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Agronomic performance of the super-early common bean cultivar BRS FC104 in response to co-inoculation

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Abstract

The common bean is one of the most produced and consumed species in Brazil, but the productivity of the crop is still low. The use of new technologies has increased the performance of the production system and allowed greater flexibility in the management of the production system. The use of super-early cultivars combined with co-inoculation with bacteria has become a promising alternative for the production system. Thus, the objective of this work was to evaluate the agronomic performance of the super-early common bean cultivar BRS FC104 in response to co-inoculation of *Rhizobium tropici* and *Azospirillum brasiliense*. Three field experiments were conducted in Santo Antônio de Goiás (water 2018/19 and winter 2019) and in Abadia de Goiás (winter 2019). A randomized block design was used in a 2 x 3 factorial scheme for all experiments, being two common bean cultivars (BRS Notável and BRS FC104 cultivars) and three nitrogen sources (co-inoculation with *R. tropici* + *A. brasilense*; nitrogen fertilization and untreated control). The co-inoculation with *Rhizobium tropici* and *Azospirillum brasilense* resulted in grain yield equal to that of the nitrogen treatment. The super-early cultivar BRS FC104 showed equivalent productivity as the normal cycle cultivar BRS Notável. Considering that N-fertilizers are a threat to the environment and intensification of sustainable production is a pressing need, the cultivation of the super-early cultivar BRS FC104 under co-inoculation is a recommendation for the sustainable production of the common bean.

Keywords: Bioagent; *Phaseolus vulgaris* L; Productivity; Sustainability; Symbiosis.
Abbreviations: AG_Abadia de Goiás; BNF_biological nitrogen fixation; CxNS_cultivars and nitrogen sources; DAE_days after emergence; GO_Goiás; GY_grain yield; N_nitrogen ; NDW_nodule dry weight; NG_number of grains; NN_number of nodules; NP_number of pods; PCA_principal component analysis; PGPR_plant growth promoting rhizobacteria; RDW_root dry weight; SAG_Santo Antônio de Goiás; SDW_shoot dry weight.

Introduction

The common bean (*Phaseolus vulgaris* L.) is a legume whose grains are an important source of protein for human consumption. Brazil is the third largest world producer with an average annual production of 3 million tons of grain, surpassed by India, with 6.4 million tons, and Myanmar, with 5.4 million tons (Ishizuka et al., 2020). In Brazil, the cultivation of this legume can be carried out in up to three crops. The first is called "water crop", the second "dry crop" and the third "fall/winter crop" (Salvador, 2018).
In the 2020/21 harvest, the cultivated area corresponded to 2.9 million hectares with an average productivity of 1,074 kg ha^{-1} (CONAB, 2020). The third crop has higher yields because it is characterized by high performance production systems with the use of new technologies, one of them being the use of early cultivars (Salvador, 2018). The use of these cultivars is a growing demand, as it allows farmers greater flexibility in managing the production system. In response to this demand, Embrapa Rice and Beans launched a super-early common bean cultivar of the carioca commercial group, BRS FC104.
Another necessary demand for this crop is the reduction of mineral nitrogen fertilization due to the increase in production costs and associated environmental problems, indicating the need for alternative sources of nitrogen supply to plants (Carvalho et al., 2018). One potential alternative is the use of plant growth promoting rhizobacteria (PGPR) in association with *Rhizobium tropici* with reports of success in several research using the co-inoculation technique (Tocheto and Boiago, 2019; Filipini et al., 2021; Vieira et al., 2021). Co-inoculation with symbiotic and asymbiotic bacteria becomes an alternative that should be further studied in legumes. This technique consists of using combinations of different microorganisms with

