Journal of Soil Sciences and Agricultural Engineering

Journal homepage & Available online at: www.jssae.journals.ekb.eg

An Investigation of the Effect of Phosphate Dissolving Bacteria, *Arbuscular mycorrhizal* Fungi, Dry Yeast, and their Stimulating Effects on Faba Bean Plants and Plant Uptake of nutrients

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ABSTRACT

The optimization of crop productivity can be achieved by enhancing the bioavailability of phosphorus through the application of phosphate-solubilizing bacteria. So, a field experiment was undertaken to assess the impact of phosphate-solubilizing bacteria (specifically *Bacillus megaterium and Bacillus subtilis*) PSB and *Arbuscular Mycorrhizal Fungi* AMF on faba bean plants. Additionally, the study involved the foliar application of two concentrations of yeast extract as well as an examination of its effects on selected soil properties. The results revealed that the concurrent application of AMF and yeast at a rate of 10 g/L exhibited the most substantial enhancement in certain aspects of vegetative growth, including shoot height, root length, the number of branches per plant, as well as fresh and dry weight. Notably, this combined application also resulted in the most significant improvements in yield parameters such as pods per plant, pods weight per plant, 100-seed weight, seeds per pod, pod length, and overall seed yield. Moreover, the application of AMF and PSB contributed to the heightened activity of specific soil enzymes, namely dehydrogenase and phosphatase. This increase was notably close to reaching significance when compared to the control treatment. Consequently, it is advisable to consider the synergistic use of AMF, PSB, and yeast extract as an integrated and sustainable approach for enhancing crop performance. This recommendation holds particular relevance in regions where phosphorus availability is limited, presenting potential advantages for agricultural practices geared towards achieving higher yields and bolstering soil health.

***Keywords*:** Mycorrhiza, yeast, faba bean

INTRODUCTION

One of the most significant legume crops is the faba bean, also known as *Vicia faba L.* While its dry seeds are a highly nutritious source of protein, particularly lysine, its green pods are consumed fresh. By absorbing atmospheric nitrogen and fixing it in symbiosis with Rhizobium leguminosarum, the faba bean also plays a significant and ecological role in increasing the amount of nitrogen that is available in the biosphere (Mohamed, 2015). Due to the insufficiency of domestic production, Egypt is one of the main importers of faba beans (Fernández et al. 2007). Because of its high protein content (25–30%) and high carbohydrate content (55–60%), faba bean is frequently grown as grain crop for consumption by people and domestic animals (Hao *et al* 2002). Additionally the entire plant can be used for feeding farm animals. The most crucial nutrient for growth and development, phosphorus plays a key role in the development of roots, shoots, flowers, and seeds as well as in crop maturity and yield, the fixation of nitrogen in legumes, and the production of plant diseases (Mohamed, 2015). One of the most important elements limiting plant growth is phosphorus P, on the other hand it is essential for plant growth and development and stimulates N2 fixation, and Photosynthesis, energy transmission, signal transduction, macromolecular biosynthesis, and respiration are all aided by it (Fernández et al. 2007). Phosphorus is already present in most soils but is unavailable to plants because it is extremely sensitive to the presence of Ca^{+2} and Mg^{+2} in alkaline soils and aluminum $Al^{+3}$and iron Fe^{+3} in acidic soils (Hao et al. 2002). As a bio-fertilizer, bacteria that solubilize phosphorus were being used. They are essential in increasing the amount of phosphorus (P) that is available to plants in the soil by mineralizing organic P and resolving precipitated P. PSB secrete protons, organic and mineral acids, phenolic compounds, and protons into the soil (Adnan et al. 2019).

Bio-fertilizer was made from phosphorus-solubilizing microorganisms. Through mineralizing organic P and solubilizing precipitated P, they serve a critical role in increasing P availability in the soil to plants. PSB release phenolic chemicals, protons, organic and mineral acids, which acidify the soil (Adnan et al. 2019).

Arbuscular Mycorrhiza Fungi (AMF) and yeast have recently attracted a lot of interest as potential bio control agents for fostering plant growth and inducing plant resistance to specific soil-borne pathogenic fungi. (Adnan et al. 2019).

Arbuscular mycorrhizal fungi (AMF) are common in nature and play an important role in the agro-ecosystem. They are stable, develop mutually advantageous plant-fungus partnerships in which the fungus is partially inside and partially outside the host, and provide a living link between the root and the soil[Prasad,(2017).. Bio stimulants, such as amino acids and yeast extract, have been proven to have a positive influence on plant development, overcoming the negative effects of environmental stress such as drought.

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DOI: 10.21608/jssae.2023.249010.1199

Many growth components (thiamine, riboflavin, niacin, pyridoxine, and vitamins B1, B2, B3, and B12)

As a natural source of cytokinins which promote cell division and enlargement as well as the synthesis of protein and nucleic acid, active dry yeast is regarded as a safe biofertilizer. By fixing nitrogen in the soil, encouraging root elongation, releasing acids that dissolve insoluble minerals, and increasing the availability of phosphorus and other nutrients in the soil, bacteria can have a positive impact on plants (Adnan et al. 2019). Yeast extract is a naturally occurring source of many growth factors, including cytokinins, many nutrient elements, protein, carbohydrates, nucleic acids, and lipids. It also contains thiamine, riboflavin, niacin, pyridoxine, and vitamins B1, B2, B3, and B12 Abd El-Hai et al. (2019). The use of active dry yeast as a foliar treatment increased plant growth, yield, and chemical components Mahmood and Ahmad (2005)

The purpose of this study to evaluate the effect of phosphate dissolving bacteria Arbuscular Mycorrhiza fungi, and yeast extract on faba bean growth, chemical constituents, uptake of nutrients and productivity.

