 mg $dm^{-3}$, Mn = 61.3 mg $dm^{-3}$ and Zn = 3.7 mg $dm^{-3}$. The result of the granulometric analysis showed: clay = 540 g $kg^{-1}$; silt = 230 g $kg^{-1}$; and sand = 230 g $kg^{-1}$.

The design used was randomized blocks in a split-plot scheme with four replications. The plots were composed of the IAC Nuance, IAC 1849 Polaco and IAC Veloz bean cultivars. The cultivars have a determinate growth habit, type I and an early cycle of 75 days. IAC Nuance has a special type of grain with a rounded shape, striped, cream color with reddish streaks, cranberry type intended for export; IAC 1849 Polaco has a carioca type grain, cream color with light brown streaks and tolerance to grain darkening; and IAC Veloz has a black grain and chocolate broth color (Carbonell et al., 2020; Chiorato et al., 2020 a,b). The subplots were formed by varied nitrogen rates applied as topdressing: 0 kg $ha^{-1}$ (no application), 60 kg $ha^{-1}$ (applied at the V4 phenological stage - third trifoliate), 120 kg $ha^{-1}$ (half the rate applied at V4 + half the rate at R5 - flower bud), 180 kg $ha^{-1}$ (one third of the rate applied at V3 – first trifoliate + one third of the rate applied at V4 + one third of the rate applied at R5). The nitrogen top-dressing fertilization was applied in a continuous stream 10 cm from the crop row using polymer-coated urea with controlled release (45% N) as the source, followed by irrigation with a 15 mm depth. Each experimental subplot consisted of five 5.0 m long rows spaced at 0.45 m, with the three central rows being considered as the useful area.

The common bean cultivar seeds were obtained from the Agronomic Institute of Campinas (IAC) and treated with StandakTop fungicide at a rate of 2 mL per kg of seed. The StarFix Feijão product was used to inoculate rhizobia at a rate of 4 mL per kg of seed. The common bean crop was grown in the fall-winter harvest of 2019 in the direct seeding system. Sowing was performed on 07/05/2019 with a spacing of 0.45 m between rows, using 11 seeds per meter. The final population was 216 thousand plants $ha^{-1}$. Base fertilization was performed using 08 kg $ha^{-1}$ of N, 40 kg $ha^{-1}$ of $P_2O_5$ and 40 kg $ha^{-1}$ of $K_2O$, following the recommendations of Ambrosano et al. (1997). The pre-emergent Dual Gold (1.25 L $ha^{-1}$ p.c.) herbicide was applied 2 days after sowing (DAS) to control invasive plants, and the post-emergence Select (0.4 L $ha^{-1}$ p.c.) and Flex (0.9 L $ha^{-1}$ p.c.) herbicides were applied at 27 DAS. In addition, the following sprays were applied to control insect pests and diseases: Benevia (750 mL $ha^{-1}$ p.c.) at 23 DAS, Engeo Pleno (125 mL $ha^{-1}$ p.c.) and Opera (0.5 L $ha^{-1}$ p.c.) at 49 DAS. A conventional sprinkler irrigation system was used, with variable irrigation shifts and a total water depth of 315 mm.

The agronomic attributes were evaluated when the plants reached the R6 stage (full flowering). First, 10 plants were collected at random from the useful area of each subplot, washed with deionized water and dried in an oven at 65 ºC for 72 hours and then weighed to determine the shoot dry mass (g $plant^{-1}$). Next, the third trifoliate with petiole from the middle third was collected from 20 plants to determine the N content in the leaves, following the recommendations of Ambrosano et al. (1997). The leaves were washed in deionized water three times and then placed in an air circulation oven at a temperature of 65 °C until constant mass was obtained. The material was subsequently ground and subjected to chemical analysis to determine the N concentrations in the leaves by means of sulfuric acid digestion, distillation in a strongly alkaline medium and titration with sulfuric acid solution.

