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INCREASED YIELD OF COMMON BEAN DURING INTERACTION BETWEEN ORGANIC SELENIUM AND TRICHODERMA SPP

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ABSTRACT
Common beans are an essential food in the diet of most Brazilians, highlighting the need to develop more sustainable methods that promote the increase of their productivity. In this context, understanding the effects of the use of organic selenium and associated with Trichoderma spp. on the performance of this crop becomes essential to achieve these goals. In this sense, the present study aimed to evaluate the interaction between Trichoderma spp. and organic selenium in the increase of common bean yield in Imperatriz, MA. The experiment was carried out in a field environment, at the Center for

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Technological Diffusion, located in Imperatriz, Maranhão, Brazil, in a randomized block design, with 4 treatments in 4 replications. The treatments consisted of foliar and soil application of organic selenium and Trichoderma spp. The results show that the use of Selenium + Trichoderma spp. had a significant impact on the production of dry matter, fresh matter, number of pods, number of grains per pod, and weight of 100 grains. The increase in these variables ended up corroborating the increase in productivity. Therefore, the combined use of Selenium + Trichoderma spp. Becomes possible and enhances the performance of the common bean crop. Thus contributing to the increase in the productivity of common beans, as well as to the promotion of sustainability and the increase in the income of local producers.

Keywords: Phaseolus vulgaris L. Foliar fertilization. Fertilization via soil. Production.

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INTRODUCTION

The common bean, *Phaseolus vulgaris* L., is widely consumed by the Brazilian population, being one of the most relevant legumes in the national agricultural scenario. It is a vegetable of the Fabaceae family, having some characteristics as a vegetable-type fruit, and the pod is joined by two valves joined by two sutures (Embrapa, 2021).

According to IBGE data (2023), in Brazil, common beans had a productivity of 2,899,043 tons with a harvested area of 2,465,222 ha and an average yield of 1,176 kg $^{ha-1}$. The state of Paraná, considered the largest producer of this legume, leads with 21% of the average production between the years 2019 and 2021 (Embrapa, 2023). In the 1st survey of the 2024/2025 harvest, it is expected that there will be an increase of 3260 thousand tons and an increase of 2880 thousand ha in the country's area, however, there will be a drop of 1132 Kg/ha in productivity (Conab, 2024).

In the Northeast region, a planted area of 432 thousand ha and productivity of 508 Kg/ha were obtained in the 2023/2024 harvests; in turn, in the 2024/2025 harvest, a planted area of 440.4 thousand ha and productivity of 453 kg ha-1 are estimated. In Maranhão, it is estimated that the next harvests of common beans will reach an average productivity of 576 kg $^{ha-1}$, with emphasis on the Balsas region, located in the south of the state, which is consolidated as the main producing area (Conab, 2024).

In Brazil, common beans are produced in practically all Brazilian states (Marco et al., 2012) and are characterized by being produced in the most diverse climate conditions, both temperate and tropical, and in different types of soils. However, as a result of the population increase, extreme climate change and the appearance of new diseases arise (Bossolani et al., 2017), thus requiring new technologies that can add to productivity.

For this, several management methods are used, requiring the correct choice of the type of system to be adopted, sowing time, soil conditions, water availability, and several other factors, especially the adoption of management with the use of biological inputs and mineral fertilization.

Thus, more sustainable alternatives are being implemented to maximize production and reduce the impacts caused by climate stress, such as the use of *Trichoderma* spp., a fungus naturally present in Brazilian soils. In addition to Selenium, found mainly in human food and animal diet, due to its availability in the soil (Bossolani et al., 2017), since vegetables absorb this mineral.

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Trichoderma spp. is one of the most studied and used biological agents in the control of pests and diseases, in addition to being considered a promoter of plant growth. In common beans, their colonization in the root system represents a basic assumption in protection against fungi that cause rot, nematodes, and productivity increases (Embrapa, 2019).

This fungus plays a significant role in promoting plant growth, primarily due to its ability to produce hormones, such as gibberellins, and auxins, such as indoleacetic acid (IAA) (Hermosa et al., 2012). These substances stimulate the development of lateral roots, expand root formation, and favor the growth of leaf area. As a consequence, there is a greater absorption of essential nutrients, resulting in increases in plant productivity.