MATERIALS AND METHODS

A two-seasonal experiment was carried out during the successive winter growing seasons of 2020–2021 and 2021–2022 in Shoha Village, Dakahlia Governorate, Egypt (Latitude 31o 07'; Longitude 31o 45'). The experimental design employed a split-plot structure, encompassing nine treatments. The main plots included a control group, phosphate-solubilizing bacteria, and Arbuscular Mycorrhizal fungi. Subsequently, the sub-plots were dedicated to the foliar application of yeast, with concentrations of 0g/l, 5g/l, and 10g/l. Each treatment was replicated three times, and the dimensions of each plot were 3 × 3.5 meters. Before the commencement of cultivation, soil samples were extracted from the experimental site at a depth of 0-30 cm and subjected to comprehensive analysis. The pH value in the soil paste was determined using a Gallenkamp pH meter (A. Gallenkamp Co. & Ltd., UK), while the electrical conductivity (EC) in a 1:2.5 soil-to-water extract was measured following the procedures outlined by Ryan et al. (2001). Mechanical analysis was conducted using the international pipette method with NaOH as a depressant, in accordance with Wirth (1946). The levels of available nitrogen (N), phosphorus (P), and potassium (K) were determined based on the methods described by Ryan et al. (2001). The organic matter content was assessed using the Walkley and Black chromic acid wet oxidation method as per Hesse (1971). Micronutrients present in the soil samples were extracted using a diethylene triamine pentaacetic acid (DTPA) solution, and their concentrations were measured using a spectrophotometer for atomic absorption, following the procedures outlined by Lindsay and Norvell (1978). The saturation percentage (SP%) was determined using the method reported by Aali et al. (2009). All these analyses were conducted considering standard agricultural practices. The chemical and physical properties of the experimental soil are detailed in Table 1.

Table 1. Physical and chemical properties of experimental soil

Physical properties								
Soil Type	**Fine sand %**	**Coarse sand %**	**Silt %**	**Clay %**	**EC (ds/m)**	**HW %**	**Field capacity %**	**S.P**
Clay loam	20.27	2.42	39.85	37.46	2.36	6.61	35.4	57.44
Chemical properties								
pH Soil paste	Organic matter (O.M %)	Available nutrients (ppm)			The texure class id clay loam			
		N	P	K				
8.12	0.94	41.23	8.46	212.35				

EC: Electric conductivity; HW: Hygroscopic water; S.P: Saturation percentage

Source of seeds and yeast extract:

The Microbial Dept., Soils, Water and Environ. Res. Instit., Agricultural Research Centre kindly provided the cell suspension of *Bacillus megatherium var. Phosphaticum*, which was used to soak faba bean seeds variety Giza716 for 30 minutes before planting. The seeds were then air dried, rinsed with water, and air dried again. This cell suspension contains 108 colony farming units (CFU). The Legume Research Department of the Field Crop Institute of the Agricultural Research Centre provided the specific Rhizobium strain that was used to inoculate faba bean seeds at a rate of 10 g per 1.0 kg of seeds for all treatments.

After being prepared, combined with sterilized peatmoss as a carrier, and used as a seed coating for surface sterilized faba bean seeds, mixed spores of AM-fungi supplied by the Microbiol. Dept., Soils, Water and Environ. Res. Instit., Agricultural Research Centre. Before planting, the seeds had the inoculants evenly coated with a sticker like Arabic gum and allowed to air dry for two hours. Yeast extract was produced using brewer's dry yeast (Saccharomyces cerevisiae), which had been dissolved in water. The yeast cells were subjected to two cycles of freezing and thawing to disrupt them after 24 hours of warm reproduction with the addition of sugar at a 1:1 ratio, and their bio-constituents were released right away before use El–Shaboury and Abd Elrahman (2021)

A random sample of three plants from each replicate was picked at the blooming stage, 65 days after sowing, to estimate the following attributes. Yeast extract, a growth promoter was purchased as a powder from El-Gomhourria Company. Three concentrations 0,5, and 10 g/L, were applied as sprays.

Yeast culture preparation:

Preparation of a yeast culture According to Jacobs and Gerstein (1960), ten grams of fresh packed commercial active dry yeast (ADY) formula were inoculated in 1000 ml of nutrient broth (3g beef extract, 5g bactopeptone (Difco) 1000 ml distilled water, pH 7.2) and incubated at 250C with shaking at 200 rpm for 72 hours. Before use, the pure yeast cells were centrifuged at 3000 rpm for 15 minutes, washed twice with 0.05 M phosphate buffer at pH 7.0, and suspended in 1000 ml distilled water. The concentration of pure yeast cells in the suspension was determined to be 4.5X108cells/ml by direct counting. This yeast concentration was confirmed to be Saccharomyces cerevisiae and was considered to be 100 percent stock cell suspension.

Harvest

It was done in 25th April.

Vegetative and chemical measurements

A random sample of three plants from each replicate was picked at the blooming stage, 65 days after sowing, to estimate the following attributes.

-Vegetative growth criteria: including Shoot height (cm), Root length (cm), Number of branches / plant, fresh and dry weight of plant (g) /plant.

-Chemical components: At the age of flowering, the amounts of chlorophyll a, b, and total carotenoids were quantitatively measured in fresh foliage leaves of treated and untreated plants. A dimethyl formamide (DMF) solution was used to extract the pigments from 0.5 g of young, fresh leaves overnight at 4 C. This allowed researchers to determine the mass of chlorophyll a, chlorophyll b, total chlorophyll, and carotenoids per leaf. The pigments at wavelengths of 663, 470, and 647 nm were identified using Moran's equation and a spectrophotometer, the Beckman Du 7400 Lichtenthaler, (1987)

-Yield characters

-Seeds measurements: Number of matured dry pods / plant, Pods weight (g/plant), Weight of100seeds (g), Number of seeds/pod, Pod length (m) and Seed yield (ton/fed).