Then at harvest, 10 plants per experimental unit were collected in the central row of each subplot to determine the number of pods per plant and number of grains per pod. The mass of 100 grains (g) was determined by weighing four subsamples of 100 grains per subplot, correcting the data to 13% moisture content. Plants were harvested from the useful area of each subplot, dried in the sun and threshed mechanically to evaluate grain yield. The grains were then weighed and the data corrected to 13% moisture content. Agronomic efficiency was obtained using the following formula:

$$AE = (GP_{WF} – GP_{WoF}) / (QF)$$

In which: AE = Agronomic efficiency; $GP_{WF}$ = grain productivity with nitrogen fertilizer; $GP_{WoF}$ = grain productivity without nitrogen fertilizer; QF = amount of N fertilizer applied. The results were expressed in kg $kg^{-1}$ (Fageria and Baligar, 2005).

The grains were classified in size and shape by passing them through sieves with oblong sieves of 4.76 × 19.05 mm, 5.16 × 19.05 mm and 5.56 × 19.05 mm in a series of agitation tests for one minute (Santis et al., 2019). The percentage of grains was calculated by the ratio between the weight of grains retained in each sieve and the total weight of the sample of each subplot. The sieve yield was given by the sum of the percentages of grains retained in sieves greater than or equal to 12, 13 and 14.

The relative economic return was calculated by the difference between the revenue obtained, calculated by the product between productivity and the price per kilo of beans, and the cost of fertilizer, calculated from the product of the rate applied and the price per kilo of N. The following prices were used for the kilo of beans: R$ 5.00 for carioca beans (US$ 1.04 $kg^{-1}$), R$ 4.72 (US$ 0.99 $kg^{-1}$) for black beans; and R$ 6.47 (US$ 1.35 $kg^{-1}$) for specialty beans. These quotes were obtained on June 27, 2023 (US$ 1.00 = R$4.79), through IBRAFE (Ibrafe, 2023). The price per kilo of fertilizer used was R$ 2.71 (US$ 0.57 $kg^{-1}$), on June 27, 2023 (Conab, 2023).

The relative gain and the economically viable rate were calculated according to the N topdressing splits and the bean cultivars used. The relative gain was obtained by the formula:

Relative gain = [($GP_{WF}$ – $GP_{WoF}$) x (100) / $GP_{WoF}$]

In which: $GP_{WF}$ = grain production with nitrogen fertilizer; $GP_{WoF}$ = grain production without nitrogen fertilizer.

The economically viable rate was established according to the Mitscherlich principles (Pimentel Gomes, 1976), also known as the law of diminishing returns, by the equation:

X* = (1/2) Xu + (1/C) log (Wu/ t Xu)

In which: X* = economically viable rate; u = increase in productivity provided by the rate Xu (90 kg N ha$^{-1}$) applied in relation to the control (without N); W = unit price of the agricultural product (kg of beans) considering a quotation of R$ 5.00 for carioca beans, R$ 4.72 for black beans and R$ 6.47 for specialty beans (Ibrafe, 2023); t = unit price of the nutrient (N) considering a quotation of R$ 3.20 per kg of fertilizer used; and C = coefficient of effectiveness 0.0049 ha kg$^{-1}$ of N (Pimentel Gomes, 1976). Economic viability was considered when X* was equal to or greater than the amount of N applied, which was 60, 120 and 180 kg of N ha$^{-1}$.

The data were subjected to analysis of variance using the F-test ($p < 0.05$) and Tukey's test ($p < 0.05$) to compare means. Polynomial regression was adopted to verify the effect of nitrogen (N) rates in topdressing and the interaction between bean cultivars x N rates. Pearson's simple correlation analysis was also performed between the agronomic attributes. The statistical programs used were AgroEstat and Statistica v.7 for univariate statistics and simple correlation.