Selenium, despite not being considered an essential nutrient, is a biofortifying element since a percentage of the population is deficient in this mineral (Prado et al., 2017). through its application in agriculture, its levels can be increased in food. In plant production, beneficial effects are observed when applied in small quantities due to the antioxidant action capable of increasing plant production (Prado et al., 2017).

Due to the aspects already mentioned, regarding the need for more sustainable alternatives to increase the productivity of common beans and mitigate edaphoclimatic changes, considering that both inputs, *Trichoderma* spp. and Selenium Thus, the present study aimed to evaluate the interaction between organic selenium and *Trichoderma* spp*.* in the increase of the productivity of common beans in the municipality of Imperatriz – MA.

METHODOLOGY

CHARACTERIZATION OF THE EXPERIMENTAL AREA

The study was carried out in a field environment at the Center for Technological Diffusion, located in Imperatriz, Maranhão, Brazil (5º 31' 32' S; 47º 26' 35' W). The climate of the region, according to the Köppen classification, is of the Aw type, tropical with an average annual rainfall of 1,221 mm and an average annual temperature of 27.1 ºC.

The soil of the locality where the experiment was developed has a texture ranging from medium to sandy, with low moisture retention and low levels of organic matter, constituting soil with high susceptibility to erosion. In the months of higher rainfall, it has points with impeded drainage, where water has difficulty infiltrating an impermeable layer of the soil.

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EXPERIMENTAL DESIGN AND TREATMENTS

The experiment was in a completely randomized design, with 4 treatments in 4 replications. The treatments consisted of foliar and soil application of organic selenium and *Trichoderma* spp., respectively. The treatments were: T0: Control treatment (without application of selenium and *Trichorderma* spp.), T1: Foliar application of organic selenium (250 mL 100 L of water), T2: Soil application of *Trichorderma* spp., and T3: Organic selenium + *Trichorderma* spp.

The foliar application of selenium took place at 45 days after sowing, at the time of flower anthesis, while the application of the bioinput *Trichorderma* spp. took place at 7 days and 35 days after seedling emergence.

INSTALLATION AND CONDUCT OF THE EXPERIMENT

The area is historically cultivated with vegetables and beans, quite uniform about soil color and topography, in addition to which there are no records of soil spots. Soil tillage was initiated with mechanical defragmentation of crop residues, followed by manual chiseling and leveling of the land. The sowing of the common bean cultivar was carried out manually, with a spacing of 0.50 m between rows and 0.30 m between plants, with 3 seeds per hole.

The experiment was installed on 04/11/2023 in an area of 92 m², with 16 rows totaling 4 plots. Each plot was composed of 4 rows of the crop, 2 m long. An initial stand of 9 plants per linear meter was accounted for. A line at each end of the plot, as well as 0.5 m at each end of the central lines, were considered as borders, not being used for the evaluations, with a useful area of 1 m2.

VARIABLES ANALYZED

After 72 days of sowing, 10 plants were collected from the useful areas of each plot to evaluate the fresh and dry mass of the aerial part, the number of vargens per plant, the number of grains per pod, the weight of 100 grains, and productivity. The determination of aerial fresh mass was carried out by weighing on a semi-analytical scale, and this measurement was carried out "*in loco*". The aerial dry mass was obtained by drying the plants in a forced air circulation oven for 72 hours and then weighing them on a precision scale.

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The number of pods and number of grains per pod were measured by counting the total pods and total grains per plant. A mass of 100 grains was obtained by selecting 100 fresh grains per plant and weighing them on a semi-analytical scale. Yield, expressed in kg $^{ha-1}$, was estimated based on the dry mass of the grains and extrapolated to the hectare.