-Seeds chemical constituents: Faba bean plant was oven dried at 70 °C till constant weight, grained and 0.2 g from each sample was then wet digested Wirth,(1946).

According to the Micro-Kjeldahl method, total nitrogen and crude protein were determined AOAC, (1995). To determine the crude protein, the nitrogen content of the seeds was multiplied by a 6.25 factor Jackson, (2005). An Abbe refractmeter was used to calculate percentages of total soluble solids (T.S.S %) Sparks et al. (2020). According to the reported method, the percentage of total carbohydrates was calculated Gul and Safdar, (2009). A molybdo-phosphoric blue color technique with stannous chloride reduction was used to visualize phosphorus Jackson, (2005). for potassium using flame photometer Jackson, (2005). Soil measurements: Soil samples (0–30 cm depth) from each plot were collected after the faba bean plants were harvested in order to assess the effects of the researched treatments.

- Soil available nutrients: available nutrients content (N, P, K) were analyzed in soil samples after harvest according to Buurman et al. (1996).

- Soil Enzymes Activity: Dehydrogenase activity was measured using a UV-160A spectrophotometer after soil was incubated with INT (2-(p-iodophenyl)-3-(p-nitrophenyl)-5-phenyl tetrazolium chloride solution) for 2 hours at 40 degrees Celsius. The reduced INTF (iodonitro -tetrazolium formazan) was then extracted from the soil with ethanol (Shimadzu, Japan) Kaiser, (1996)

-Statistical analysis: Appropriate analysis of variance was performed using COSTATEV 6.4(2005) for Windows. The Least Significant Differences test at the 0.05 level of probability was used to compare the differences among the means of the various treatment combinations as illustrated by a computer software program based on significant differences among the mean of various treatments as determined by the Least Significant (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Results

Vegetative growth parameters:

Shoot height, Root length, N. of branches /plant, fresh and dry weight

Mycorrhiza, Bacillus megaterium, Bacillus subtilis, and yeast significantly increase shoot height, root length, the number of branches per plant, as well as their fresh and dry weight during the2020/2021and 2021/2022 growing seasons (Figure1). For two seasons, every mycorrhizal application outperformed the control in terms of phosphate-dissolving bacteria (Bacillus megaterium, Bacillus subtilis), shoot height, root length, fresh and dry weight, and microbial weight (table 1). The number of branches per plant was equally influenced by Bacillus megaterium, Bacillus subtilis, and Mycorrhiza. Individual yeast applications at 10g/L have a greater inductive effect than those at 5g/L on shoot length, root length, number of branches/plant, fresh and dry weight, as well as over the control. The highest increase in shoot height and root length was seen when Mycorrhiza and yeast were combined (10g/plant), followed by Mycorrhiza and 5g/L yeast. The addition of Mycorrhiza mixed with 5g/L and (*B. subtilis* +*B. megaterium*) +10g/L, as well as Bacillus megaterium and Bacillus subtilis and yeast, produced the greatest increases in shoot and root length of faba bean plants, as shown in Table 2. With the interaction of Mycorrhiza + yeast 10g/L in the same table, the number of branches / plant recorded highest values, and the same was discovered in fresh and dry weight.

Table 2. Average shoot length (cm), root length, number of branches/plant, fresh and dry weight (g/plant) and their interaction as influenced by Mycorrhiza, *Bacillus subtilis, Bacillus megaterium,* and yeast and their interaction during two seasons.

		After 60 days				
Treatments		**Shoot height cm**	**Root length cm**	**No. of branches plant^{-1}**	**Fresh weight g plant^{-1}**	**Dry weight g plant^{-1}**
			Main			
Control		77.30c	13.91c	3.73c	92.28c	12.92c
Mycorrhiza		92.42a	15.51a	4.62a	111.31a	16.64a
Bacteria		87.32b	15.01b	4.36a	104.57b	15.38b
LSD at 5%		1.99	0.18	0.30	1.74	0.28
			Sub			
0		80.81c	14.28c	3.95c	96.76c	13.86c
Yeast 5 g/L		86.71b	14.93b	4.28b	103.68b	15.12b
Yeast 10 g/L		89.52a	15.23a	4.47a	107.72a	15.96a
LSD at 5%		1.29	0.16	0.18	1.40	0.17
			Interaction			
	0	74.78h	13.43f	3.53g	89.21i	12.33i
C	Yeast 5 g/L	77.93g	14.00e	3.75fg	92.52h	12.87h
	Yeast 10 g/L	79.20g	14.29d	3.90ef	95.11g	13.57g
	0	85.65e	14.91c	4.21d	102.84e	15.02e
M	Yeast 5 g/L	94.06b	15.65b	4.72ab	112.95b	16.97b
	Yeast 10 g/L	97.55a	15.98a	4.93a	118.14a	17.93a
	0	82.00f	14.49d	4.10de	98.23f	14.24f
B	Yeast 5 g/L	88.13d	15.13c	4.38cd	105.57d	15.52d
	Yeast 10 g/L	91.82c	15.42b	4.59bc	109.90c	16.39c
LSD at 5%		2.23	0.28	0.31	2.44	0.30

Chemical component

Chlorophyll a, chlorophyll b, and carotene content:

The indicator of chlorophyll content of faba bean leaves was significant higher when plants were treated with Mycorrhiza during the 2020/2021and 2021/2022 seasons as opposed to Bacillus subtitles and Bacillus megaterium (Table3). There were noticeable increases in the amount of chlorophyll a, chlorophyll b, and carotene when faba bean plants received a mixture of Mycorrhiza and yeast 10g/L over the course of two growing seasons (Fig 1, 2 and Fig3).