## 3. Results and Discussion

It was possible to observe that nitrogen fertilization in topdressing promoted an increase in the leaf N content, with a significant difference for the cultivars and for the interaction between cultivars (C) x N rates (Table 1, Figure 1). IAC Nuance presented the lowest leaf N content among the cultivars, with values below the adequate or sufficiency range for the bean crop at a rate of 60 kg ha$^{-1}$ and in the treatment without N application. According to Quaggio et al. (2022), the leaf nitrogen content for beans considered adequate are in the range of 30 and 50 g kg$^{-1}$. The highest leaf N value was found at a rate of 180 kg ha$^{-1}$ for the Veloz cultivar, constituting a higher value than the recommended sufficiency level. Both the IAC Veloz and IAC 1849 Polaco cultivars presented high leaf N contents even in treatments without nitrogen application in topdressing. This may have occurred due to the presence of residual nitrogen from soybeans previously cultivated in the area (Quaggio, 2022) due to the plant's ability to perform biological nitrogen fixation (Aragão et al., 2020; Bettiol et al., 2020, Dias et al., 2020) and the soil fertility of the experimental area.

Nitrogen accumulation showed a significant difference only for the cultivar factor (Table 1). The IAC Veloz cultivar showed greater nitrogen accumulation, with 91 and 51% more N accumulation compared to IAC Nuance and IAC 1849 Polaco. A positive correlation was found in the correlation analysis between leaf N content and N accumulation (r=0.75**).

The final plant population did not show statistical difference for cultivars, nitrogen rates or C x N interaction (Table 1), showing that this variable did not influence the production components, especially productivity. This result demonstrates high control in the experiment's sowing.

Next, the IAC Veloz cultivar was superior to the other cultivars regarding the number of grains per plant (Table 1). This indicates that it is productively superior, since the greater the number of grains produced by the plant, the greater the yield. IAC Nuance was inferior, presenting a smaller quantity of grains. This result can be explained by the fact that this cultivar presents larger grains, as it is part of the specialty group (Carbonell et al., 2020). The number of grains per plant variable showed positive correlations with the leaf N content (r=0.68**) and N accumulation (r=0.66**) variables.

The IAC Veloz cultivar stood out for grain productivity as it presented the highest value, with 100 and 63% more compared to the IAC Nuance and IAC 1849 Polaco cultivars. These cultivars obtained statistically equal productive performance (Table 1). The grain productivity of common bean cultivars generally increased linearly with increasing N rates (Figure 2). According to the calibrated regression, yield increased by 17 kg ha$^{-1}$ for every 10 kg ha$^{-1}$ of N added as topdressing.

Based on the principles of efficiency and responsiveness in nutrient use reported by Fageria et al. (2015), it can be inferred that the IAC Veloz cultivar proved to be the most efficient and responsive to using N applied as topdressing, since it presented higher productivity compared to the others, regardless of the N rate. These results corroborate Leal et al. (2019), in which they verified differences in productive performance in 16 common bean cultivars from the Carioca commercial group, with BRSMG Uai, BRS FC402, IPR Campos Gerais, IPR Maracanã and TAA Bola Cheia all classified as efficient and responsive to applying N as topdressing. The experiment was conducted in soil with high natural fertility (eutrophic), with high concentrations of phosphorus, potassium, calcium and magnesium, and average organic matter concentration (Fernandes et al., 2019) in an irrigated production system and with adequate fertilization.

**Table 1.** Agronomic attributes and relative economic return of early-cycle common bean cultivars fertilized with nitrogen as topdressing.[1]

