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BIOFERTILIZER IMPACT ON THE PRODUCTIVITY OF BROAD BEAN (*VICIA FABA* L.)

A.H.A. AL-ZUBAIDI

Al-Musaib Technical College, Al-Furat Al-Awsat Technical University, Babylon, Iraq
Corresponding author's email: com.ali22@atu.edu.iq

SUMMARY

The presented study determined the effect of biofertilizers on the growth and production of broad bean (*Vicia faba* L.) cultivars conducted during the autumn season of 2020–2021 at the Al-Mahaweel area, Babylon Governorate, Iraq. The experiment followed a randomized complete block design with two factors and three replicates. The first factor was the three broad bean cultivars—local, Turkish, and Spanish—while the second was four biofertilizer levels(control, *Bacillus mucilaginous*, and mycorrhizal fungi). The results showed the Spanish cultivar significantly excelled over other cultivars in yield-related traits, pods per plant (16.82), seeds per pod (6.11), seed yield (5,884.29 kg ha^{-1}), and biological yield (12,599.05 kg ha^{-1}). The mycorrhizal fungi biofertilizer treatment remarkably excelled for all treatments, i.e., pods per plant (17.84), seeds per pod (6.98), seed yield (5,874.11 kg ha^{-1}), and biological yield (14,495.79 kg ha^{-1}). Meanwhile, the interaction treatment (Spanish cultivar + mycorrhiza fungi) superbly shone and gave the highest rate for most studied traits.

Keywords: Broad bean (*Vicia faba* L.), cultivars, biofertilizer**,** mycorrhizal, yield-related traits

Key findings: Broad bean (*Vicia faba* L.) cultivar Spanish and mycorrhiza, individually and in combination, significantly showed better performance for most studied traits.

INTRODUCTION

The broad bean (*Vicia faba* L.) is one of the winter crops in the Fabaceae family and one of the oldest crops that has undergone domestication and consumed as food because of the high protein content, estimated between 40% and 25% (Natalia *et al*., 2008). Given that it is the most economical source of protein compared with pricey animal proteins and its seeds contain carbohydrates, minerals, fiber, and vitamins, it is essential to both people and animals due to its high nutritional value (Salem, 2009). Broad beans are applicable in

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crop rotation to improve soil conditions, critical for enhancing soil characteristics by fixing the soil's atmospheric nitrogen through root nodules with rhizobium bacteria (Carmen *et al*., 2005).

Mycorrhizal fungi are a symbiotic relationship between fungi and plant roots. Mycorrhizal fungi exchange nutrients with plants. This relationship allows plants to obtain additional nutrients and increase their ability to absorb water and nutrients from the soil. Mycorrhizal fungi are an influential part of the environmental structure. It improves soil health and promotes plant growth (Miyauchi *et al.,* 2020). The mycorrhizal fungi colonize both the root tissues of higher plants and the area surrounding the roots in a symbiotic manner. It is crucial in plant nutrition and enhancing macro- and micronutrient absorption; thus, infected plants appear in better condition than uninfected ones. Mycorrhizal fungi can infect 90% of plant species. They have a primary role in increasing the readiness of some macronutrients, such as phosphorus, through various mechanisms, including reducing the phosphorus traveling distance by spreading, increasing the surface area for absorption (Dhiyab, 2012), high affinity between phosphorus and mycorrhizal roots, and high speed of phosphorus transfer.

During the fungus growth compared with its transport in the roots, the fungi highly absorb the low-concentration soil solution, and they secrete many organic compounds that can dissolve complex phosphate forms in the area around the roots and make them ready for absorption (Lopez-Raez *et al.,* 2010). In addition to the mycorrhizal contribution, it produces compounds that increase growth and yield, including indole acetic acid, gibberellins, cytokinins, ethylene, salicylic acid, and jasmonic acid. These are then secreted in the rhizosphere and transported to plant tissues through the symbiotic relationship with the mycorrhizal fungi, which regulates and improves plant growth. It also reduces pathogenic Mycorrhizae and limits the activity of pathogenic organisms in the soil through several mechanisms in protecting their host plants from pathogens (Lutz *et al.,* 2023).

One of the core elements for achieving high productivity of the economic yield is cultivating suitable cultivars; cultivars alone do not guarantee high productivity. Agricultural technology advancements require development, including using biofertilizers that are safe for the environment, a chief source of nutrients for plants that are significant in boosting soil fertility by enhancing nutrient content reflected favorably in crop yields (Pal *et al*., 2015). Additionally, it participates in releasing plant hormones, such as cytokinins, gibberellic acid, and indole acetic acid, indirectly stimulating plant development by producing antibiotics that lessen the inhibitory effects of specific pathogens (Mitra *et al*., 2021). This study sought the impact of bacterial and fungal biofertilizers on broad bean yields.