Table 3. Average chlorophyll a chlorophyll b, Carotene, carbohydrates% and T.S.S% as influenced by Mycorrhiza, *Bacillus subtilis*, *Bacillus megaterium*, and yeast during two seasons.

Treatments	Leaves after 60 days			Seeds at harvest	
	Chlorophyll a mg.g^{-1}	Chlorophyll b mg.g^{-1}	Carotene mg.g^{-1}	Carbohydrates %	TSS %
Control	0.902c	0.612c	0.195c	52.77c	3.03c
Mycorrhiza	1.047a	0.711a	0.232a	53.65a	3.53a
Bacteria	1.003b	0.683b	0.220b	53.38b	3.38b
LSD at 5%	0.010	0.003	0.006	0.06	0.01
0	0.934c	0.639c	0.204c	53.01b	3.16b
Yeast 5 g/L	0.996b	0.675b	0.217b	53.31a	3.34a
Yeast 10 g/L	1.022a	0.692a	0.225a	53.48a	3.43a
LSD at 5%	0.017	0.011	0.005	0.25	0.10

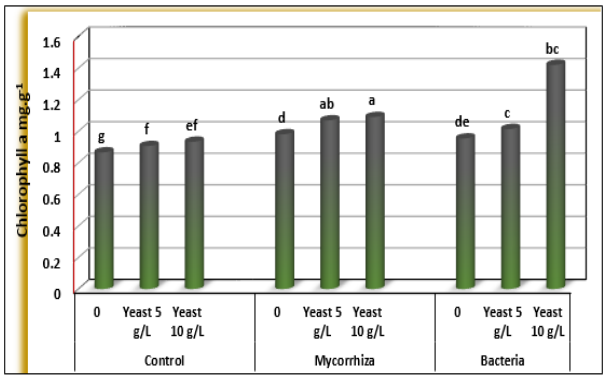

Fig. 1. Interaction effect of Mycorrhiza, bacteria (*Bacillus megaterium, Bacillus subtilis*) and yeast during the 2020/ 2021and 2021/ 2022 seasons on chlorophyll a content in faba bean leaves.

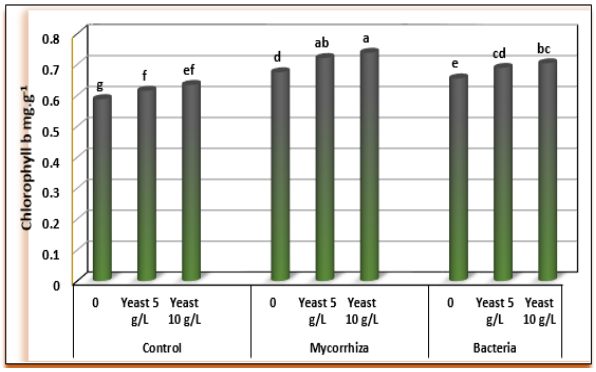

Fig. 2. Interaction effect of Mycorrhiza, bacteria (*Bacillus megaterium, Bacillus subtilis*) and yeast during the 2020/2021 and 2021/2022 seasons on chlorophyll b content in faba bean leaves.

Significant increases in chlorophyll a and chlorophyll b content were observed when faba bean plants were treated with Mycorrhiza, bacteria (Bacillus megaterium, Bacillus subtilis), and yeast individually or in combination during the 2021-2022 and 2022-203 growing seasons (Table3, Figures 1&2). Individual application of Mycorrhiza had a greater inductive effect on the increase of chlorophyll a &b content when compared to Bacillus megaterium and Bacillus subtilis (Table 3). The faba bean plants treated with 10g/L of Mycorrhiza and yeast for both years had the highest chlorophyll a& b content (Figures 1&2). The following results are for yeast5g/L and Mycorrhiza (Figures 3&4). During two seasons, faba bean plants treated with Mycorrhiza, bacteria (*Bacillus megaterium, Bacillus subtilis*), and yeast either separately or together experienced a significant rise in their carotene content (Table3, and Fig3). As can be seen in table 5, the results showed that plants treated with Mycorrhiza had the highest content of carotene compared to plants treated with (*Bacillus megaterium, Bacillus subtilis*). Compared to control plants, plants treated with a 10g/L mycorrhizal yeast application had the highest levels of carotene, according to the results in (Fig. 3).

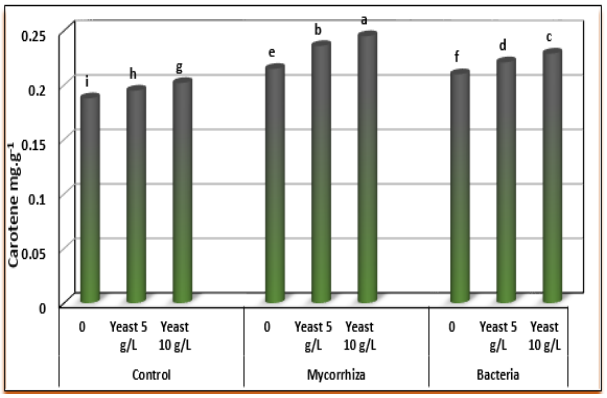

Fig. 3. Interaction effect of Mycorrhiza, bacteria (*Bacillus megaterium, Bacillus subtilis*) and yeast during the 2020/2021and 2021/2022 seasons on carotene content in faba bean plant.