| Cultivar | LNC ($g\ kg^{-1}$) | NA ($kg\ ha^{-1}$) | FPP (thousand plants $ha^{-1}$) | NGP (no.) | GP ($t\ ha^{-1}$) | AE ($kg\ kg^{-1}$) | RER (R$ $ha^{-1}$) |
|---|---|---|---|---|---|---|---|
| IAC Nuance | 31.50 c | 8.34 b | 213 | 3.63 c | 1.3 b | 2.56 a | 8,438.55 b |
| IAC 1849 Polaco | 39.20 b | 10.60 b | 215 | 4.00 b | 1.6 b | 2.17 a | 8,119.92 b |
| IAC Veloz | 45.37 a | 15.96 a | 219 | 4.81 a | 2.6 a | 1.26 a | 11,751.71 a |
| F-test | | | | | | | |
| Cultivar (C) | $45.67^{**}$ | $32.41^{**}$ | $0.34^{NS}$ | $55.42^{**}$ | $38.81^{**}$ | $0.41^{NS}$ | $12.70^{**}$ |
| N rates (D) | $5.98^{**}$ | $1.56^{NS}$ | $0.53^{NS}$ | $0.75^{NS}$ | $4.79^{**}$ | $615.49^{**}$ | $1.09^{NS}$ |
| C*D | $4.31^{**}$ | $0.43^{NS}$ | $0.43^{NS}$ | $0.70^{NS}$ | $0.67^{NS}$ | $0.76^{NS}$ | $0.65^{NS}$ |
| CV for cultivar (%) | 10.63 | 23.67 | 1.84 | 8.57 | 18.86 | 31.08 | 23.92 |
| CV for rates (%) | 7.28 | 12.61 | 1.38 | 7.78 | 14.37 | 27.13 | 15.64 |

[1]LNC – leaf nitrogen content; NA – nitrogen accumulation; FPP – final plant population; NGP – number of grains per plant; AE – agronomic efficiency; GP – grain productivity; RER – relative economic return. Means followed by distinct letters in the rows differ from each other by Tukey's test at 5% probability. $^{NS}$ - Not significant by the F-test. **Significant by the F-test ($p < 0.01$). *Significant by the F-test ($p < 0.05$).

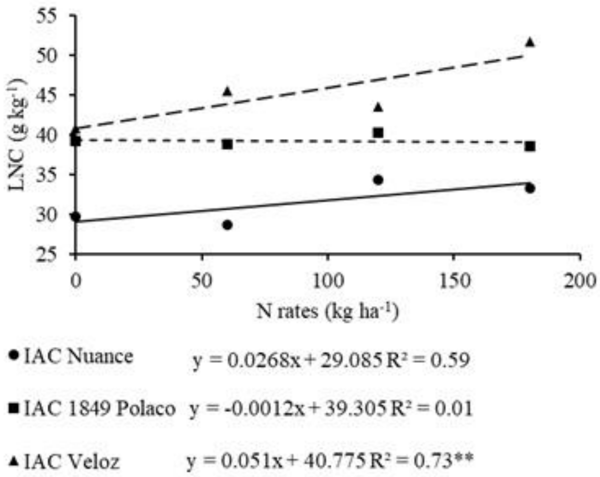


**Figure 1.** Graphic visualization of the cultivar x nitrogen rate interaction for leaf N content (LNC).

According to Leal et al. (2023), priority under these conditions should be given to using cultivars which are responsive to N use, whose productivity increases with the increase in nutrient availability. In evaluating a series of studies with common beans and nitrogen fertilization, Pias et al. (2022) found that adding nitrogen increased grain productivity in most studies, with an average increase of 17% (354 kg $ha^{-1}$) in grain yield. Grain productivity showed positive correlations with the leaf N content (r=0.53**), N accumulation (r=0.56**) and number of grains per plant ($r=0.89^{**}$) variables.

There were differences for agronomic efficiency (AE) only for the N rates evaluated (Table 1, Figure 3). The 60 and 120 kg $ha^{-1}$ N rates presented higher AE compared to the rate of 180 kg $ha^{-1}$. This occurred due to decreasing increments in the GP of common beans as a function of the increase in N rates (Pimentel Gomes, 1976), meaning that the AE increases proportionally less than the rates applied. It was found that the yields of sieves 12, 13, and 14 were influenced by the cultivar factor (Table 2), and only the yield of sieve 13 showed significance in the C x N interaction. The IAC Veloz cultivar presented a higher yield in sieve 12, while the IAC Nuance cultivar presented a higher yield in sieve 14; this is explained by the fact that this cultivar belongs to the export specialty group, which is characterized by larger and rounded grains (Carbonell et al., 2020). In turn, the IAC 1849 Polaco cultivar showed the highest sieve yield 13, and the other cultivars evaluated for this sieve did not differ statistically. Jardim et al. (2023) found no differences for sieve yields greater than or equal to 12 in relation to applying nitrogen as topdressing for common beans.