synergistic effect, in which they overcome the productive results (Tocheto and Boiago, 2019).
Besides the genus *Rhizobium*, another very promising group is represented by associative bacteria capable of promoting an increase in grain yield through various processes, acting in nutrition, protection and stimulation of plant growth, such as *Azospirillum brasilense*, which stands out in the production of phytohormones and has been widely studied in legumes (Cassán et al., 2020). *Azospirillum* is widespread in South America, where studies on inoculation in various crops have shown positive and variable results, due in part to crop management practices and environmental conditions. In recent years, combined inoculation of *Azospirillum* with *Rhizobium* in legumes (co-inoculation) has become an emerging agricultural practice, showing high reproducibility and efficiency under field conditions (Cassán et al., 2020).
BRS FC104 is a super-early material with a 65-day life cycle. However, its ability to establish symbiotic associations with *Rhizobium* bacteria and its efficiency in biological nitrogen fixation (BNF) is under question. Therefore, a performance response regarding nodulation and grain production equal to that of a normal cycle cultivar such as BRS Notável would already be an advantage (Embrapa, 2017). Although the bean is a legume capable of performing BNF through associations with bacteria of the genus *Rhizobium*, results of this symbiosis in early cultivars are scarce (Tocheto and Boiago, 2019). Thus, the complete replacement of N-mineral by inoculation is still a goal to be achieved, requiring studies in different cultivars and soil and climate conditions.
Therefore, the objective of this study was to evaluate the agronomic performance of the super-early common bean cultivar BRS FC104 in response to co-inoculation with *Rhizobium tropici* and *Azospirillum brasiliense*.

Results and discussion

Variables of common bean cultivars cultivated with different sources of N

The group analysis of the experiments showed significant differences between the crops. Therefore, the data were analyzed separately within each site.
The analysis of variance revealed significant effect of cultivars on root dry weight (RDW) in SAG-water 2018/2019 and SAG-winter 2019. In SAG-water 2018/2019 a significant result was also observed for the number of pods (NP). The NP and number of grains (NG) were significantly influenced by cultivars in SAG-winter 2019. The effect of N sources was significant for number of nodules (NN), nodule dry weight (NDW) and shoot dry weight (SDW) in SAG-water 2018/2019 and in AG-winter 2019. In SAG-water 2018/19, significant effects were observed for the interaction between cultivars and nitrogen sources (CxNS) on NG. In SAG-winter 2019, the same interaction was also observed on NDW and SDW, whereas in AG-winter 2019 interaction effects only influenced NN (Table 2).
The NP showed significant results for both locations but in different harvests. NG was positively influenced only in AG-winter 2019 (Table 2). Meier et al. (2019) compared different crops and concluded that there was a significant difference between the cultivars Pérola, BRS MG Majestoso and BRS Cometa, in which these cultivars showed a higher number of pods per plant in the winter crop.
Common bean cultivars are usually sensitive to environmental variations and may differ from one harvest to another, affecting the production components in different ways. Therefore, the higher productive performance of a cultivar in each location can be explained by the better adaptation of this cultivar to the soil and climate conditions of the region (Marconato et al., 2021). According to Meier et al. (2019) the number of grains is determined by the genetic factor of the cultivar and can be influenced by the environment.
Although the production system used was different for the two locations, this factor possibly did not influence the cultivars and consequently the yield components. Corroborating this finding, Caixeta et al. (2016) stated that the number of pods per plant and the number of grains per pod are traits of high heritability and are hardly influenced as a function of management. In opposition, Ávila et al. (2019) stated that the number of pods per plant, the number of grains per pod, and the mass of grains can be affected by climatic conditions and the production systems used.
Regarding the interaction of cultivars with N sources, it is inferred that each cultivar responds in a different way to the available N source. According to Vieira et al. (2021), some cultivars respond to N application (responsive) and also produce well when soil N availability is low (efficient). These adjust to both low and high nitrogen crops. Caixeta et al. (2016), concluded that when plants are well nourished, they end up responding in greater height and greater number of productive branches, probably reflecting in a greater number of pods.

