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Impact of some Specific Phosphorus Solubilizing Microorganisms and Different Phosphorus Fertilizers on Nutrients Content and Yield of Faba Bean (*Vicia faba* L.) in Sandy Soil

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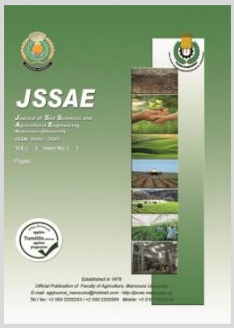

ABSTRACT

A field experiment was conducted on a sandy soil conditions at El-Khtara Farm, Sharkia Governorate, Egypt, during the growth season of 2016-2017 to study the effect of phosphorus fertilization from different sources *i.e.* rock phosphate (RP), ordinary super phosphate (OSP) and triple super phosphate (TSP) and phosphorus solubilizing bacterial inoculation *i.e. Rhizobium leguminosarum*, *Bacillus megaterium* (as phosphate-solubilizing bacteria) and *Glomus fasciculatum* (as phosphate-mobilizing fungi) on nutrients content and yield of faba bean (*Vicia faba* L.). All P sources were applied at the rate of 37 and 74 kg P ha^{-1}**.** Results showed that the application of different phosphate fertilizers as individual application or after inoculated with phosphorus solubilizing bacterial gave an increasing in nodules numbers $plant^{-1}$, nodules dry weight $plant^{-1}$, phosphatase activity, biomass $plant^{-1}$, yield, protein, N, P content of faba bean plants as well as available N and P compared to untreated soil. The highest values of studied attributes were obtained with TSP at 74 kg P ha^{-1}application and *G. fasciculutum* inoculation.

***Keywords**:* phosphorus, solubilizing, fertilization, broad bean, *Rhizobium leguminosarum*, *Bacillus megaterium*, *Glomus fasciculatum*

INTRODUCTION

Faba bean (*Vicia faba* L.) is an important grain legume crop in many countries. It can be used as a green vegetable or dried as human food in developing countries. In Egypt it is consumed in as human food. In Egypt, it constitutes a common staple food eaten in different popular dishes (El-Mergawi and Taie, 2014; FAO, 2016). New areas of reclaimed desert were brought into faba bean cultivation for increasing the production (El-Wakeil and El-Sebai, 2007; Hassan and Abakeer, 2013; Rakha and El-Said, 2013).

Phosphorus is the second important element after nitrogen (Demissie *et al.*, 2013; Sharma *et al.*, 2013). It is important especially in early stages of plant growth and is a component of nucleic acids, phospholipids, and ATP, and, consequently, plants cannot grow without enough supply of this nutrient (Schachtman *et al.*, 1998; Grant *et al.*, 2005; Vetterlein and Tarkka, 2018). An adequate supply of phosphorus during early plant growth is important for plant reproductive parts. It plays a vital role in increasing root ramification, strength and disease resistance as well as seed formation in cereals and legumes (Sharma *et al.*, 2013).

Plants acquire phosphorus from soil solution as phosphate anion. It is the least mobile element in plant and soil. Soluble phosphate precipitates in soil and is adsorbed by Fe and Al oxides through legend exchange (Khan *et al.*, 2009). Deficiency in plant-available phosphorus is a major limiting factor for plant growth (Arcand and Schneider, 2006; Czarnecki *et al.*, 2013)**.**

Mineral resources are necessary to restore soil phosphorus content. In regions where conventional fertilizers are not used due to cost limitations or adverse environmental effects, local sources of phosphate rock can be used (Arcand and Schneider, 2006). Egyptian soils are generally slightly alkaline to alkaline pH values (7.5–8.7) (Abd-Alla *et al.*, 2014).

Most arable soils in Egypt cause fixation of phosphate turning applied soluble phosphates into insoluble ones (Demissie *et al.*, 2013; Rakha and El-Said, 2013)**.** Rhizosphere microorganisms such as *Bacillus* spp. and *Rhizobium* spp. are essential for facilitating P mobilization in alkaline soil since they can solubilize insoluble phosphates through different mechanisms (Abd-Alla, 1994; Höflich *et al.*, 1994; Zheng *et al.*, 2017). Principal mechanism in soil for mineral phosphate solubilization is lowering of soil pH by microbial production of organic acids and mineralization of organic P by acid phosphatases (Khan *et al.*, 2009)**.**

Vesicular-arbuscular mycorrhizae (VAM) are effective in the mobilizing insoluble phosphates in soil and play a key role in natural and agricultural ecosystems (Ingraffia *et al.*, 2019). Application of mycorrhiza or phosphate dissolving bacteria increase P availability for plants. Some mechanisms regarding the positive effect of VAM in increasing the uptake of P have been suggested (Bolan, 1991; Sims and Pierzynski, 2005; and Khan *et al.*, 2009). They include: (1) exploration of larger soil volume by mycorrhiza through decreasing the distance that P ions diffuse to plant roots and increasing the surface area for adsorption; (2) faster movement of P into mycorrhizal hyphae and decreasing the threshold concentration required

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for absorption of P; and (3) solubilization of soil P by organic acids and phosphatase enzymes. Combined application of mycorrhiza and P dissolving bacteria enhances soil fertility, and crop productivity (Zaki and Radwan, 2006). Microbial-based mechanisms are low-cost and appropriate for enhancing solubilization of phosphate rock (Arcand and Schneider, 2006).

The present work aims to study the effect of different phosphorus fertilization *i.e.* rock phosphate (RP), ordinary super phosphate (OSP) and triple super phosphate (TSP) and phosphorus solubilizing bacterial inoculation *i.e. Rhizobium leguminosarum* (as a nitrogen fixer), *Bacillus megaterium* (as phosphate-solubilizing bacteria) and *Glomus fasciculatum* (as phosphate-mobilizing fungi) on yield, NP content of faba bean and available N and P in sandy soil.