The relative economic return (RER) showed differences for the cultivar factor (Table 1). IAC Veloz stood out in relation to the others with a higher economic return, reaching R$ 11,751.71. The IAC Nuance and IAC 1849 Polaco cultivars presented similar economic returns. This result is explained by the higher productivity obtained by IAC Veloz, which, associated with the sales price, enables greater relative economic return for the producer.

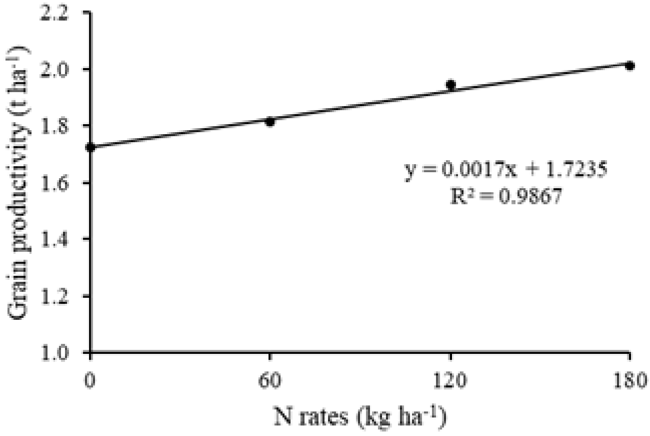


**Figure 2**. Common bean productivity as a function of nitrogen topdressing rates.

**Table 2.** Yield for sieves 12, 13 and 14 in early cycle bean cultivars fertilized with nitrogen as topdressing.[1]

| Cultivar | SY 12 (%) | SY 13 (%) | SY 14 (%) |
|---|---|---|---|
| IAC Nuance | 2.56 c | 10.87 b | 24.43 a |
| IAC 1849 Polaco | 25.50 b | 50.38 a | 12.00 b |
| IAC Veloz | 46.69 a | 21.63 b | 1.81 c |
| F-test | | | |
| Cultivar (C) | $831.75^{**}$ | $24.39^{**}$ | $43.25^{**}$ |
| N rates (D) | $1.67^{NS}$ | $0.65^{NS}$ | $1.99^{NS}$ |
| C*D | $0.43^{NS}$ | $3.39^{*}$ | $2.2.78^{NS}$ |
| CV for cultivar (%) | 10.94 | 48.37 | 52.10 |
| CV for rates (%) | 15.25 | 16.38 | 31.65 |

[1] SY12 – sieve yield equal to 12; SY13 – sieve yield equal to 13; SY14 – sieve yield equal to 14. Means followed by distinct letters in the lines differ from each other by Tukey's test at 5% probability. NS - Not significant by the F-test. **Significant by the F-test ($p < 0.01$). *Significant by the F-test ($p < 0.05$).

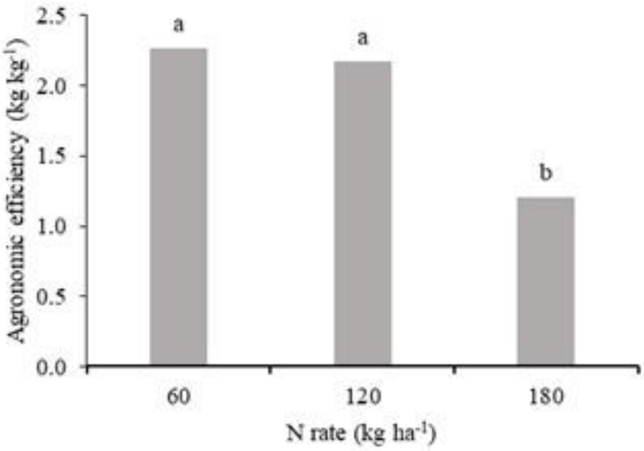


**Figure 3.** Agronomic efficiency of common beans as a function of nitrogen rates in topdressing.

Even with a higher sales price, the IAC Nuance cultivar obtained an equal economic return to that of IAC 1849 Polaco due to its lower productivity.