MATERIALS AND METHODS

The promising study aimed to determine the effect of biofertilizers on the growth and production of broad bean (*Vicia faba* L.) cultivars, conducted during the autumn season of 2020–2021 at the Al-Mahaweel area, Babylon Governorate, Iraq. The experiment followed a randomized complete block design with two factors and three replicates. The first factor was the three broad bean cultivars: local, Turkish, and Spanish. The second factor had four levels of biofertilizer (control, *Bacillus mucilaginosus*, and mycorrhizal fungi). The biofertilizer came from the Department of Agricultural Research, Baghdad, Iraq. Before planting, random sampling ensued on soil from a depth of around 0 to 30 cm, taken from the experimental location after its plowing, leveling, and smoothing to learn more about some of its chemical and physical traits (Table 1).

Cultivation commenced on rows of about 1 m, with a distance between them at 40 cm and the distance between one plant and another at 25 cm. The seed sowing transpired manually on 1 November 2020 at an amount of two seeds in each pit, then the thinning method followed. Adding phosphate fertilizer

Table 1. Chemical and physical properties of the experimental soil.

Trait		Unit	Value
EC		ds m^{-1}	2.3
pH		------	7.14
N		mg kg^{-1}	22
P		mg kg^{-1}	5.21
K		mg kg^{-1}	105.01
O.M.		mg kg^{-1}	8.1
Soil separators	Sand	mg kg^{-1}	464
	Loamy	mg kg^{-1}	336
	Clay	mg kg^{-1}	200
Texture		-----------	Loam

Table 2. Effect of cultivars, biofertilization, and their interaction on the number of pods in broad beans.

Cultivars	Biofertilizers			Means (pods $plant^{-1}$)
	Control	*Bacillus mucilaginosus*	Mycorrhiza Fungi	
Local cultivar	11.10	14.07	16.27	13.81
Turkish cultivar	12.07	15.37	18.10	15.18
Spanish cultivar	14.13	17.17	19.17	16.82
Means (pods $plant^{-1}$)	12.43	15.54	17.84	

$LSD_{0.05}$ Biofertilizer: 1.942, Cultivars: 1.942, Biofertilizer × Cultivars: 3.363

Before planting had an amount of 35 kg ha^{-1} and nitrogen fertilizer at 50 kg ha^{-1} in two stages: the first at planting and the second at the beginning of flowering (Aguilera and Recalde, 1995). Seed harvesting was at the end of April.

Traits studied

The number of pods in the plant (pod $plant^{-1}$) calculation had the total number of pods taken from three plants from each experimental unit and then averaged. The number of seeds per pod (seed pod^{-1}) computation had 20 seeds randomly taken from each experimental unit, with the average extracted from them. Accounting for total seed yield (kg ha^{-1}) continued by harvesting three plants from each experimental unit, with the seed weight taken, and based on the plant density, calculating the productivity of one plant, then converted to t ha^{-1}. The biological yield (kg ha^{-1}) calculation proceeded when all plant parts became dry by air-drying, and as the seed yield, calculating the quantity per plant converted to t ha^{-1}. The harvest index computation for three plants from each experimental unit used the formula grain yield / biological yield × 100.

Statistical analysis

After collecting and tabulating the data related to the study, these underwent statistical analysis according to the factorial experiment system applied by randomized complete block design using the GenStat15 program. The least significant difference ($LSD_{0.05}$) test helped compare and separate the means (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Pods per plant

The local cultivar excelled and gave the highest average of 16.82 pods $plant^{-1}$, while the Spanish cultivar gave an average of 13.81 pods $plant^{-1}$ (Table 2). The difference in the number of pods of a variety can result from natural evolution and adapting to the environment, with cultivars usually affected by factors, such as environment, nutrition, and genetics (Monreal *et al.,* 2011).

Fertilization treatments also significantly affected the number of plant pods, as the treatment with mycorrhizal fungi achieved the highest average of 17.84 pods plant^{-1} compared with the control treatment, which recorded the lowest average of 12.43 pods plant^{-1}. Some fungi types, including mycorrhizal, work to improve water and nutrient absorption from the soil, stimulating growth and development processes from increased food and nutrition availability (Mącik *et al.,* 2020). The interaction was significant, as the highest interaction surfaced when treated with the mycorrhizal fungi with the local variety, with an average of 19.17 pods plant^{-1}. Meanwhile, the Spanish variety and the control recorded the lowest rate of 11.10 pods plant^{-1} (Table 2).