Carbohydrates%:

Total carbohydrate concentrations in the leaves of faba bean plants were significantly influenced by the addition of Mycorrhiza, bacteria, and yeast to the plants during the seasons. 2020/2021and 2021/2022 (Table 3and Figure4) The addition of Mycorrhiza resulted in the greatest significant increase in total carbohydrate, followed by mixed bacteria (*Bacillus megaterium, Bacillus subtilis*). The addition of 10g/L yeast ranks higher than the addition of 5g/L yeast. The interaction among all studied applications as shown in fig6 illustrated that the highest effect was by adding Mycorrhiza +yeast10g/L as compare with control.

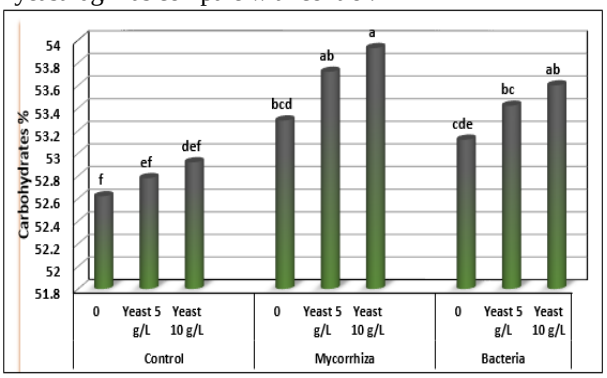

Fig. 4. Interaction effect of Mycorrhiza, bacteria (*Bacillus megaterium, Bacillus subtilis*) and yeast during the 2020/2021 and 2021/2022 seasons on carbohydrates% in faba bean plant.

Total soluble solids (T.S.S):

During the 2020/2021and 2021/2022 growing seasons, treatment of faba bean plants with ,Mycorrhiza, bacteria (Bacillus megaterium, Bacillus subtilis), and yeast alone or in combination resulted in noticeably higher T.S.S content (Table 3 and Figure 5).When compared to *Bacillus*

megaterium and Bacillus subtilis, the application of Mycorrhiza had a greater inductive effect on the increase of T.S.S content (table5).T.S.S. increased equally with yeast additions of 10g/L and 5g/L. Mycorrhiza mixed with yeast at 10 g/L or 5 g/L had the same interaction effect, increasing T.S.S (Fig. 5).

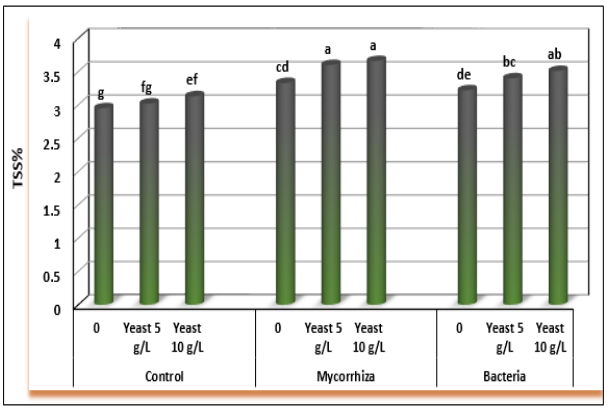

Fig. 5. Interaction effect of Mycorrhiza, bacteria (*Bacillus megaterium, Bacillus subtilis*) and yeast during the2020/2021and 2021/2022 seasons on TSS% in faba bean plant.

Yield and Yield-Related Traits:

Pods number/plant, Pods weight g/plant, 100seed weight (g), seeds number/pod, Pod length (cm) and seed yield ton/fed.

The number of pods plant-1, pods weight g/plant, 100-seed weight (g), number of seeds pod^{-1}, pod length (cm), and seed yield (ton fed^{-1}) were significantly maximized when plants were treated with Mycorrhiza, *Bacillus subtilis*, *Bacillus megaterium*, and yeast and their interaction during two seasons, 2020/2021and 2021/2022 (Table 4). The number of pods per plant, pod weight per plant, 100 seed weight per pod, number of seeds per pod, pod length per pod, and seed yield significantly increased when faba bean plants were treated with individual applications of Mycorrhiza, followed by Bacillus subtilis, Bacillus megaterium, and the dual application of Mycorrhiza mixed with yeast at 10 g/L. (t fed-1).

Table 4. Average number of pods plant^{-1}, pods weight g /plant, 100-seed weight (g), number of seeds pod^{-1}, pod length(cm), and seed yield (t fed^{-1}) as influenced by Mycorrhiza, *Bacillus subtilis*, *Bacillus megaterium*, and yeast and their interaction during two seasons.

Treatments		Yield					
		Pods No. plant^{-1}	Pods Weight (g plant^{-1})	100 seed weight (g)	Seeds No. pod^{-1}	Pod length cm	Seed Yield (ton fed^{-1})
Main							
Control		17.62c	158.57c	80.41c	3.62c	9.80c	1.360c
Mycorrhiza		22.10a	209.83a	83.82a	4.14a	11.62a	1.578a
Bacteria		20.67b	193.70b	82.60b	3.98b	10.86b	1.515b
LSD at 5%		0.29	5.18	0.41	0.09	0.12	0.017
Sub							
0		18.73c	171.30c	81.22c	3.74c	10.18c	1.418c
Yeast 5 g/L		20.40b	190.83b	82.39b	3.94b	10.87b	1.494b
Yeast 10 g/L		21.26a	199.97a	83.22a	4.06a	11.23a	1.541a
LSD at 5%		0.39	3.85	0.26	0.04	0.13	0.015
Interaction							
	0	16.65h	148.10i	79.74h	3.48i	9.42g	1.320h
C	Yeast 5 g/L	17.75g	159.70h	80.45g	3.63h	9.86f	1.362g
	Yeast 10 g/L	18.46f	167.90g	81.03f	3.74g	10.11e	1.398f
	0	20.05e	186.40e	82.15e	3.91e	10.82d	1.491d
M	Yeast 5 g/L	22.58b	216.70b	84.00b	4.20b	11.84b	1.598b
	Yeast 10 g/L	23.68a	226.40a	85.31a	4.32a	12.19a	1.645a
	0	19.50e	179.40f	81.76e	3.83f	10.30e	1.442e
B	Yeast 5 g/L	20.86d	196.10d	82.71d	4.00d	10.91d	1.523c
	Yeast 10 g/L	21.65c	205.60c	83.32c	4.11c	11.38c	1.580b
LSD at 5%		0.68	6.68	0.44	0.07	0.23	0.027