MATERIALS AND METHODS

Experimental site

A field experiment was conducted on a sandy soil at El-khtara Farm, Faculty of Agric. Zagazig University Sharkia Governorate Egypt, during 2016-2017 season to study the effect of phosphorus fertilization from different sources *i.e.,* rock phosphate (RP), ordinary super phosphate (OSP) and triple super phosphate (TSP) and phosphorus solubilizing bacterial inoculation *i.e., Rhizobium leguminosarum*, *Bacillus megaterium* (as phosphate-solubilizing bacteria) and *Glomus fasciculatum* (as phosphate-mobilizing fungi) on yield, nutrients content and protein content of faba bean. The physical and chemical properties of the soil (Table 1) were determined according to Piper, (1950) and Black (1968).

Table 1. Some chemical and physical properties of the soil in the experimental site

Soil property	Unit	Value
- Sand	%	88.0
- Silt	%	7.10
- Clay	%	4.90
- Texture class		Sand
- Organic matter	g kg^{-1}	2.20
- $CaCO_3$	g kg^{-1}	27.0
- pH	1:2.5 (soil suspension)	7.98
- EC	dSm^{-1}(soil: water extract)	2.40
- CEC	cmolc kg^{-1}	10.8
- Available N	mg kg^{-1}	18.0
- Available P	mg kg^{-1}	5.50

Experimental design

The design was a split plot with three replicates involving two factors *i.e*. mineral P and bio P-fertilizer. The main plots were assigned to the mineral fertilizers of RP, OSP and TSP. Treatments of each factor are as follows: Factor 1: Mineral P: 7 treatments *i.e.* none, RP1, RP2, OSP1, OSP2, TSP1 and TSP2. Factor 2: 4 treatments *i.e.* none, *Rhizobium leguminosarum*, *Glomus fasciculatum*, *Bacillus megaterium* and *Rhizobium leguminosarum*. Each of the P sources was applied at 37 and 74 kg P ha-1as P1 and P2, respectively. Main properties of the P-sources are shown in Table 2. Phosphate reactivity in the sources were calculated according to Lehr and McClellan (1972) as follows:

Phosphate reactivity = (Solubility÷Total P) × 100

The sub-plots were assigned to biofertilizers of *Rhizobium leguminosarum*, *Bacillus megaterium* (P-solubilizing bacteria) and *Glomus fasciculatum* (a P-mobilizing fungi).

Table 2. Some selected properties of the used commercial phosphate sources

Property	Phosphate source		
	Rock phosphate (RP)	Ordinary Super phosphate (OSP)	Triple Super phosphate (TSP)
pH (1:50)	7.12	2.69	3.82
Total P, g kg^{-1}	112	68.2	139
Formic acid Solubility,%	10.9	13.5	41.9
Reactivity,%	42.7	71.8	91.3

Microbial cultures

Baciluus megaterium biovar. *phosphaticum*, as an efficient local isolate of phosphate solubilizing bacteria (PSB) was used as a good phosphate solubilizer and was grown on nutrient broth medium for 4 days at 30°C for obtaining heavy cells suspension. Liquid culture of the bacteria was adjusted to contain 5.0×10^8 cells/ml.

Specific culture of *Rhizobium leguminosarum* biovar *viceae* was grown on yeast extract manitol broth (YEM) for 4 days at 30°C (Somasegaranand Hoben, 1985) and the cell density of liquid culture was adjusted to contain 5.0×10^8 cells/ml before being used for inoculation as bacterial nitrogen fixer (BNF).

Regarding fungal endophyte, a starter culture of *Glomus fasciculatum* was multiplied in pot cultures using onion as a host. The growth medium consisted of 1:1 sand: peat (V/V) mixture steamed for 90 min. After 10 weeks, the inoculums used consisted of soil containing spores, mycelium and infected roots. This culture was contained 150 spores /g soil. VAM spores were counted as described by (Khalil and Loynachan, 1994).

The bacteria and fungus were kindly obtained from Agricultural Microbiology Department; Soils, Water and Environment Research Institute. ARC, Giza, Egypt.

Inoculation of seeds

Seeds of faba been (*Vicia faba* L.) cv Giza 3 mohassan was obtained from the Agronomy Res. Inst. ARC. Giza Egypt. Before planting, seeds were surface sterilized with acidified 0.01 % $HgCl_2$ for 5 minutes and after several washings with sterilized water, they were inoculated by soaking them for one hour in the prepared inocula.

An amount of Gum Arabic (2%) was added as adhering agent, spread in plates and allowed to air drying before sowing. The control seeds were soaked in the same manner, but in corresponding heat-sterilized inoculums. Using plate count technique, the microbial counts per seeds in case of single culture at the time of inoculation were as follows: 4.0×10^6 in *Baciluus megaterium*, and 3.6×10^6 in *Rhizobium leguminosarum*. Mycorrhizal inoculum was applied by hand at 200 g. m^{-1} in seed furrows 5 cm deep just before sowing.

Culture practices and sampling techniques

The experimental plot area was 10.5 m^2 and included 5 rows (each was 3.5 m length and 60 cm width) and the distance between hills was 20 cm.The planting was done on both sides of the row (the optimum plant density is 33 plants per m^2). Faba bean was seeded in mid-November 2016 and mature plants were harvested at the 2nd of May 2017. Each phosphate source was uniformly spread over

the soil surface and thoroughly incorporated into the top 25 cm soil layer before seeding. Mineral nitrogen was added at a rate of 50 kg N ha^{-1} as ammonium sulphate (205 g N kg^{-1}) in two equal doses, the first dose was applied after 20 days of planting and the second dose was added at tillering stage (45 days of planting), respectively. Potassium sulfate (400 g K kg^{-1}) was applied at 150 kg K ha^{-1} in two equal doses after 20 and 45 of planting. Drip irrigation technique was used for irrigation process.

