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Agroeconomic Viability of Co-inoculation in Common Beans

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Introduction

Common beans (*Phaseolus vulgaris* L.) in Brazil are grown in three annual crops. The first crop takes place during spring-summer, mainly in the South and Southeast regions. The second crop happens during summer-autumn in the South, Southeast and Midwest Regions. And the third crop is grown during winter in tropical areas under sprinkler irrigation, usually with central pivot systems, under commercial farming, mainly in the Center-West and Southeast regions of the country, mainly in the states of Minas Gerais, São Paulo, Goiás, Distrito Federal, Tocantins, Mato Grosso and the western region of Bahia state (Silva et al., 2012).

In 2014, national production of common bean was 2.7 million tons, harvested at 1.9 million hectares, yielding 1,389 kg/ha. Bean production in the 1st and 2nd crops was 1.1 million tons and 1.1 million tons, respectively. The area harvested with common bean in the first and second crops was 849.7 thousand hectares and 898.6 thousand hectares, respectively, with yields of 1,748 kg/ha and 1,467 kg/ha, in the first and second harvests, respectively. The irrigated harvest produced 473 thousand tons of common bean harvested in 194 thousand hectares, with an average yield of 2,437 kg/ha. This irrigated bean crop represents 17.5% and 10.0% of the production and area harvested with common bean in the country, respectively (Embrapa Arroz e Feijão, 2015).

Commercial agriculture is responsible for about 38% of the national bean production in Brazil, corresponding to 757.975 thousand tons harvested in 533.927 thousand hectares, with an average yield of 1,420 kg/ha. On the other hand, the production of common bean, under the care of family farmers (Law No. 11,326/2006) is carried out mainly by most the first and second crop producers, which are spread throughout the different states and regions of Brazil. The share of family farms in common bean production is higher in black beans (77%) than in coloured beans (54%). And the share of family farming in national common bean production is 62% (Silva & Wander, 2013).

The increasing use of modern technologies and cultural practices are becoming increasingly necessary to obtain superior yields that guarantee a more profitable common bean production system (*Phaseolus vulgaris* L.) to producers, who usually face soil and phytosanitary problems inherent in production, high production costs, product price fluctuations and increasingly demanding market.

Thus, not only the adoption of new bean varieties with proven high yields, but the proper management of crops, using the processes and good practices recommended by the institutions responsible for the development of such technologies and management appear as a corollary to success of the common bean cultivation.

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Among the technological innovations sought by the producers to improve the performance of common bean crops and to obtain a higher profitability at reduced costs, there are available on the market some inoculant strains of proven effectiveness in the biological nitrogen fixation (BNF), such as *Azospirillum brasilense* and *Rhizobium tropici*. These inoculants may enable reductions in nitrogen fertilizer use in the bean crop.

Several studies of nitrogen fertilization have already been carried out with common bean, being necessary to know the variety, the conditions of development of the crop to produce grains. For the increase in yield, searching for an association with biological fertilizers, commercial strains SEMIA 4077 (CIAT 899) and SEMIA 4080 (PRF 81) were used at that time. Basically, fertilization with 20 kg/ha of nitrogen, plus inoculant with the strain of *Rhizobium tropici* CIAT 899 made it possible to obtain grain yield in the bean crop equivalent to the use of up to 160 kg/ha of nitrogen (Brito et al., 2011).

The use of inoculant containing *R. tropici* strains CIAT 899 (= SEMIA 4077) and PRF 81 (= SEMIA 4080) promoted significant increases in nodulation and grain yield of assessed bean varieties (BRS Pontal, BRS Requinte, BRS Vereda, and BRS Timbó), even in soils with high populations of native rhizobia. The yields obtained with the inoculation of selected rhizobia in the different bean cultivars were higher than those corresponding to the treatments with doses of up to 80 kg/ha of nitrogen, showing the possibility of obtaining significant increases in the average yield of this crop, at low economic and environmental costs (Mercante et al., 2006).

According to Peres (2014), the co-inoculation of *R. tropici* and *A. brasilense*, the inoculation of *R. tropici*, the inoculation of *A. brasilense* associated with 40 kg/ha of nitrogen in top dressing and the control without inoculation with application of 80 kg/ha of nitrogen in top dressing do not provide yield increases compared to the control without inoculation with 40 kg/ha of nitrogen in top dressing.

From this point of view, the variety Pérola ("carioca" grain type) was analysed agroeconomically, considering the use of BNF technology, which was based on the cropping system of control, i.e. without using nitrogen. In parallel, differentiated treatments of two biological inoculants, namely *R. tropici* and *A. brasilense*, were tested in commercial farming in the states of Goiás and Minas Gerais, and in family agriculture of Goiás state.

Bean cultivation in these two states was carried out in commercial agriculture, under no-tillage system, during the winter crop, with central pivot sprinkler irrigation, from 2013 to 2015. Only at Goianésia municipality, the field experiment took place under family farming, in the second crop of 2014, with sprinkler irrigation, using electric pumping.