Seeds per pod

The Spanish cultivar remarkably shone and gave the highest average of 6.11 seeds pod^{-1}, with the Turkish cultivar giving the lowest average of 4.82 seeds pod^{-1} (Table 3). The variation between bean cultivars may result from their adaptation to different environmental conditions. Some cultivars may produce large quantities of seeds as a reproductive strategy; others may focus on generating fewer seeds to direct their energy toward plant growth or to adapt to highly competitive environments (Mohammed *et al.,* 2020).

The results showed that treatment with biofertilizer notably increased the number of seeds, as the mycorrhizal fungi treatment achieved the foremost average of 6.98 seeds pod^{-1} compared with the control treatment that gave the lowest average of 3.81 seeds pod^{-1} (Table 3). It may be due to the joint role between root nodule bacteria of the bean plant and mycorrhizal fungi, which may contribute to expanding the root system and increasing the absorption of water and nutrients from the soil, enhancing plant growth and increasing its ability to produce seeds, especially mycorrhizal fungi, which increased the nutrient exchange between plants. Plant and soil improved plant nutrition and boosted seed production (Mahdi and Al-kurtany, 2020).

The interaction between the cultivars and biofertilizer also achieved substantial differences, as the Spanish variety treated with the mycorrhizal fungi achieved the maximum average of 7.80 seeds pod^{-1}. The Turkish variety with the control treatment achieved the minimum average of 3.10 seeds pod^{-1}.

Biological yield

Significant differences were evident between the cultivars under study in biological yield, as the local variety excelled by giving the highest average of 13,853.67 t ha^{-1}; the lowest average was in the Turkish cultivar variety at 11,842.72 t ha^{-1} (Table 4). The difference between bean cultivars in biological yield is mainly due to genetic diversity among these cultivars. Each type of bean may differ in adapting to the environment and conditions surrounding it and to the extent of its tolerance to drought or heat conditions, affecting the nature of the variety's growth and influencing the dry matter it produces (Hussain *et al.,* 2020).

The biological fertilization treatments relevantly influenced the biological yield, as the treatment with the mycorrhiza fungi excelled with an average of 14,495.79 t ha^{-1} compared with the control treatment, which reached 11,740.33 t ha^{-1} (Table 4). Biofertilization is vital in increasing the biological yield of bean plants. It provides the organic materials and nutrients necessary for proper plant growth. In addition, biofertilization helps improve the composition of the soil and increases its ability to retain water and nutrients, which contributes to enhancing plant growth and increasing production (Ibraheem, 2021).

The results of the same table also showed a significant interaction between the bean cultivars and biofertilization treatments, as the highest interaction emerged in the treatment with the mycorrhiza fungi on the local variety. It gave an average of 15,373.34 t ha^{-1}, while the lowest interaction was in the control treatment with the Spanish variety, with an average of 10,371.67 t ha^{-1}.

Table 3. Effect of cultivars, biofertilization, and their interactions on the seeds per pod in broad beans.

Cultivars	Biofertilizers			Means (seeds pod^{-1})
	Control	*Bacillus mucilaginosus*	Mycorrhiza Fungi	
Local cultivar	4.03	6.07	6.83	5.64
Turkish cultivar	3.10	5.07	6.30	4.82
Spanish cultivar	4.30	6.23	7.80	6.11
Means (seeds pod^{-1})	3.81	5.79	6.98	

$LSD_{0.05}$ Biofertilizer: 1.337, Cultivars: 1.337, Biofertilizer × Cultivars: 2.316

Table 4. Effect of cultivars, biofertilization, and their interactions on the biological yield in broad beans.

Cultivars	Biofertilizers			Means (kg ha^{-1})
	Control	*Bacillus mucilaginosus*	Mycorrhiza Fungi	
Local cultivar	12424.66	13763.01	15373.34	13853.67
Turkish cultivar	10776.12	11196.38	13555.68	11842.72
Spanish cultivar	10371.67	12867.13	14558.37	12599.05
Means (kg ha^{-1})	11740.33	12608.84	14495.79	

$LSD_{0.05}$ Biofertilizer: 54.743, Cultivars: 54.743, Biofertilizer × Cultivars: 94.817

Seed yield

A remarkable effect appeared on the seed yield of the cultivars under study, as the Spanish variety excelled by giving the highest average of 5,884.29 t ha^{-1}, while the Turkish cultivar variety had the lowest average of 5,284.32 t ha^{-1} (Table 5). In addition to factors like weather, soil quality, and texture, a cultivar's genetic ability to express itself in its cultivation environment can account for some variation in yield characteristics among cultivars. These results agreed with Hassoon *et al.* (2017) and Al-Selawy and Al-Farttoosi (2018).