Regarding the relative gains (Table 3), the IAC Nuance cultivar obtained a similar relative gain for the rates of 60 and 120 kg ha$^{-1}$, in the range of 21%. The relative gain for the rate of 180 kg ha$^{-1}$ was slightly higher, approximately 28%. The greatest relative gain for the IAC 1849 Polaco cultivar was at the rate of 120 kg ha$^{-1}$ (of 21%), with a decrease to 17% at the rate of 180 kg ha$^{-1}$, which indicates that the highest rate applied provided a smaller gain in productivity. The IAC Veloz cultivar presented a negative relative gain at the rate of 60 kg ha$^{-1}$, meaning that the control treatment without N application as top dressing provided greater productivity in relation to the rate of 60 kg ha$^{-1}$.

**Table 3.** Relative gain and economically viable rate in early cycle common bean cultivars fertilized with nitrogen as topdressing.

| | Relative gain (%) | | |
|---|---|---|---|
| N rate (kg ha$^{-1}$) | IAC Nuance | IAC 1849 Polaco | IAC Veloz |
| 0 | - | - | - |
| 60 | 21.84 | 5.84 | -2.83 |
| 120 | 21.38 | 21.56 | 3.58 |
| 180 | 27.89 | 16.68 | 11.65 |
| | Economically viable rate (kg ha$^{-1}$) | | |
| N rate (kg ha$^{-1}$) | IAC Nuance | IAC 1849 Polaco | IAC Veloz |
| 0 | | - | - |
| 60 | 233.20 | 118.21 | -94.64 |
| 120 | 199.89 | 202.55 | 84.12 |
| 180 | 217.50 | 173.89 | 182.72 |

The rate of 120 kg ha$^{-1}$ increased productivity by 3.5%, and the rate of 180 kg ha$^{-1}$ provided a gain of approximately 12%.

The rates of 60 and 120 kg ha$^{-1}$ were economically viable for the IAC Nuance and IAC 1849 Polaco cultivars. The rate of 180 kg ha$^{-1}$ was the only economically viable rate for the IAC Veloz cultivar. This rate was also economically viable for IAC Nuance (Table 3).

## 4. Conclusions

Early-cycle common bean cultivars with different grain types respond differently to topdressing N rates in terms of agronomic, qualitative and financial attributes. The IAC Veloz cultivar stood out in terms of leaf N content, N accumulation, number of grains per plant and relative economic return, and was also the most efficient and responsive to N use. The average productivity of the evaluated cultivars increased by 17 kg ha$^{-1}$ for every 10 kg ha$^{-1}$ of N added. The IAC Nuance cultivar stood out in terms of yield for sieve 14, as it is a cultivar belonging to the specialty group. The IAC Veloz cultivar obtained a higher relative economic return compared to the others due to its higher productivity; however, the N dosage rates of 60 and 120 kg ha$^{-1}$ were not economically viable for this cultivar. The rate of 180 kg ha$^{-1}$ was the only one considered economically viable for the three cultivars evaluated in the experiment.

## Authors’ Contribution

Work extracted from the master’s dissertation by Neuza Helena Carvalho de Oliveira, under the supervision of Prof. Dr. Leandro Borges Lemos. The authors Neuza Helena Carvalho de Oliveira, Anderson Prates Coelho and Leandro Borges Lemos were responsible for the conceptualization, methodology, data collection, statistical analysis, interpretation and writing of the manuscript. Ancelmo Cazuza Neto and Flávia Constantino Meirelles were responsible for data collection, review and correction of the manuscript.

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