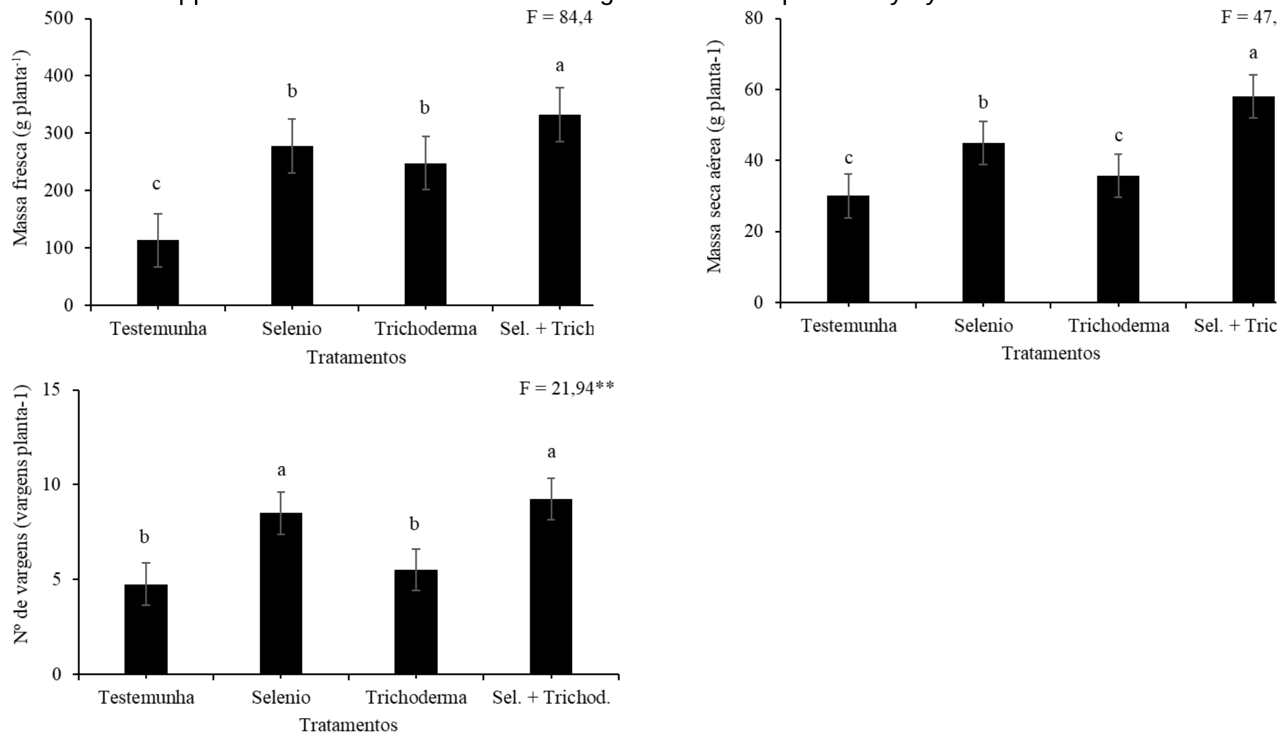
2.5 STATISTICAL ANALYSIS

The data obtained were tested for normality of errors (Royston, 1995) and homogeneity of variance (Gastwirth et al., 2009), and were submitted to analysis of variance by the F test (p<0.05), and the means were compared by Tukey's test (p<0.05), using the Agroestat software, version 1.0.

RESULTS

The results obtained for the variables fresh and dry mass of the shoot and number of vargens per plant revealed that there was a significant difference (p-value<0.01), inferring that the association of organic selenium + *Trichoderma* spp. Contributes to morphological increases of the common bean crop.

Figure 1. Fresh and dry shoot mass and number of common bean pods submitted to foliar application of selenium and application via *Trichoderma soil*. ** significant to 1% probability by the F-test.



Source: Bandeira (2024)