The agroeconomic viability analysis was based on the benefit-cost ratio, based on the use of different doses of inoculants that were divided for the seeds at sowing and at top dressing, by spraying.

This study aims to analyse the agroeconomic viability of the common bean cropping system using the variety Pérola, sprinkler irrigation and inoculation with *R. tropici* and *A. brasilense* in several different doses and different forms of application that are economically feasible for the use of bean producers in commercial and family agriculture of the states of Goiás and Minas Gerais.

Material and Methods

The economic viability analysis of BNF technology in common bean (*Phaseolus vulgaris* L.) was based on the agronomic experiments at Embrapa Rice and Beans demonstration units, on family and commercial farms. The variety Pérola ("carioca" commercial grain type) was used to collect data of seven treatments, i.e. the Control Treatment (TC); the nitrogen fertilized witness (TN), which received 80 kg/ha of nitrogen (178 kg/ha of urea); seed inoculation with two doses of *R. tropici* (Rt); inoculation of the seed with two doses of *R. tropici* plus one dose of *A. brasilense* (Rt+Ab1s); seed inoculation with two doses of *R. tropici* plus two doses of *A. brasilense* (Rt+Ab2s); seed inoculation with two doses of *R. tropici* plus spraying of two doses of *A. brasilense*

(Rt+Ab2p); and inoculation of the seed with two doses of *R. tropici* plus spraying of three doses of *A. brasilense* (Rt+Ab3p), as described in De Souza & De Brito Ferreira (2017).
The economic analysis of the cropping system was performed according to a methodology developed by Guiducci et al. (2012), in the economic surplus proposed by Ávila et al. (2008), in the surveys of the technical coefficients of variety Pérola, in field visits carried out in the technology coverage regions, with the producers, technicians of technical assistance and technical staff of Embrapa Rice and Beans.
These technical coefficients of common beans were processed on a production costs worksheet using Microsoft Excel, crossed with the average unit prices of production factors in the Goiás and Minas Gerais markets for each considered year. Factor and product prices for the years 2013 and 2014 were updated by the Getúlio Vargas Foundation General Price Index (base: April / 2015 = 1.00) and the price received by the bean producers at the time of harvest were corrected by the Getúlio Vargas Foundation General Price Index (base: September / 2015 = 1.00).
The methodology used to create the economic balance of the cropping system was based on the Benefit-Cost-Ratio.

Results and Discussion

All agronomic results relevant to this study were described in De Souza & De Brito Ferreira (2017).
The Benefit-Cost-Ratio was higher than 1.0 in all treatments in commercial farming. In family farming, only the nitrogen fertilised witness and inoculation of the seed with two doses of *Rhizobium tropici* plus spraying of three doses of *Azospirillum brasilense* had a BCR > 1, i.e., economically viable (Table 1).

Table 1. Benefit-Cost-Ratio of co-inoculation in common bean, in the three-year average of consecutive crops (2013, 2014 and 2015), during the winter crop, with central pivot sprinkler irrigation, in the States of Goiás and Minas Gerais.

Treatment[1]	Goiás state[2] (commercial farming)	Goiás state[3] (family farming)	Minas Gerais state[4] (commercial farming)
TC	1.49	0.83	1.96
TN	1.65	1.03	1.77
Rt	1.69	0.84	1.90
Rt+Ab1s	1.70	0.86	1.93
Rt+Ab2s	1.79	0.95	1.98
Rt+Ab2p	1.73	0.85	2.04
Rt+Ab3p	1.90	1.13	2.14

[1] Treatments: TC = Control treatment; TN = nitrogen fertilized witness; Rt = seed inoculation with two doses of *Rhizobium tropici*; Rt+Ab1s = inoculation of the seed with two doses of *Rhizobium tropici* plus one dose of *Azospirillum brasilense*; Rt+Ab2s = seed inoculation with two doses of *Rhizobium tropici* plus two doses of *Azospirillum brasilense*; Rt+Ab2p = seed inoculation with two doses of *Rhizobium tropici* plus spraying of two doses of *Azospirillum brasilense*; Rt+Ab3p = inoculation of the seed with two doses of *Rhizobium tropici* plus spraying of three doses of *Azospirillum brasilense*.
[2] Average of the municipalities of Goiás state: Itaberaí, Santo Antônio de Goiás and Cristalina.
[3] Municipality of Goiás state: Goianésia.
[4] Average of the municipalities of Minas Gerais state: Unaí and Paracatú.
Source: Research results, based on agronomic data of De Souza & De Brito Ferreira (2017).

However, the highest BCR, i.e. best economic performance, in all cropping systems, was obtained using inoculation of the bean seed with two doses of *Rhizobium tropici* plus spraying of three doses of *Azospirillum brasilense*.

Conclusions and Outlook

The best economic performance, measured by the benefit-cost-ratio, was obtained in treatment of inoculation of the seed with two doses of *Rhizobium tropici* plus spraying of three doses of *Azospirillum brasilense*.

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