Interaction between cultivars and nitrogen sources on the variables

Analyzing the unfolding of the interaction (Table 3), in SAG-winter 2018/2019, it was observed that the cultivar BRS FC104 presented higher NG compared to BRS Notável in all treatments referring to the different N sources, and the co-inoculation and nitrogen treatment did not differ statistically. In SAG-winter 2019, it was observed that BRS FC104 presented higher NDW than BRS Notável only in control condition, which could indicate a greater ability to establish association with the native rhizobium population in the soil.
The cultivar BRS FC104 also accumulated greater SDW in relation to the cultivar BRS Notável in the nitrogen and control treatments, not statistically different in the co-inoculation. The nitrogen treatment showed higher SDW accumulation compared to the other N sources in BRS FC104. In AG-winter 2019, the unfolding of the interaction showed that both cultivars presented higher NN in the treatment with co-inoculation and within this treatment, BRS Notável presented NN higher than BRS FC104 (Table 3).
It can be inferred that the cultivars and the sources of N influenced the production components of common bean. The genotypic differences of each cultivar associated with other factors such as climatic conditions can influence the development process of the crop. Santis et al. (2019) observed a significant difference for number of grains per pod in the cultivar BRS Notável and the common bean. But they did not differ in grain yield. According to the authors, this can be justified by the fact that productivity is the result of the combination of production components, being influenced by genetic and environmental factors.
Both cultivars showed higher NN in the treatment with co-inoculation (Table 3). This result can be explained by the action of *R. tropici* and *A. brasilense* used together.

However, the early cultivar presented a lower number of nodules when compared to the normal cycle cultivar. According to Andraus et al. (2016), cultivars with different growth cycles respond in different ways to nodulation processes and productivity gains.

Knupp et al. (2017) stated that there is a great variability in nodulation capacity and in the efficiency of this symbiosis among bean varieties. Heritability is low in bean for traits related to nodulation due to quantitative inherent of these traits, governed by several genes, which makes the improvement process difficult. The quantitative traits suffer a strong environmental influence (Milcheski, 2018).

Variables analyzed of common bean cultivars

*In both crops (SAG-water 2018/19 and SAG-wint*er 2019), the RDW variable was influenced only by the cultivars, with BRS Notável showing higher RDW than BRS FC104 (Table 4). However, the NP was higher for the super-early cultivar in SAG-water 2018/2019, as well as in AG-winter 2019, where the cultivar BRS FC104 showed higher NP compared to BRS Notável, followed by higher NG. The variables, NN, NDW and SDW showed statistical differences among nitrogen sources, where co-inoculation in SAG-water 2018/19 showed higher results than the nitrogen treatment for NN and NDW, which did not differ statistically from the untreated control. The accumulation of SDW was higher in the control but did not statistically differ from the nitrogen treatment. In AG-winter 2019, co-inoculation provided higher NDW than the other treatments (Table 4).

The NDW in AG-winter 2019 showed much higher results in the treatment under co-inoculation compared to the other treatments. The results obtained in this study may be related to the greater root development, enabling greater area for nutrient and water uptake, greater area for nodule formation, better BNF efficiency, and increased synthesis of nodulation factors in common bean through co-inoculation of *Rhizobium* and *Azospirillum*. The positive effect of co-inoculation has been demonstrated in common bean crop by the increase in the NN, NDW, RDW, SDW, and GY, compared to standard inoculation and plants that received nitrogen fertilization (Steiner et al., 2019).

According to Guimarães et al. (2019), co-inoculation stimulates nodulation and potentiates nodule activity, total number and mass of nodules, differentiation of epidermal cells into root hairs, root surface area and productivity of cowpea. According to Steiner et al. (2019), in common bean, conventional inoculation of *R. tropici* can decrease nitrogen fertilizer use by up to 50%, and when inoculated together with other growth-promoting bacteria, the gains in nodulation, shoot and root biomass and productivity are even greater.

Grain yield of common bean cultivars in different locations and crops

Figure 1 shows that in the three harvests evaluated in this study, the cultivars and nitrogen sources did not influence productivity. However, it is observed that in SAG-winter 2019 and AG-winter 2019 the GY exceeded 3,500 kg ha^{-1}. Considering that the super-early cultivar BRS FC104 presented a productive performance equal to that of the normal cycle cultivar (BRS Notável), its shorter cycle makes it suitable to be recommended for grain production, ensuring the producer greater flexibility in the management of the productive system. Under the economic aspect, BRS FC104 can contribute to the reduction of production costs, since under co-inoculation the productive performance was statistically equal to that of the nitrogen treatment. Silva and Wander (2014) evaluated the economic viability of BRS FC104 in relation to BRS Estilo and concluded that there is an economic gain for the super-early cultivar in relation to the normal cycle.