Chemical contents and physiological processes:

a. Nitrogen, phosphorus and, potassium %:

During the 2020/2021and 2021/2022growing seasons, plants treated with Mycorrhiza, Bacillus subtilis, Bacillus megaterium, and yeast had higher concentrations of nitrogen (N) and phosphorus and potassium (P and K) ions than controls did (Table 5). The number of leaves and seeds on faba bean plants treated with Mycorrhiza, *Bacillus subtilis*, *Bacillus megaterium*, and yeast increased significantly in the2020/2021and 2021/2022 seasons. The application of Mycorrhiza led to the highest increases in nitrogen, phosphorus, and potassium compared to *Bacillus subtilis* or *Bacillus megaterium*. According to Table 5, the highest increase in N, P, and K was produced by the interaction of Mycorrhiza and yeast (10g/L). This was followed by a mixture of Mycorrhiza and yeast (5g/L).

Table 5. Average Nitrogen, phosphorus, potassium and protein% as influenced by Mycorrhiza, *Bacillus subtilis*, *Bacillus megaterium*, and yeast and their interaction during two seasons.

Treatments		Leaves			Seeds			Protein % in seeds
		N %	P %	K %	N %	P %	K %	
Main								
Control		3.72b	0.390c	2.63c	3.39b	0.369c	2.53c	21.19b
Mycorrhiza		4.08a	0.461a	3.10a	3.76a	0.425a	2.93a	23.49a
Bacteria		3.97a	0.445b	2.95b	3.66a	0.410b	2.83b	22.86a
LSD at 5%		0.17	0.004	0.14	0.15	0.003	0.07	0.92
Sub								
0		3.81c	0.416c	2.74c	3.49c	0.381c	2.64b	21.83c
Yeast 5 g/L		3.94b	0.433b	2.93b	3.62b	0.406b	2.80a	22.61b
Yeast 10 g/L		4.02a	0.447a	3.03a	3.70a	0.416a	2.86a	23.10a
LSD at 5%		0.07	0.007	0.09	0.06	0.004	0.07	0.41
Interaction								
	0	3.66g	0.377g	2.47g	3.32g	0.351i	2.37g	20.77g
C	Yeast 5 g/L	3.71g	0.384g	2.67f	3.37fg	0.373h	2.58f	21.06fg
	Yeast 10 g/L	3.78fg	0.409f	2.76ef	3.48ef	0.382g	2.66ef	21.75ef
	0	3.91de	0.441de	2.90de	3.61cd	0.401e	2.80cd	22.58cd
M	Yeast 5 g/L	4.12ab	0.466ab	3.17ab	3.80ab	0.432b	2.97ab	23.73ab
	Yeast 10 g/L	4.20a	0.476a	3.25a	3.86a	0.443a	3.02a	24.15a
	0	3.85ef	0.430e	2.84de	3.54de	0.393f	2.75de	22.13de
B	Yeast 5 g/L	4.00cd	0.449cd	2.96cd	3.69bc	0.413d	2.86bcd	23.04bc
	Yeast 10 g/L	4.07bc	0.457bc	3.07bc	3.75b	0.423c	2.90abc	23.42b
LSD at 5%		0.12	0.012	0.15	0.11	0.004	0.12	0.71

b. Protein content %:

The typical protein content of faba bean seeds was also determined in Table 5. In terms of seed protein percentage, Mycorrhiza and mixed bacteria (Bacillus subtilis, Bacillus megaterium) are at the top of the list of treatments. Protein ranking was highest for yeast (10g/L) when compared to yeast (5g/L). The interaction effect of all treatments is shown in the same table, with Mycorrhiza mixed with yeast 10g/L showing the highest increase in protein% when compared to control. This came after Mycorrhiza mixed with 5g/L of yeast**.**

Soil Quality Indicators:

a. Soil Enzyme Activity Dehydrogenase and phosphatase enzyme activity

Dehydrogenase and phosphatase enzyme activity in the soil was significantly increased when faba bean plants were treated with Mycorrhiza, bacteria (Bacillus megaterium, Bacillus subtilis), and yeast during the 2020/2021 and 2021/2022seasons (Table 6, Figs 6 and 7). Applying Mycorrhiza alone or in combination with yeast during both seasons significantly increased the soil's dehydrogenase and phosphatase enzyme activity. Application of individual Mycorrhiza had a greater effect on increasing soil dehydrogenase and phosphatase enzyme activity under either yeast at 5 g/L or 10 g/L than application of Bacillus. When yeast was added at a rate of 5g/L rather than 10g/L, the increase in dehydrogenase activity was greater. The interaction of Mycorrhiza + yeast at 5 g/L led to the greatest increase in dehydrogenase activity, which was then followed by the interaction between Mycorrhiza and yeast at a concentration of 5 g/L resulted in the greatest increase in the activity of the phosphatase enzyme(fig1).