After 55 and 95 days after sowing, random samples of 10 plants were carefully uprooted from each plot, soaked in water and washed several times and the following data were recorded: Number of nodules/plant, nodules dry weight, root and shoot dry weight (Somasegaran and Hoben, 1985). Also, three rhizospheric soil samples were taken to determine alkaline phosphatase activity as described by (Tabatabi, 1984). The unit of alkaline phosphatase was reported as mg *p*-nitrophenol released from 100 g soil h^{-1}. Such samples were taken in 3 occasions; one shortly before P application, second at maximum flowering (95 days after planting) and the last at harvest (168 days after planting). Whole plots were harvested for seeds and straw yields.

At harvest, plant samples were separated into straw and seeds, dried at 70°C, ground and digested with concentrated mixture of $H_2SO_4/HClO_4$ for chemical analysis and total N was determined using the micro Kjeldahl method according to Chapman and Pratt (1961). P was determined colourmetrically using ascorbic acid (Watanabe and Olsen, 1965). Protein content expressed as g kg^{-1} "yield quality" in seeds were calculated by multiplying N (g kg^{-1}) × 6.25 (Bishni and Hughes, 1979).

RESULTS AND DISCUSSION

Nodulation status and change in alk. phosphatase activity in the rhizosphere

Results in Table 3 show that phosphate fertilizer applications significantly increased the number of nodules per plant as well as nodules dry weight/plant and phosphatase activity in the two intervals (*i.e.* 55 and 95 days after planting). However, the treatment of TSP2 recorded the highest nodules $plant^{-1}$(42.03 and 70.48) as compared to control (11.40 and 23.23), which gained the lowest nodules in the 55 and 95 days after planting, respectively.

Table 3. Nodulation status and change in alkaline phosphatase activity in the rhizosphere of faba bean plants after treatment with different phosphate solubilizing inoculations and phosphate fertilizer applications.

Studied factors		Nodules No. $plant^{-1}$(±SE)		Nodules dry weight $plant^{-1}$(±SE)		Phosphatase activity (±SE)	
		55 days	95 days	55 days	95 days	95 days	168 days
P sources with different rates effects (A)							
Control	Con.	11.40 ± 2.14 g	23.23 ± 4.46 g	57.00 ± 4.87 g	116.75 ± 13.75 g	5.89 ± 0.16 f	6.60 ± 0.2 g
RP at 37 kg P ha^{-1}	RP1	16.08 ± 2.96 f	30.98 ± 6.36 f	106.75 ± 9.77 f	161.00 ± 27.31 f	6.16 ± 0.12 e	6.72 ± 0.19 f
RP at 74 kg P ha^{-1}	RP2	25.60 ± 2.36 e	41.45 ± 6.23 e	208.00 ± 19.55 c	269.00 ± 27.93 d	6.47 ± 0.08 d	7.99 ± 0.34 d
OSP at 37 kg P ha^{-1}	OSP1	30.00 ± 3.33 d	48.45 ± 5.00 d	150.75 ± 14.18 e	218.50 ± 29.69 e	6.49 ± 0.15 d	6.96 ± 0.2 e
OSP at 74 kg P ha^{-1}	OSP2	40.93 ± 4.28 b	55.90 ± 6.41 c	220.00 ± 20.45 b	278.50 ± 36.16 c	7.20 ± 0.21 b	8.31 ± 0.4 b
TSP at 37 kg P ha^{-1}	TSP1	37.25 ± 4.25 c	60.98 ± 6.49 b	194.50 ± 17.47 d	279.75 ± 31.32 b	7.00 ± 0.24 c	8.22 ± 0.48 c
TSP at 74 kg P ha^{-1}	TSP2	42.03 ± 5.44 a	70.48 ± 7.85 a	237.25 ± 21.63 a	338.00 ± 38.78 a	7.48 ± 0.27 a	8.96 ± 0.52 a
Inoculation effects (B)							
No Inoculation	I0	17.31 ± 2.22 d	25.73 ± 2.4 d	97.29 ± 8.27 d	114.29 ± 7.68 d	5.86 ± 0.08 d	6.12 ± 0.08 d
R. leguminosarum	I1	47.57 ± 3.76 a	79.63 ± 4.22 a	238.57 ± 20.49 a	380.29 ± 22.14 a	6.67 ± 0.09 c	7.29 ± 0.13 c
G. fasciculutum	I2	27.94 ± 2.64 b	37.26 ± 3.27 c	158.14 ± 12.9 c	206.86 ± 15.6 c	7.29 ± 0.21 a	8.87 ± 0.33 a
B. megaterium	I3	23.33 ± 1.78 c	46.79 ± 4.2 b	177.00 ± 13.44 b	248.00 ± 19.87 b	6.85 ± 0.15 b	8.44 ± 0.25 b
Interaction effects (A×B)							
Con.	I0	4.60 ± 0.03 v	10.6 ± 0.03 y	40.00 ± 0.17 b	58 ± 0.23 a	5.2 ± 0.02 m	5.5 ± 0.04 r
	I1	23.3 ± 0.12 p	48.3 ± 0.04 l	82.00 ± 0.16 w	184± 0.22 q	6.66 ± 0.02 fg	6.8 ± 0.04 l
	I2	9.00 ± 0.07 u	15.0 ± 0.22 w	46.00 ± 0.23 a	100 ± 0.06 y	5.9 ± 0.02 k	6.9 ± 0.01 l
	I3	8.70 ± 0.02 u	19.0 ± 0.13 v	60.00 ± 0.17 y	125 ± 0.22 w	5.78 ± 0.01 kl	7.18 ± 0.02 ij
RP1	I0	2.3.0 ± 0.05 w	12 ± 0.07 x	54 ± 0.06 z	71 ± 0.17 z	5.64 ± 0.01 l	5.88 ± 0.01 q
	I1	29.7 ± 0.02 k	66.6 ± 0.02 g	141 ± 0.17 p	312 ± 0.17 i	6.14 ± 0.01 j	6.45 ± 0.05 n
	I2	14.0 ± 0.23 t	20 ± 0.12 u	110 ± 0.23 v	125 ± 0.18 w	6.41 ± 0.31 hi	7.04 ± 0.02 k
	I3	18.3 ± 0.07 r	25.3 ± 0.04 s	122 ± 0.24 s	136 ± 0.22 v	6.45 ± 0.06 gh	7.52 ± 0.04 h
RP2	I0	18.4 ± 0.03 r	21.6 ± 0.43 t	119 ± 0.17 t	137 ± 0.16 u	6.12 ± 0.06 j	6.23 ± 0.02 o
	I1	38.7 ± 0.03 g	76 ± 0.18 d	301 ± 0.02 c	397 ± 0.12 d	6.37 ± 0.02 hi	7.76 ± 0.1 g
	I2	24.0 ± 0.06 o	31.6 ± 0.35 q	195 ± 0.23 k	255 ± 0.23 l	6.87 ± 0.01 ef	9.22 ± 0.02 d
	I3	21.3 ± 0.03 q	36.6 ± 0.37 p	217 ± 0.16 h	287 ± 0.17 j	6.53 ± 0.02 gh	8.73 ± 0.05 e
OSP1	I0	15.0 ± 0.12 s	26.6 ± 0.27 r	77 ± 0.17 x	104 ± 0.13 x	5.88 ± 0.01 k	6.04 ± 0.04 p
	I1	46.0 ± 0.12 d	71.6 ± 0.38 f	201 ± 0.07 j	375 ± 0.17 f	6.33 ± 0.01 hij	6.82 ± 0.02 l
	I2	31.3 ± 0.13 j	41.3 ± 0.06 n	145 ± 0.24 o	185 ± 0.22 p	7.23 ± 0.01 d	7.87 ± 0.01 g
	I3	27.7 ± 0.14 m	54.3 ± 0.06 k	180 ± 0.18 n	210 ± 0.51 o	6.51 ± 0.02 gh	7.1 ± 0.02 jk
OSP2	I0	23.7 ± 0.02 o	32 ± 0.13 q	133 ± 0.24 r	142 ± 0.22 s	6.13 ± 0.01 j	6.43 ± 0.08 n
	I1	63.0 ± 0.12 b	89.6 ± 0.49 c	323 ± 0.19 b	470 ± 0.19 b	7.08 ± 0.01 de	7.84 ± 0.02 g
	I2	40.7 ± 0.02 f	46 ± 0.24 m	205 ± 0.17 i	232 ± 0.14 n	7.87 ± 0.02 c	9.86 ± 0.01 c
	I3	36.3 ± 0.05 h	56 ± 0.3 j	219 ± 0.58 g	270 ± 0.14 k	7.71 ± 0.13 c	9.11 ± 0.18 d
TSP1	I0	29.3 ± 0.03 l	38.3 ± 0.1 o	118 ± 0.22 u	139 ± 0.58 t	5.85 ± 0.01 kl	6.15 ± 0.02 op
	I1	60.7 ± 0.02 c	95.3 ± 0.13 b	281 ± 0.18 d	419 ± 0.18 c	6.88 ± 0.01 e	7.29 ± 0.02 i
	I2	35.0 ± 0.06 i	48.3 ± 0.13 l	185 ± 0.23 m	236 ± 0.35 m	8.1 ± 0.01 b	10.22 ± 0.02 b
	I3	24.0 ± 0.17 o	62 ± 0.13 h	194 ± 0.58 l	325 ± 0.58 g	7.16 ± 0.01 d	9.21 ± 0.02 d
TSP2	I0	27.9 ± 0.1 m	39 ± 0.06 o	140 ± 0.18 q	149 ± 0.22 r	6.23 ± 0.2 ij	6.61 ± 0.04 m
	I1	71.6 ± 0.38 a	110 ± 0.58 a	341 ± 0.17 a	505 ± 0.18 a	7.23 ± 0.03 d	8.05 ± 0.01 f
	I2	41.6 ± 0.01 e	58.6 ± 0.38 i	221 ± 0.24 f	315 ± 0.22 h	8.64 ± 0.09 a	10.96 ± 0.01 a
	I3	27 ± 0.12 n	74.3 ± 0.04 e	247 ± 0.13 e	383 ± 0.19 e	7.8 ± 0.04 c	10.22 ± 0.02 b