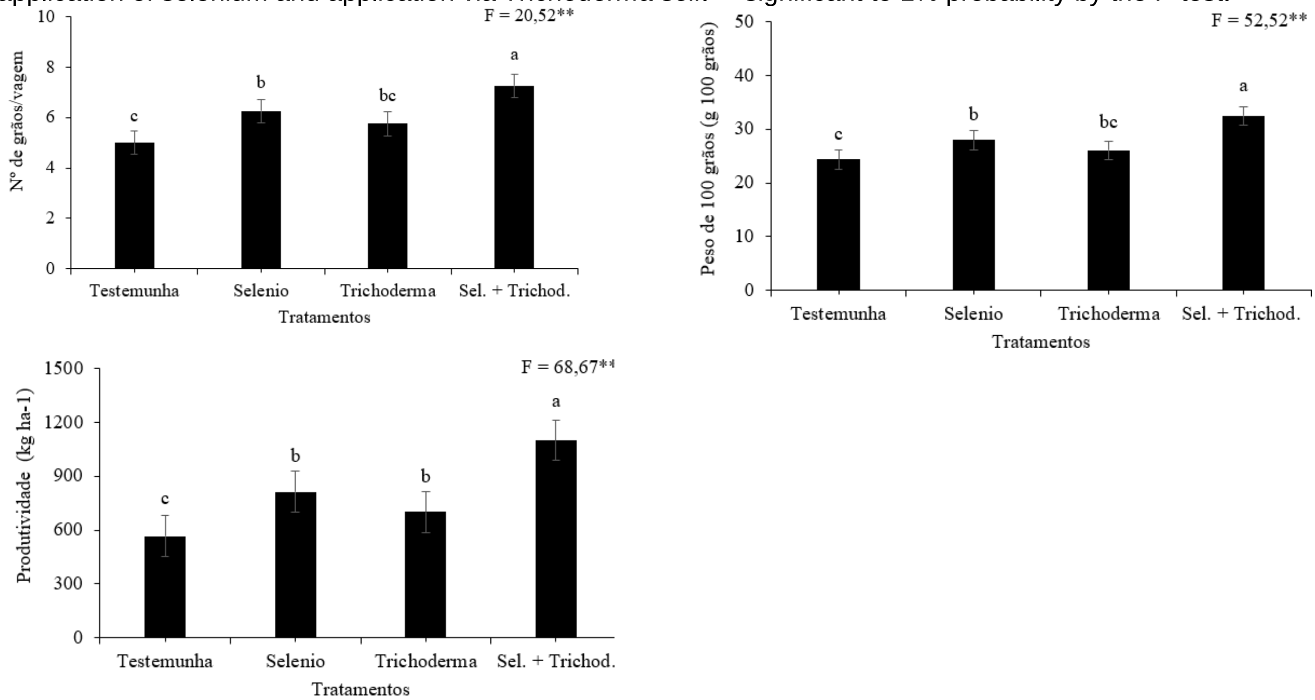
It was found that with the association of selenium + *Trichorderma* spp., there was an increase of 93.46% in aerial dry mass, 58.04 g plant-1, compared to the control treatment, 30 g plant-1 (Figure 1). This expressive increase has a direct correlation with the gain in fresh air mass, in which the same behavior was observed for the same treatment.

Figure 1 shows that the number of pods per plant showed a significant response when submitted to foliar application of organic selenium, with an average value of 8.5 vargens plant-1, and by the association selenium + *Trichoderma* spp., 9.25 vargens plant-1.

The analysis of variance revealed statistically significant differences ($p < 0.01$) for the variables number of grains per pod, weight of 100 grains, and yield (Figure 2), showing that the combined application of organic selenium and *Trichoderma* promotes significant increases in the productive performance of the common bean crop.

The data on the number of grains per vargem (Figure 2) showed that the selenium + *Trichorderma treatment* produced a higher number of grains, 7.25 vargem-1 grains, when compared to the control treatment, 5 vargem-1 grains.

Figure 2. Number of grains per pod, weight of 100 grains and yield of common bean submitted to foliar application of selenium and application via *Trichoderma soil*. ** significant to 1% probability by the F-test.



Source: Bandeira (2024).

All the variables analyzed, fresh and dry shoot mass, number of pods per plant, number of grains per pod, and weight of 100 grains significantly influenced the final yield of

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the common bean (Figure 2). The yield of common bean grains obtained for the treatment of selenium + *Trichoderma* spp., 1098.17 kg $^{ha-1}$, was higher than the estimate of the national average production of 1081 kg $^{ha-1}$, with a percentage difference of 1.58%, according to data from CONAB (2023).