Thus, the evaluation of cultivars with super-early cycle in different production environments and the comparison of the agronomic performance of these cultivars can help technicians and producers in decision making. The results observed in this study can be used to help producers in the selection of the most productive cultivars to obtain higher yields in the soil and climate conditions studied and for Brazil to begin a process of self-sufficiency in the production of this grain.

Principal component analysis of variables

Regarding the principal component analysis (PCA), we found that in SAG-water 2018/2019 (Figure 2a), the F1 axis represents 58.34% of the data variation. It is observed that the cultivar BRS FC104 with nitrogen fertilization (Obs4) contributed 62.3% positively to the highest values of NG and NP. The cultivar BRS Notável without fertilization (Obs3) contributed 27.2% negatively to the values of RDW, SDW and GY. The positive correlation between the factors for NP (0.95) and NG (0.77) and the negative correlation for GY (-0.89) and RDW (-0.87) stands out (Figure 2a).

In SAG-winter 2019 (Figure 2b), the F1 axis represents 43.41% of the variation in the data. It can be seen that the cultivar BRS Notável with nitrogen fertilization (Obs1), contributed positively with 44.1% to the highest values of RDW, NP, NG and GY. The cultivar BRS FC104 with nitrogen fertilization (Obs4) or with co-inoculation (Obs5) contributed 18.2% and 20.5%, respectively, to the lowest values of SDW. It is observed that there were positive correlations for NP (0.87), RDW (0.87), GY (0.82) and NG (0.72) and negative correlation for SDW (-0.52) (Figure 2b).

In AG-winter 2019 (Figure 2c), the F1 axis explains 51.57% of the variations in the data. The cultivar BRS FC104 with nitrogen fertilization (Obs4) contributed positively by 32.9% to the highest NG and NP values. However, the cultivar BRS Notável with nitrogen fertilization (Obs1) or co-inoculated (Obs2) contributed 31.4% and 24.8%, respectively, to the lowest values of RDW, SDW and GY. The factors were found to correlate positively for NP (0.98) and NG (0.97), and negatively for GY (-0.95) (Figure 2c).

In Figure 2, it is observed that there was positive contribution of GY and RDW in SAG-winter 2019 and, negative in SAG-water 2018/2019 and AG-winter 2019. However, NP and NG proved to be more stable variables, as they correlated positively in all three locations. According to soil analysis in SAG-winter 2019 (table 1), it is observed that in this location the organic matter, phosphorus, calcium, magnesium, and iron contents are higher than the others, thus obtaining a higher base saturation. In addition, the soil in SAG-winter 2019 has low copper content and no aluminum. Thus, soil fertility may have been one of the factors that favored RDW and GY at this location.

The responses of cultivars to nitrogen sources depend on the location of cultivation, requiring specific recommendations for each condition. In Figure 2a, in SAG-water 2018/2019, co-inoculation provided a positive

Table 1. Soil chemical attributes of the experimental areas in Santo Antônio de Goiás - GO and Abadia de Goiás - GO.

Location/ Harvest	pH	M.O.	P	Al	H+Al	K	Ca	Mg	CTC	V%
		%	mg dm^{-3}	---------------cmolc dm^{-3}-------------------						%
SAG-water 2018/19	4.9	3.4	11.1	0.1	3.9	102.0	2.5	1.3	8.0	51.0
SAG-winter 2019	5.7	4.2	20.6	0.0	2.3	110.0	3.9	1.7	8.2	71.9
AG-winter 2019	4.9	2.9	12.0	0.1	2.8	132.0	2.0	1.1	6.2	55.1

	Cu	Fe	Mn	Zn
	mg dm^{-3}			
SAG-water 2018/19	2.3	42.0	27.0	6.1
SAG-winter 2019	1.1	65.0	20.0	11.4
AG-winter 2019	2.1	58.0	16.0	11.3

SAG- Santo Antônio de Goiás-GO, AG- Abadia de Goiás-GO.