Generally, nodules number $plant^{-1}$ were markedly increased with the increase of phosphate application doses and this trend is found in all sources of phosphorus. The relative increases of number of nodules $plant^{-1}$ were 41, 125, 163, 259, 227, and 269% after 55 days after planting and 33, 78, 109, 141, 163 and 203% after 95 days of

planting for RP1, RP2, OSP1, OSP2, TSP1 and TSP2, respectively.

The results of nodules dry weight plant^{-1} and phosphatase activity were followed the same trend, where TSP2 recorded the highest values (237.25 after 55 days of planting and 338 after 95 days of planting) for nodules dry weight plant^{-1} and 7.48 after 95 days of planting and 8.96 after 168 days of planting for phosphatase activity compared with control which gained the lowest nodules. (El-Ghandour *et al.*, 1996) reported that, nodules number and nodule dry weights were increased by addition of different P-sources.

Concerning the effect of phosphate solubilizing inoculations, the data show that plants inoculation with *R. leguminosarum* exhibited higher nodules numbers and nodules dry weight plant^{-1} of faba bean plants as compared to control for the two intervals (*i.e.* 55 and 95 days after planting), respectively. Results of the current study are similar to those reported by (El-Wakeil and El-Sebai, 2007; Demissie *et al.*, 2013; Abd-Alla *et al*., 2014**).** Phosphatase activity was significantly affected by seed inoculation and followed the order: *G. fasciculutum* > *B. megaterium* > *R. leguminosarum* > no inoculation.

The interaction between two studied factors as shown in Table 3 was significant. Higher nodules number and nodules dry weight plant^{-1} were recorded for plants treated with TSP2 and inoculated with *R. leguminosarum* in the 55 and 95 days after planting, respectively as compared to the other treatments. Higher phosphatase activity was recorded for plants fertilized with TSP2 and inoculated by *G. fasciculutum*. In this respect, Zaki and Radwan (2006) found that, mycorrhizal inoculation positively affected nodulation in sandy soils. (Talaat and Abdallah, 2008) noted positive effect on phosphatase activity owing to applying biofertilizers.