Biofertilization treatments had a noteworthy effect on seed yield, as the treatment with the mycorrhiza fungi shone, with an average of 5,874.11 t ha^{-1} compared with the control treatment, reaching 5,296.13 t ha^{-1} (Table 5). It may be due to the superiority of the biological fertilization treatment (mycorrhiza fungi) in the number of pods and seeds per pod (Tables 2 and 3), which occurred in the superiority of the same treatment in the total seed yield. The efficiency of biofertilization in increasing the readiness of nutrients and their concentration in soil, as well as the role of mycorrhizae in improving metabolic processes and absorbing water and nutrients (nitrogen, phosphorus, potassium, calcium, sulfur, and iron) from the soil and transferring them to the plant through the roots, may account for the increase in yield and its components when adding biofertilizers. These results agreed with Utobo *et al.* (2011) and Hassoon *et al.* (2020).

The results from the same table also indicated a significant interaction between the cultivars and biofertilization treatments, as the optimum interaction appeared in the treatment with the mycorrhiza fungi with the Spanish variety, giving an average of 6,130.10 t ha^{-1}. The lowest interaction was in the control treatment with the Turkish variety, with an average of 5,023.34 t ha^{-1}.

Harvest index

The findings revealed notable differences in the harvest index for the cultivars under study (Table 6). The Turkish variety excelled with the highest average of 49.68%, while the local variety had the lowest average of 41.46%. Cultivars may differ in the ratio between fruit yield to dry matter yield, and this is due to the genetic nature of the variety and the extent of this variety's adaptation to the prevailing conditions (Alnuaimi *et al.,* 2019; Hussein *et al.,* 2024; Sarhan *et al*., 2024).

Table 5. Effect of cultivars, biofertilization, and their interactions on the total yield in broad beans.

Cultivars	Biofertilizers			Means (kg ha^{-1})
	Control	*Bacillus mucilaginosus*	Mycorrhiza Fungi	
Local cultivar	5308.31	5647.69	5940.33	5632.11
Turkish cultivar	5023.34	5277.57	5552.09	5284.32
Spanish cultivar	5556.69	5966.08	6130.10	5884.29
Means (kg ha^{-1})	5296.13	5630.44	5874.11	
$LSD_{0.05}$ Biofertilizer: 7.459, Cultivars: 7.459, Biofertilizer × Cultivars: 12.919				

Table *6*. Effect of cultivars, biofertilization, and their interactions on the harvest index in broad beans.

Cultivars	Biofertilizers			Means (%)
	Control	*Bacillus mucilaginosus*	Mycorrhiza Fungi	
Local cultivar	38.64	42.72	43.03	41.46
Turkish cultivar	45.22	51.56	53.28	49.68
Spanish cultivar	38.13	48.42	41.01	42.52
Means (%)	40.52	44.11	45.65	
$LSD_{0.05}$	Biofertilizer: 2.67, Cultivars: 2.67, Biofertilizer × Cultivars: 5.37			

The results showed that biological fertilization had a significant effect on the harvest index, as the treatment with the mycorrhiza fungi was superior, with an average of 45.65%, considerably different from the *Bacillus mucilaginosus* treatment, which amounted to 44.11% compared with the control treatment at 40.52% (Table 6). Probably, the high percentage of harvest index in biofertilization treatments is due to its broad role in the rate of nutrient processing, which contributed to increasing photosynthesis resources. Thus, it improved the performance of the biological processes that transfer materials stored in the stem and leaves and ultimately increased production from grains to biological yield (El-Gedwy, 2021).

As for the interaction, the results of the same table showed a meaningful interaction between the cultivars and the biofertilization treatments. The maximum interaction surfaced in the application with the mycorrhiza fungi with the Turkish variety at an average of 53.28%, while the lowest interaction was in the control treatment with the Spanish variety at an average of 38.13%.

CONCLUSIONS

In light of the results obtained, a conclusion can be that biological fertilization increased the productivity of the bean crop and its components, especially the treatment with mycorrhiza fungi. The cultivars also differed in their productivity, indicating their difference in their growth, adaptation, and their exploitation of available resources.

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