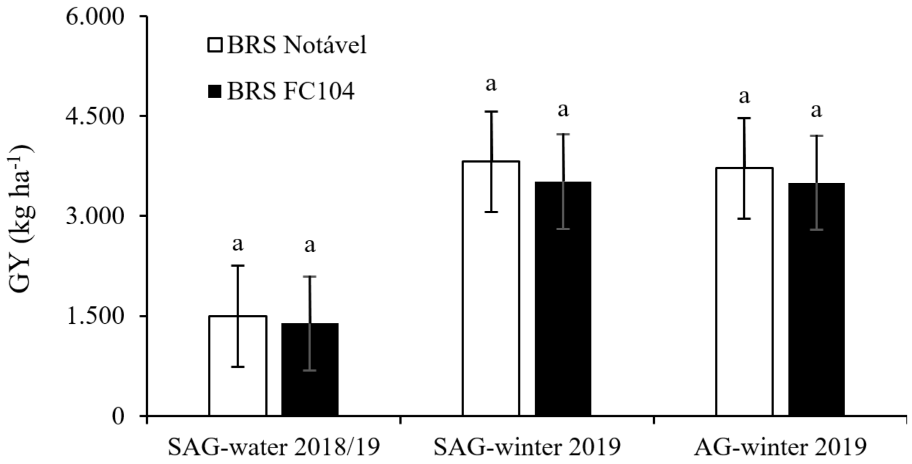

Figure 1. Grain yield (kg ha^{-1}) of two common bean cultivars in different locations and crops. SAG- Santo Antônio de Goiás-GO, AG- Abadia de Goiás-GO. Means followed by the same lowercase letter within site do not differ statistically by the Tukey test ($p \leq 0.05$).

Table 2. Summary of analysis of variance with F values for growth and yield variables of common bean cultivars grown with different N sources.

SAG–water 2018/2019							
Factors	NN	NDW	RDW	SDW	NP	NG	GY
Cultivars	0.6^{ns}	0.05^{ns}	5.8*	0.00^{ns}	6.9**	96.9**	1.1^{ns}
Source N	56.8**	42.5**	0.7^{ns}	3.8*	3.0^{ns}	5.3**	0.5^{ns}
C x NS	0.7^{ns}	0.9^{ns}	1.5^{ns}	1.2^{ns}	1.9^{ns}	9.6**	0.01^{ns}
C.V(%)	20.2	31.7	17.8	12.2	15.8	11.1	16.3
SAG–winter 2019							
Cultivars	0.3^{ns}	0.7^{ns}	19.4*	15.7**	1.0^{ns}	0.8^{ns}	2.5^{ns}
Source N	1.9^{ns}	4.7*	0.7^{ns}	5.1*	0.3^{ns}	0.07^{ns}	1.4^{ns}
C x NS	0.7^{ns}	4.7*	0.2^{ns}	4.0*	0.7^{ns}	1.3^{ns}	0.5^{ns}
C.V(%)	58.2	48.3	19.4	22.9	31.4	29.4	12.2
AG–winter 2019							
Cultivars	6.4*	0.07^{ns}	0.83^{ns}	3.5^{ns}	8.9**	13.9**	3.9^{ns}
Source N	20.5**	7.4**	2.00^{ns}	1.1^{ns}	1.1^{ns}	0.4^{ns}	0.5^{ns}
C x NS	3.5*	0.1^{ns}	0.00^{ns}	0.1^{ns}	2.2^{ns}	1.9^{ns}	1.6^{ns}
C.V(%)	62.0	58.3	22.5	29.4	14.2	16.2	7.3

SAG- Santo Antônio de Goiás-GO, AG- Abadia de Goiás-GO. **significant ($p < 0.01$). *significant ($p < 0.05$). nonsignificant.