Root and shoot biomass plant^{-1}

As shown in Table 4, application of different phosphate sources significantly increased root and shoot biomass in the two intervals (*i.e.* 55 and 95 days after planting). Highest biomass was recorded for plants treated with TSP2 and this trend was found through the all intervals i.e. 55 and 95 days after planting. The root and shoot biomass in the two intervals (*i.e.* 55 and 95 days after planting) as well as after harvest were higher in treatments of TSP2 + I2 as compared with the other treatments.

Table 4. Root and shoot biomass (g plant^{-1}) of faba bean plants as affected by different phosphate fertilizer and phosphate solubilizing inoculations.

Studied factors		Root biomass, g plant^{-1} (±SE)		Shoot biomass, g plant^{-1} (±SE)		
		55 days	95 days	55 days	95 days	After harvest
P sources with different rates effects (A)						
Control	Con.	2.17 ± 0.05 g	2.72 ± 0.10 d	2.85 ± 0.04 g	5.02 ± 0.04 g	9.60 ± 0.13 g
RP at 37 kg P ha^{-1}	RP1	2.76 ± 0.06 f	3.93 ± 0.14 c	3.45 ± 0.08 f	12.67 ± 0.72 f	17.59 ± 1.08 f
RP at 74 kg P ha^{-1}	RP2	3.05 ± 0.06 d	4.11 ± 0.12 bc	3.86 ± 0.05 e	15.40 ± 0.93 d	19.24 ± 0.81 d
OSP at 37 kg P ha^{-1}	OSP1	2.88 ± 0.07 e	4.28 ± 0.18 bc	4.32 ± 0.2 d	13.75 ± 0.92 e	18.48 ± 1.16 e
OSP at 74 kg P ha^{-1}	OSP2	3.64 ± 0.09 b	4.51 ± 0.14 abc	4.75 ± 0.15 b	16.03 ± 0.55 b	20.78 ± 0.86 c
TSP at 37 kg P ha^{-1}	TSP1	3.09 ± 0.08 c	4.69 ± 0.26 ab	4.70 ± 0.18 c	15.54 ± 1.01 c	21.68 ± 1.37 b
TSP at 74 kg P ha^{-1}	TSP2	3.70 ± 0.11 a	5.04 ± 0.52 a	5.00 ± 0.16 a	18.14 ± 1.16 a	24.09 ± 1.33 a
Inoculation effects (B)						
No Inoculation	I0	2.71 ± 0.09 d	3.34 ± 0.11 c	3.48 ± 0.11 c	9.58 ± 0.54 d	13.34 ± 0.57 d
R. leguminosarum	I1	2.95 ± 0.1 c	4.25 ± 0.18 b	4.45 ± 0.2 a	14.94 ± 0.99 b	20.28 ± 1.08 b
G. fasciculutum	I2	3.29 ± 0.13 a	4.81 ± 0.20 a	4.44 ± 0.18 a	16.16 ± 1.08 a	21.40 ± 1.18 a
B. megaterium	I3	3.20 ± 0.12 b	4.32 ± 0.30 b	4.16 ± 0.18 b	14.49 ± 0.97 c	20.10 ± 1.04 c
Interaction effects (A×B)						
Con.	I0	1.98 ± 0.01 u	2.20 ± 0.03 m	2.66 ± 0.01 v	4.83 ± 0.03 x	8.9 ± 0.02 v
	I1	2.10 ± 0.07 t	2.86 ± 0.03 lm	2.90 ± 0.03 t	5.03 ± 0.02 w	9.7 ± 0.03 u
	I2	2.40 ± 0.02 r	3.10 ± 0.02 klm	3.02 ± 0.01 s	5.18 ± 0.02 w	10.1 ± 0.02 t
	I3	2.20 ± 0.02 s	2.70 ± 0.03 lm	2.80 ± 0.02 u	5.02 ± 0.02 w	9.7 ± 0.02 u
RP1	I0	2.49 ± 0.01 q	3.27 ± 0.01 j-m	3.03 ± 0.02 s	8.84 ± 0.02 u	11.4 ± 0.03 s
	I1	2.68 ± 0.02 o	3.71 ± 0.03 f-l	3.61 ± 0.05 p	13.99 ± 0.09 o	19.54 ± 0.02 l
	I2	2.91 ± 0.01 l	4.47 ± 0.02 c-i	3.74 ± 0.01 mn	15.23 ± 0.06 m	20.26 ± 0.07 jk
	I3	2.94 ± 0.01 l	4.27 ± 0.03 d-k	3.43 ± 0.03 q	12.62 ± 0.02 q	19.17 ± 0.03 m
RP2	I0	2.73 ± 0.02 no	3.61 ± 0.01 g-l	3.65 ± 0.01 op	10.26 ± 0.08 s	14.7 ± 0.27 p
	I1	3.10 ± 0.02 j	3.86 ± 0.03 d-l	4.12 ± 0.06 j	16.02 ± 0.13 k	20.07 ± 0.05 k
	I2	3.21 ± 0.01 h	4.63 ± 0.02 c-g	3.87 ± 0.02 l	18.32 ± 0.01 e	21.43 ± 0.01 h
	I3	3.15 ± 0.05 ij	4.34 ± 0.02 c-j	3.81 ± 0.03 lm	16.99 ± 0.01 g	20.75 ± 0.1 i
OSP1	I0	2.56 ± 0.02 p	3.30 ± 0.02 i-m	3.26 ± 0.03 r	8.63 ± 0.03 v	11.85 ± 0.03 r
	I1	2.80 ± 0.02 m	4.24 ± 0.01 d-k	4.83 ± 0.03 g	15.43 ± 0.02 l	20.44 ± 0.06 j
	I2	3.02 ± 0.01 k	4.85 ± 0.02 a-f	4.88 ± 0.02 g	16.53 ± 0.12 ij	21.33 ± 0.14 h
	I3	3.14 ± 0.01 ij	4.72 ± 0.03 b-g	4.31 ± 0.03 i	14.4 ± 0.03 n	20.29 ± 0.2 j
OSP2	I0	3.18 ± 0.01 hi	3.72 ± 0.02 e-l	3.99 ± 0.01 k	12.94 ± 0.03 p	15.94 ± 0.06 o
	I1	3.66 ± 0.01 e	4.63 ± 0.02 c-g	5.12 ± 0.04 cd	16.81 ± 0.10 h	22.1 ± 0.08 g
	I2	3.99 ± 0.01 b	4.89 ± 0.06 a-e	5.26 ± 0.03 b	17.71 ± 0.01 f	23.19 ± 0.04 f
	I3	3.72 ± 0.01 d	4.81 ± 0.03 a-f	4.62 ± 0.03 h	16.67 ± 0.14 hi	21.90 ± 0.05 g
TSP1	I0	2.75 ± 0.02 mn	3.41 ± 0.01 h-l	3.7 ± 0.03 no	9.91 ± 0.03 t	13.9 ± 0.01 q
	I1	2.91 ± 0.01 l	4.99 ± 0.02 a-d	5.04 ± 0.05 e	17.14 ± 0.03 g	23.98 ± 0.01 d
	I2	3.33 ± 0.02 fg	5.83 ± 0.02 ab	5.10 ± 0.1 de	18.72 ± 0.03 d	25.19 ± 0.03 c
	I3	3.36 ± 0.03 fg	4.51 ± 0.03 c-h	4.96 ± 0.04 f	16.38 ± 0.02 j	23.65 ± 0.04 e
TSP2	I0	3.31 ± 0.03 g	3.84 ± 0.02 d-l	4.09 ± 0.03 j	11.63 ± 0.04 r	16.71 ± 0.04 n
	I1	3.38 ± 0.01 f	5.48 ± 0.04 abc	5.52 ± 0.02 a	20.19 ± 0.03 b	26.11 ± 0.01 b
	I2	4.20 ± 0.03 a	5.92 ± 0.01 a	5.20 ± 0.02 b	21.42 ± 0.06 a	28.29 ± 0.04 a
	I3	3.91 ± 0.02 c	4.91 ± 2.18 a-d	5.19 ± 0.02 bc	19.33 ± 0.06 c	25.25 ± 0.01 c