Table 6. The effect of Mycorrhiza, bacteria (*Bacillus megaterium, Bacillus subtilis*) and yeast during the 2020/2021and 2021/2022 seasons on dehydrogenase and phosphatase enzyme activity in the soil.

Treatments	Dehydrogenase (mg/g soil/24h)	Phosphatase (µ inorganic phosphorus/g dry soil/day)
	Main	
Control	50.80b	6.70b
Mycorrhiza	58.77a	7.78a
Bacteria	56.02b	7.66a
LSD at 5%	0.78	0.15
	Sub	
0	55.91c	7.55a
Yeast 5 g/L	63.38a	7.57a
Yeast 10 g/L	46.29b	7.01b
LSD at 5%	0.95	0.18

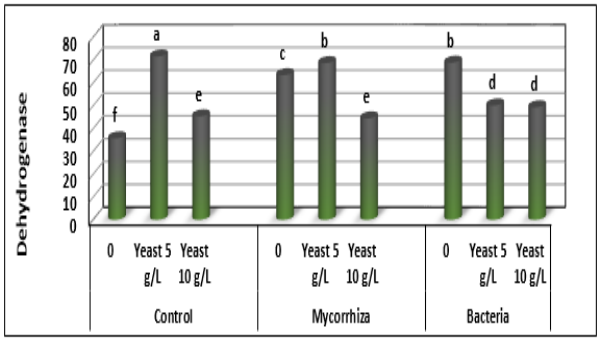

Fig. 6. Interaction effect of Mycorrhiza, bacteria (*Bacillus megaterium, Bacillus subtilis*) and yeast during the 2020/ 2021 and 2021/ 2022 seasons on dehydrogenase and phosphatase enzyme activity in the soil.

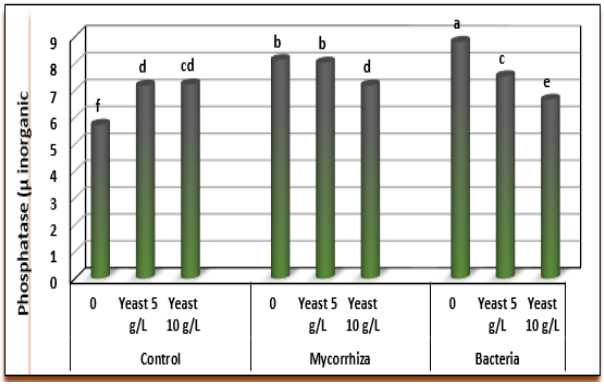

Fig. 7. Interaction effect of Mycorrhiza, bacteria (*Bacillus megaterium, Bacillus subtilis*) and yeast during the 2020/ 2021 and 2021/ 2022 seasons on dehydrogenase and phosphatase enzyme activity in the soil.

b. Soil available nutrients

The data presented in Table 7 illustrate the impact of Mycorrhiza, bacteria (*Bacillus megaterium, Bacillus subtilis*), and yeast during the 2020/2021 and 2021/2022 seasons on the availability of nutrients in the studied soil. A noticeable observation is that the application of Mycorrhiza and bacteria (*Bacillus megaterium, Bacillus subtilis*) resulted in an increase in the values of available nitrogen (N) and potassium (K) compared to the control treatment, which exhibited the highest values. Conversely, the highest values of available phosphorus (P) were recorded with the *Mycorrhiza* treatment. Regarding yeast treatments, the trend appears to be unclear, and the impact on the availability of nutrients is not distinctly discernible from the data in Table 7.

Table 7. The effect of Mycorrhiza, bacteria (*Bacillus megaterium, Bacillus subtilis*) and yeast during the 2020/2021and 2021/2022 seasons on soil available nutrients in the studied soil.

Treatments		N mg.kg^{-1}	P mg.kg^{-1}	K mg.kg^{-1}
		Main		
Control		55.40a	11.28b	251.59a
Mycorrhiza		53.07c	14.25a	238.36b
Bacteria		54.22b	13.81a	246.43c
LSD at 5%		0.58	1.12	1.26
		Sub		
0		54.54a	13.29a	247.57a
Yeast 5 g/L		54.26ab	13.15ab	245.64b
Yeast 10 g/L		53.89a	12.89b	243.17c
LSD at 5%		0.47	0.34	0.82
		Interaction		
	0	55.62a	11.53c	253.39a
C	Yeast 5 g/L	55.40a	11.41cd	251.53b
	Yeast 10 g/L	55.17ab	10.89d	249.86c
	0	53.56de	14.39a	240.94g
M	Yeast 5 g/L	53.17ef	14.24ab	238.99h
	Yeast 10 g/L	52.49f	14.11ab	235.15i
	0	54.43bc	13.94ab	248.39d
B	Yeast 5 g/L	54.22cd	13.81ab	246.41e
	Yeast 10 g/L	54.02cd	13.67b	244.49f
LSD at 5%		0.81	0.59	1.42