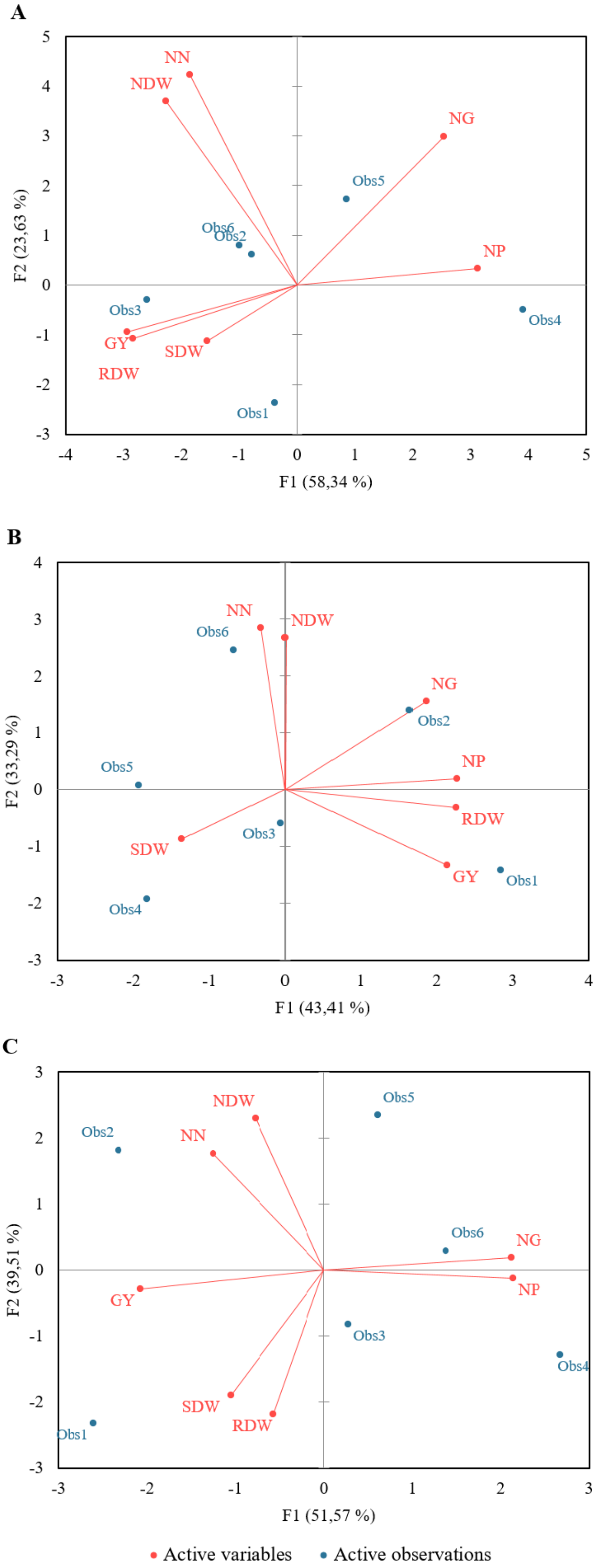

Figure 2. Principal component analysis explaining correlations between variables (NN - number of nodules, NDW - nodule dry weight, RDW – root dry weight, SDW - shoot dry weight, NP – number of pods, NG - number of grains and GY - grain yield) and treatments (Obs1 - BRS Notável with nitrogen fertilization, Obs2 - BRS Notável co-inoculated, Obs3 - BRS Notável untreated control, Obs4 - BRS FC104 with nitrogen fertilization, Obs5 - BRS FC104 co-inoculated, Obs6 - BRS FC104 witness) within each location (A. SAG-water 2018/2019, B. SAG-winter 2019 and C. AG-winter 2019).

Table 3. Interaction between cultivars and nitrogen sources on the number of grains (NG = nº plant^{-1}), nodule dry weight (NDW = mg plant^{-1}), shoot dry weight (SDW = g plant^{-1}) and number of nodules (NN = nº plant^{-1}) of common bean.