Results in Table 4 indicated that plots receiving seeds treated with *G. fasciculutum* giving highest increases of root and shoot biomass in the two intervals (55 and 95 days after planting) as well as after harvest comparing with

the other phosphate solubilizing inoculations and control except for shoot biomass at 55 days after planting which gave the highest increase due to inoculation with *R. leguminosarum*. A similar positive effect was observed by Talaat and Abdallah (2008).

Seed and straw yield of faba bean plants

Results in Table 5 show that application of different phosphate sources significantly increased seed and straw yield of faba bean plants. Highest seed and straw yield of faba bean were obtained due to OSP application at 74 kg P ha.$^{-1}$, while the lowest value ones was found with control.

Also, seed and straw yield of faba bean plants significantly increased with the inoculation with different phosphate solubilizing inoculations, where the inoculation with *G. fasciculutum* was superior to the others and gave the highest values (3.47 and 5.69 Mg ha.$^{-1}$ for seed and straw, respectively) followed by *B. megaterium* (3.14 and 5.57 Mg ha.$^{-1}$for seed and straw, respectively) then *R. leguminosarum* (2.99 and 5.47 Mg ha.$^{-1}$ for seed and straw, respectively). A similar positive effect was observed by Rugheim and Abdelgani (2012) who found that phosphate solubilizing bacteria (PSB) inoculation significantly increased faba bean seed yield. Also, Ahmed *et al*. (2000) reported that dry matter production and seed yield were significantly greater in mycorrhizal plants. This is probability due to enhancing of P uptake by mycorrhiza.

Table 5. Faba bean yield and its nitrogen and phosphorus contents as affected by phosphate source and biological inoculation.