Discussion

Yeast play a positive role during vegetative and reproductive growth by enhancing flower formation and their set in some plants due to its high auxin and cytokinin content and enhancement of carbohydrates accumulation. Due to its high auxin and cytokinin content and promotion of carbohydrates accumulation, yeast extract has been proposed

to play a beneficial role during vegetative and reproductive growths by enhancing flower formation and their set in some plants Dawood et al. (2019). Active dry yeast is a safe biofertilizer; it is a natural source of cytokinin, which drive cell division and expansion, as well as protein and nucleic acid production. Bacteria can benefit plants through a variety of ways, including soil fertility, nitrogen fixation, root elongation, the generation of acids to dissolve insoluble minerals, and improving the availability of phosphorus and other nutrients in soil Mady,(2009) Yeast accelerated the production of chlorophyll, postponed its deterioration, and prevented the senescence of bean plants. Regarding the interaction of moisture stress and bio stimulants, it can be seen that the use of amino acids or yeast extract significantly increased photosynthetic pigments while attenuating the negative effects of drought stress Wanas,(2002) In this regard.Imara et al. (2018) demonstrated that the application of yeast significantly increased the concentration of carotenoids and chlorophyll in faba bean plants grown with the least amount of water. Additionally Phosphate solubility in soils is increased by Mycorrhiza, which also improves legume nitrogen fixation(Imara et al.(2018). Similarly, inoculating faba bean seeds with Mycorrhiza or yeast improves their growth and yield by increasing nutrient uptake and producing growth promoting compounds, as well as providing plant protection against a variety of diseases and parasitic weeds Elnahal et al. (2022).When compared to untreated control plants, AMF-treated plants showed significant increases in nutritional content, phenolic, and chlorophyll content Komeil and Badry, (2021). AMF can have a significant impact on plant nutrition, soil biological activity, and nutrient availability of plants in both natural and agricultural environment Ingraffia et al. (2019)and Elnahal et al. (2022)].The additive effect of yeast extract could be attributed to its influence on metabolism as well as its stimulating effect on photosynthetic pigments and enzyme activity, which in turn increased vegetative growth of Faba bean. Yeast extract had the highest total sugar content and a beneficial effect on carbohydrate accumulation in Faba bean leaves Hammad and Ali(2014).The increase in protein percentage and free amino acid could be attributed to yeast-produced growth hormones or to the fact that yeast treatment stimulates protein synthesis Agamy, et al. (2013). As a natural supply of cytokinin, yeast stimulates cell division and expansion, as well as protein and nucleic acid production Abbas,(2013)These organisms also help plants grow by improving nutrient intake and producing phytohormones, as well as converting insoluble phosphorous into soluble phosphorous, increasing phosphorous availability to plants Itelima et al. (2018). Because of its high auxin and cytokinin content, as well as the promotion of carbohydrates accumulation, yeast extract has been reported to have a favorable role during vegetative and reproductive growths by increasing flower development and set in some plants Mahmoud et al. (2016). Abbas et al. (2013) mentioned that the incremental effect of yeast extract may be attributed to the influence on photosynthetic pigments, phytohormones, and enzyme activity, which in turn increased faba bean plant vegetative growth.

CONCLUSION

In conclusion, the combined application of Mycorrhiza and yeast extract, particularly at a concentration of 10 g/L, significantly improved the vegetative growth and yield parameters of faba bean plants, enhancing their productivity. Furthermore, the application of Mycorrhiza and phosphate-solubilizing bacteria demonstrated a positive impact on soil enzyme activity, specifically dehydrogenase and phosphatase, leading to the restoration of soil quality and the increased availability of phosphorus. As such, it is recommended that the integrated use of Mycorrhiza, phosphate-solubilizing bacteria, and yeast extract be considered as a sustainable approach for enhancing crop performance, especially in regions where phosphorus availability is limiting, offering potential benefits for agricultural practices aimed at achieving higher yields and improving soil health.

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دراسة تأثير البكتيريا المذيبة للفوسفات و الميكروهايزا والخميرة الجافة وتأثيراتها المحفزة على نباتات الفول البلدي وامتصاص النبات للعناصر الغذائية

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الملخص

يمكن تحسين إنتاجية المحاصيل من خلال تعزيز التوافر الحيوي للفوسفور باستخدام البكتيريا المذيبة للفوسفات. لذلك، تم إجراء تجربة حقلية لتقييم تأثير البكتيريا المذيبة للفوسفات (*Bacillus megaterium* و *Bacillus subtilis*) PSB والميكروهيزاAMF على نباتات الفول البلدي. بالإضافة إلى ذلك، تضمنت الدراسة الرش الورقي لتركيزين من مستخلص الخميرة بالإضافة إلى فحص آثار تلك المعاملات على خصائص التربة. كشفت النتائج أن الاستخدام المتزامن لـ AMF والخميرة بمعدل 10 جم / لتر أظهر أفضل تحسن في جوانب معينة من النمو الخضري، مثل ارتفاع النبات، وطول الجذر، وعدد الفروع لكل نبات، وكذلك الوزن الطازج والوزن الجاف. ومن الجدير بالذكر أن هذة المعاملة المشتركه أدت أيضًا إلى تحسينات مهمة في معايير الإنتاجية مثل عدد القرون لكل نبات، ووزن القرون لكل نبات، ووزن 100 بذرة، والبذور لكل قرن، وطول القرون، وإنتاجية البذور الكلية. علاوة على ذلك، ساهمت إضافة ال AMF وPSB في زيادة نشاط إنزيمات التربة، وهي هيدروجيناز وفوسفاتيز. وكانت هذه الزيادة قريبة بشكل ملحوظ من الوصول إلى المعنوية بالمقارنة مع معاملة الكنترول. وبالتالي، فمن المستحسن النظر في الاستخدام التآزري لـ AMF وPSB ومستخلص الخميرة كنهج متكامل ومستدام لتعزيز أداء المحاصيل. تحمل هذه التوصية أهمية خاصة في المناطق التي يكون فيها توافر الفوسفور محدودًا، مما يوفر مزايا محتملة للممارسات الزراعية الموجهة نحو تحقيق محصول أعلى وتعزيز خصوبة التربة.