DISCUSSION

The fresh mass of the aerial part of the plants showed a significant increase under the treatment with selenium + *Trichoderma* spp., reaching an average of 332.25 g plant^{-1}, compared to the control treatment, which recorded 113.25 g plant^{-1}. This effect can be attributed mainly to the ability of organic selenium to promote plant growth, acting to increase chlorophyll contents, intensify photosynthesis, reduce the production of reactive oxygen species (ROS) and increase the activity of enzymes in the antioxidative system, as reported by Djanaguiraman et al. (2010), Hasanuzzaman and Fujita (2011).

The combination of selenium and *Trichoderma* has been shown to enhance the growth of fresh mass from the aerial part of plants. This effect can be explained by the action of *Trichoderma in the* rhizosphere, which promotes greater absorption of nutrients by the roots, resulting in a significant increase in the fresh mass of common bean leaves.

Research conducted by Chauhan et al. (2017) indicates that the accumulation of dry matter in leaves is directly related to the greater capacity of plant roots to absorb water, an essential factor for plant growth. In this context, studies carried out by Santos et al. (2010) corroborate these findings, showing positive results in the increase of both fresh and dry mass in passion fruit plants from cuttings. Such results highlight the synergy between biological agents and selenium, contributing to the sustainable and efficient development of crops.

The increase in the number of pods can be attributed, as described by Turakainen et al. (2005), to the application of selenium in low concentrations, which promotes the increase of antioxidant activity in plants, increasing plant productivity. In the case of *Trichoderma*, Santos (2008) demonstrated the efficacy of biofungicides by using ten species of *Trichoderma* sp. in the treatment of bean seeds, a factor that also contributed significantly to the increase in pod production. These studies corroborate the results obtained in this study.

The number of grains per pod is an agronomic parameter of great relevance, as it directly influences the final productivity of the crop. Although there are few studies on this variable, Brito et al. (2014) report that the isolated application of selenium does not promote significant increases in this parameter. However, the results obtained in this study show that the association with *Trichoderma* resulted in a significant increase in the number of grains per pod.

This effect can be attributed to the application of *Trichoderma* via soil, directly in the planting furrow, which enhanced the rootability of the bean plant. This greater rooting capacity provided an expanded area for nutrient absorption, as highlighted by Waheed et al. (2020). The increase in root volume intensifies the transport of raw sap to the active growth zones, thus favoring the increase in the number of grains per pod. These findings highlight the synergy between *Trichoderma* spp. and selenium as an effective strategy for maximizing yield performance in bean crops.

It is possible to observe a similar behavior for the selenium + *Trichoderma* spp. Treatment under the variable weight of 100 grains reached an average value of 32.45 g 100 grains, a value 33.31% higher than the control treatment (Figure 2). This behavior can be attributed to selenium's ability to act as an antioxidant trace element, reducing the process of cell death in the leaves. This action prolongs the maintenance of the active photosynthetic area compared to plants not treated with this element.

In addition, fungi of the genus *Trichoderma* stand out for their ability to produce and act on the homeostasis of phytohormones that promote the development of crops. In addition, they can colonize both the rhizosphere and plant tissues; during mutualistic interaction, they produce enzymes and organic acids that increase nutrient availability and improve uptake by plants (Khan et al., 2019). This beneficial interaction not only improves the nutritional status of the plants, but also enhances the filling of the grains, reflecting in a significant increase in the final weight of the seeds.

The joint application of organic selenium and *Trichoderma* increases bean yield due to the antioxidant effect of selenium, which attenuates oxidative stress and optimizes photosynthetic efficiency. At the same time, *Trichoderma* favors the availability and absorption of nutrients and stimulates root growth. This interaction between selenium and *Trichoderma* spp. Promotes the improvement of the development of the bean plant, reflecting an increase in the number of grains per pod and, consequently, in the overall yield of the crop. However, it is observed that few studies and investigations evidence these effects on the yield of common beans.

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CONCLUSION

It was found that the treatment Organic Selenium + *Trichorderma* spp. It provided a significant performance, which ended up benefiting the productivity of the common bean crop.

The cultivation using organic selenium as a bioinput proved to be highly effective for the production of common beans in the region of Imperatriz, MA. These results reveal the possibility of obtaining high levels of productivity in the crop through the use of simpler management of these inputs and in a sustainable way, which can be of great interest to farmers in the region.

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