Treatments	SAG–water 2018/2019		SAG-winter 2019				AG–winter 2019	
	NG		NDW		SDW		NN	
	Notável	BRS FC104	BRS Notável	BRS FC104	BRS Notável	BRS FC104	BRS Notável	FC104
Co-inoculation	51.72Ba	63.3Aab	17.7Aa	6.3Ab	5.5Aa	5.8Ab	103.6Aa	47.9Ba
Nitrogenated	34.6Bb	72.0Aa	5.2Aa	2.8Ab	5.3Ba	9.6Aa	20.2Ab	7.1Ab
Untreated control	36.9Bb	58.9Ab	10.6Ba	38.3Aa	4.2Ba	6.4Ab	16.6Ab	17.0Aab
CV (%)	11.1		48.3		22.9		62	

SAG- Santo Antônio de Goiás-GO, AG- Abadia de Goiás-GO. Means followed by the same upper case letter within the row and by the same lower case letter within the column, do not differ statistically by the Tukey test ($p \leq 0.05$)

Table 4. Mean values of root dry weight (RDW = g plant^{-1}), number of pods (NP = nº plant^{-1}), number of grains (NG = nº plant^{-1}), number of nodules (NN = nº plant^{-1}), nodule dry weight (NDW = mg plant^{-1}) and shoot dry weight (SDW = g plant^{-1}) of beans cultivars.

Cultivars	SAG-water 2018/2019		SAG-winter 2019	AG-winter 2019	
	RDW	NP	RDW	NP	NG
BRS Notável	0.89 a	13.51 b	0.78 a	15.32 b	70.25 b
BRS FC104	0.75 b	16.03 a	0.55 b	18.25 a	90.12 a
CV(%)	17.8	15.8	19.4	14.2	16.2
Sources N	SAG–water 2018/2019			AG–winter 2019	
	NN	NDW	SDW	NDW	
Nitrogenated	2.75 b	1.54 b	6.49 ab	11.75 b	
Co-inoculation	9.79 a	13.32 a	6.04 b	160.7 a	
Untreated control	9.33 a	14.49 a	7.16 a	49.82 b	
CV(%)	20.2	31.7	12.2	58.3	

SAG- Santo Antônio de Goiás-GO, AG- Abadia de Goiás-GO. Means followed by the same lowercase letter within the column do not differ statistically by the Tukey test ($p \leq 0.05$).

contribution (0.86) for BRS FC104 (Obs5), but for BRS Notável (Obs2) the contribution was negative (-0.78). In these same conditions, BRS FC104 showed better response to nitrogen fertilization when compared to BRS Notável, showing positive contribution (3.91) in Obs4 and negative (-0.39) in Obs1. In relation to the untreated controls, BRS Notável (Obs3) (-2.59) showed lower results than BRS FC104 (Obs6) (-0.99). Therefore, the cultivar BRS FC104 shows greater adaptability to this growing condition and better response to nitrogen fertilization and co-inoculation.

In SAG-winter 2019 (Figure 2b), the cultivar BRS Notável showed better response than BRS FC104, regardless of fertilizer sources. Obs2 (co-inoculated BRS Notável) showed superior response to the untreated control (Obs3). However, it did not replace nitrogen fertilization (Obs1). The co-inoculated cultivar BRS FC104 (Obs5) provided results close to nitrogen fertilization. Under these cultivation conditions, it is possible to observe a divergence between the cultivars in relation to the efficiency of co-inoculation with the cultivar BRS Notável being more efficient with co-inoculation and nitrogen fertilization.

In AG-winter 2019 conditions (Figure 2c), the cultivar BRS Notável showed low response to nitrogen fertilization and co-inoculation (Obs1 and Obs2), while in contrast, BRS FC104 showed better response to nitrogen fertilization (Obs4) at this location.

However, it is observed that the efficiency of the source adopted as a strategy for the supply of nitrogen in the crop depends on the growing conditions and the cultivar adopted.

Material and methods

Characterization of the experimental areas

The experiments were conducted under field conditions at Embrapa Rice and Beans, in Santo Antônio de Goiás - GO (latitude 16°29'13.90 "S, longitude 49°17 '47.68 "W and altitude 767 m); and at Chácara Quita dos Sonhos, in Abadia de Goiás - GO (latitude 16°48'43.44 "S, longitude 49°23'24.54 "W and altitude 814 m). According to the Köppen classification, the climate of the two locations is Aw, tropical savanna, megathermal, and the rainfall regime is well defined, with rainy season October/March and dry season April/September, with an average annual rainfall of 1460 mm.