Studied factors		Yield (Mg ha^{-1})		Nitrogen and phosphorus contents (g kg^{-1})				Protein (g kg^{-1})
				Seed		Straw		
		Seed	Straw	N	P	N	P	
P sources with different rates effects (A)								
Control	Con.	2.19 ± 0.01 e	2.93 ± 0.02 g	31.2 ± 0.64 f	1.26 ± 0.07 e	9.23 ± 0.25 f	0.7 ± 0.06 e	195 ± 3.97 f
RP at 37 kg P ha^{-1}	RP1	2.88 ± 0.03 d	5.21 ± 0.03 f	33.83 ± 0.4 e	1.54 ± 0.09 de	10.2 ± 0.15 e	0.85 ± 0.1 de	211.41 ± 2.48 e
RP at 74 kg P ha^{-1}	RP2	3.19 ± 0.04 b	5.76 ± 0.04 c	36.88 ± 0.66 c	1.7 ± 0.1 cd	11.3 ± 0.24 c	0.94 ± 0.07 cd	230.52 ± 4.13 c
OSP at 37 kg P ha^{-1}	OSP1	2.93 ± 0.03 d	5.36 ± 0.02 e	33.7 ± 0.42 e	1.96 ± 0.15 c	10.2 ± 0.14 e	1.11 ± 0.1 c	210.63 ± 2.6 e
OSP at 74 kg P ha^{-1}	OSP2	3.71 ± 0.05 a	6.76 ± 0.04 a	40.66 ± 0.47 b	2.48 ± 0.18 b	12.89 ± 0.27 a	1.4 ± 0.11 b	254.14 ± 2.94 b
TSP at 37 kg P ha^{-1}	TSP1	3.07 ± 0.03 c	5.55 ± 0.03 d	35.13 ± 0.13 d	2.52 ± 0.11 b	10.48 ± 0.08 d	1.41 ± 0.06 b	219.53 ± 0.84 d
TSP at 74 kg P ha^{-1}	TSP2	3.67 ± 0.05 a	6.64 ± 0.04 b	41.46 ± 0.66 a	3.02 ± 0.25 a	12.55 ± 0.2 b	1.69 ± 0.09 a	259.1 ± 4.15 a
Inoculation effects (B)								
No inoculation	I0	2.76 ± 0.04 d	5.12 ± 0.11 d	35 ± 0.91 c	1.58 ± 0.12 c	10.45 ± 0.32 c	0.88 ± 0.08 c	218.78 ± 5.71 c
R. leguminosarum	I1	3.00 ± 0.04 c	5.57 ± 0.11 b	36.99 ± 0.89 a	1.86 ± 0.11 b	11.37 ± 0.36 a	1.04 ± 0.07 b	231.18 ± 5.56 a
G. fasciculutum	I2	3.47 ± 0.06 a	5.69 ± 0.12 a	36.85 ± 0.98 a	2.48 ± 0.16 a	11.26 ± 0.32 a	1.38 ± 0.1 a	230.31 ± 6.15 a
B. megaterium	I3	3.14 ± 0.04 b	5.47 ± 0.11 c	35.64 ± 0.56 b	2.35 ± 0.19 a	10.83 ± 0.19 b	1.32 ± 0.1 a	222.78 ± 3.48 b
Interaction effects (A×B)								
Con.	I0	2.05 ± 0.01 m	2.71 ± 0.01 p	28.5 ± 0.06 r	1.07 ± 0.09 n	8.1 ± 0.06 p	0.59 ± 0.14 i	178.13 ± 0.36 q
	I1	2.12 ± 0.01 m	3.02 ± 0.01 o	30.1 ± 0.06 q	1.15 ± 0.1 mn	8.9 ± 0.1 o	0.63 ± 0.04 i	188.13 ± 0.36 p
	I2	2.31 ± 0.01 l	3.09 ± 0.02 o	32.1 ± 0.15 p	1.52 ± 0.13 j-n	9.6 ± 0.15 n	0.84 ± 0.03 ghi	200.63 ± 0.95 o
	I3	2.28 ± 0.01 l	2.93 ± 0.01 o	34.1 ± 0.06 n	1.3 ± 0.06 lmn	10.3 ± 0.06 ijk	0.72 ± 0.17 hi	213.13 ± 0.36 m
RP1	I0	2.52 ± 0.01 k	4.76 ± 0.01 n	32.2 ± 0.21 p	1.12 ± 0.04 n	9.6 ± 0.12 n	0.62 ± 0.17 i	201.25 ± 1.3 o
	I1	2.83 ± 0.01 ij	5.31 ± 0.02 klm	35.3 ± 0.06 jk	1.43 ± 0.12 k-n	10.7 ± 0.06 fgh	0.8 ± 0.06 ghi	220.63 ± 0.36 ij
	I2	3.26 ± 0.01 ef	5.38 ± 0.02 jkl	34.9 ± 0.1 lm	1.81 ± 0.09 h-l	10.6 ± 0.15 f-i	1.01 ± 0.37 e-h	218.13 ± 0.63 kl
	I3	2.93 ± 0.01 i	5.4 ± 0.02 jk	32.9 ± 0.06 o	1.78 ± 0.04 h-l	9.9 ± 0.1 lmn	0.98 ± 0.13 e-h	205.63 ± 0.36 n
RP2	I0	2.76 ± 0.01 j	5.21 ± 0.01 lm	34.77 ± 0.06 m	1.23 ± 0.13 mn	10.53 ± 0.04 g-j	0.68 ± 0.17 hi	217.33 ± 0.4 l
	I1	3.26 ± 0.02 ef	6.12 ± 0.01 e	39.97 ± 0.06 e	1.65 ± 0.11 i-m	12.38 ± 0.14 d	0.93 ± 0.04 f-i	249.81 ± 0.41 e
	I2	3.59 ± 0.02 c	5.93 ± 0.01 f	37.93 ± 0.09 h	2 ± 0.16 g-j	11.69 ± 0.12 e	1.11 ± 0.05 d-g	237.07 ± 0.54 g
	I3	3.14 ± 0.01 gh	5.78 ± 0.01 fg	34.86 ± 0.13 lm	1.91 ± 0.06 g-k	10.61 ± 0.12 f-i	1.05 ± 0.1 d-g	217.86 ± 0.79 kl
OSP1	I0	2.62 ± 0.02 k	5.19 ± 0.01 m	33.2 ± 0.06 o	1.29 ± 0.07 lmn	10 ± 0.15 klm	0.74 ± 0.07 hi	207.5 ± 0.36 n
	I1	2.76 ± 0.02 j	5.33 ± 0.01 m	35.8 ± 0.06 i	1.75 ± 0.08 h-l	10.9 ± 0.06 f	0.98 ± 0.17 e-h	223.75 ± 0.36 h
	I2	3.26 ± 0.01 ef	5.4 ± 0.01 jk	32 ± 0.15 p	2.42 ± 0.1 d-g	9.7 ± 0.12 mn	1.36 ± 0.19 cd	200 ± 0.95 o
	I3	3.07 ± 0.01 h	5.5 ± 0.06 ij	33.8 ± 0.06 n	2.39 ± 0.05 d-g	10.2 ± 0.06 jkl	1.34 ± 0.09 cde	211.25 ± 0.36 m
OSP2	I0	3.24 ± 0.01 fg	6.43 ± 0.01 cd	39.91 ± 0.1 ef	1.6 ± 0.12 j-n	12.42 ± 0.06 d	0.92 ± 0.16 f-i	249.43 ± 0.6 e
	I1	3.62 ± 0.01 bc	6.97 ± 0.01 b	43.2 ± 0.06 b	2.29 ± 0.1 e-h	14.25 ± 0.03 a	1.28 ± 0.13 cde	270 ± 0.36 b
	I2	4.31 ± 0.01 a	7.14 ± 0.01 ab	40.51 ± 0.05 d	3.2 ± 0.06 abc	12.82 ± 0.47 c	1.8 ± 0.06 ab	253.2 ± 0.3 d
	I3	3.64 ± 0.02 bc	6.52 ± 0.02 c	39.03 ± 0.13 g	2.83 ± 0.03 cde	12.08 ± 0.07 d	1.59 ± 0.07 bc	243.92 ± 0.79 f
TSP1	I0	2.78 ± 0.01 j	5.26 ± 0.1 klm	35.2 ± 0.15 jkl	2.15 ± 0.1 f-i	10.2 ± 0.15 jkl	1.2 ± 0.04 def	220 ± 0.95 ijk
	I1	2.93 ± 0.01 i	5.66 ± 0.01 ghi	34.9 ± 0.1 lm	2.2 ± 0.06 f-i	10.4 ± 0.06 hij	1.24 ± 0.03 def	218.13 ± 0.63 kl
	I2	3.36 ± 0.02 de	5.69 ± 0.02 gh	35.4 ± 0.52 j	2.83 ± 0.07 cde	10.8 ± 0.06 fg	1.55 ± 0.1 bc	221.25 ± 3.25 i
	I3	3.19 ± 0.02 fg	5.59 ± 0.01 hi	35 ± 0.15 klm	2.89 ± 0.06 bcd	10.5 ± 0.06 g-j	1.64 ± 0.03 bc	218.75 ± 0.95 jkl
TSP2	I0	3.36 ± 0.02 de	6.33 ± 0.02 d	41.25 ± 0.16 c	2.59 ± 0.07 def	12.28 ± 0.18 d	1.44 ± 0.11 cd	257.8 ± 1.02 c
	I1	3.4 ± 0.01 d	6.57 ± 0.01 c	39.65 ± 0.11 f	2.56 ± 0.16 def	12.08 ± 0.17 d	1.44 ± 0.09 cd	247.8 ± 0.66 e
	I2	4.24 ± 0.05 a	7.16 ± 0.01 a	45.1 ± 0.15 a	3.57 ± 0.03 a	13.62 ± 0.13 b	1.95 ± 0.03 a	281.88 ± 0.95 a
	I3	3.71 ± 0.03 b	6.52 ± 0.01 c	39.83 ± 0.06 ef	3.36 ± 0.96 ab	12.22 ± 0.13 d	1.91 ± 0.16 ab	248.93 ± 0.4 e