The experiments were implemented in Santo Antônio de Goiás in the 2018/19 water harvest and in the 2019 winter harvest, and in Abadia de Goiás in the 2019 winter harvest. The experimental areas differed in terms of soil preparation, being managed in Santo Antônio de Goiás in direct seeding system and in Abadia de Goiás in conventional system with plowing and harrowing before seeding.

Before the implementation of the trials, the chemical analysis of the soils was performed according to the methodology proposed by Embrapa (2017) and the results are presented in Table 1.

Design and set up of the experiments

The experimental design was randomized in 2x3 factorial scheme with four repetitions. The treatments consisted of two common bean cultivars (BRS Notável and BRS FC104) and three sources of nitrogen: (1) co-inoculation with *R.*

tropici + *A. brasilense*; (2) nitrogen fertilization at a dose of 80 kg ha^{-1} of N and (3) absolute control (no nitrogen fertilization and no co-inoculation). The plots consisted of six four-meter long lines, spaced at 0.45 m in the Santo Antônio de Goiás trial and at 0.50 m in the Abadia de Goiás trial.

The opening of the planting furrows was done mechanically, and the sowing was done manually, distributing 14 seeds per meter. Before planting, the common bean seeds used in the co-inoculation treatment were inoculated with *R. tropici* bacteria using peat inoculant, at the proportion of 500 g of inoculant for 50 kg of seeds, containing 1x10^{9} cells g^{-1} of peat from the mixture of three commercial strains (SEMIA 4080, SEMIA 4088 and SEMIA 4077).

The application of *A. brasilense* was done via spraying when the plants reached the V2/V3 vegetative development stage, which occurred at 14 days after emergence (DAE). The inoculant of *A. brasilense* used contained the strain Ab-V5 at a concentration of 1x108 cells mL^{-1}, of which the equivalent of three doses ha^{-1} diluted in a syrup volume of 200 L ha^{-1} were applied.

In the treatments with nitrogen fertilization, urea was used as a source of N, and the application was applied in two installments: 20 kg ha^{-1} of N applied at sowing and 60 kg ha^{-1} of N applied 30 DAE.

The phytosanitary management was done according to the recommendation for the common bean and the areas were irrigated, in Santo Antônio de Goiás by central pivot and in Abadia de Goiás by sprinkling, according to the water needs of the crop.

Evaluations and statistical analysis

When the plants reached the full bloom (R6 development stage) three plants were collected from each plot and the roots were removed with the help of a straight shovel. The shoot was separated, and the roots were washed in running water and the nodules were detached and counted to determine the number of nodules (NN). After that, the nodules, roots and leaves were dried separately in an oven (65 ºC; 72 h) and weighed to determine the nodule dry weight (NDW), root dry weight (RDW) and shoot dry weight (SDW).

At the R9 development stage, when the plants reached physiological maturity, 10 plants were collected from each plot to determine the number of pods (NP) and number of grains (NG). The grain yield (GY) was determined using the central area of the plot with 4.5 m², and expressed in kg ha^{-1}, with the values corrected to 13% humidity.

The data obtained in the experiments were grouped and analyzed by group of experiments. When significant differences were observed, the results of each crop were analyzed separately. The data were submitted to variance analysis and if there was significance in the F test ($p \leq 0.05$), the mean values were compared by the Tukey test at 5% probability using the SISVAR software (Ferreira, 2019).

Additionally, multivariate analysis of the data was performed using principal component analysis (PCA) using the XLSTAT 2022 program.

Conclusions

Co-inoculation with *Rhizobium tropici* and *Azospirillum brasilense* positively influenced the nodule number, nodule dry weight, pod number and grain number of the two common bean cultivars.

The super-early cultivar BRS FC104 showed similar productivity to the normal cycle cultivar BRS Notável.

The response of the cultivars to nitrogen sources depends on the growing conditions, requiring specific recommendations.

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