The interaction between the two tested factors was significant (p value < 0.05). However, the highest seed yield (4.31 Mg ha^{-1}) was recorded for plants received OSP at 74 kg P ha^{-1} and inoculated with *G. fasciculutum* while the highest straw yield (7.16 Mg ha.$^{-1}$) was obtained as affected by addition treatment of TSP2 + *G. fasciculutum*. Phosphate solubilizing microorganisms have established their role for optimum growth of plants under nutrient imbalance conditions (Czarnecki *et al.,* 2013).

Nitrogen and phosphorus content of faba bean plants

The effect of P-fertilization, biofertilizer inoculation and their interaction between them on N, P and protein contents of faba bean plants are presented in Table5. The highest values of N, P and protein content of faba bean plants were recorded with TSP application at 74 kg P ha.$^{-1}$, while the lowest ones were found with control. *R. leguminosarum*, *B. megaterium* and *G. fasciculutum* treatments exhibited positive effects on N and P content of faba bean plants as well as protein content. Highest values

obtained for P content in seed and straw were due to inoculation with *G. fasciculutum* followed by *B. megaterium* and then *R. leguminosarum*, while the effect of inoculation followed the order of: *R. leguminosarum* ≥ *G. fasciculutum* > *B. megaterium* for N and protein contents in seed and straw of faba bean plants.

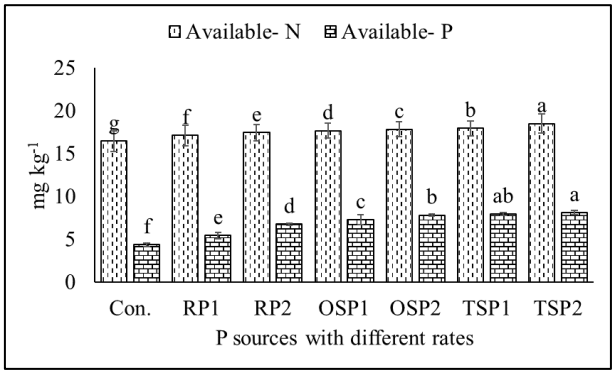
The highest N, P and protein contents were recorded for plants received TSP at 74 kg P ha^{-1} + *G. fasciculutum*. Phosphorus uptake in many crops increases with mycorrhizal fungi (Grant *et al.*, 2005). Vesicular-arbuscular mycorrhizal and phosphate dissolving bacteria enhanced P availability in soil (Zaki and Radwan, 2006). The enhancement of nitrogen fixation of faba is due to mycorrhiza fungi facilitating the mobilization of certain elements such as P, Fe and other minerals (Abd-Alla et *al.*, 2014). The mineral P sources increase P availability in the soil (El-Fahham, 1997; Nassar, *et al.*, 2000).

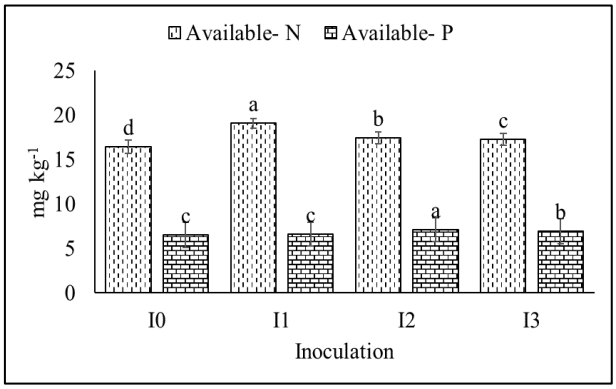
Available N and P (mg kg^{-1}):

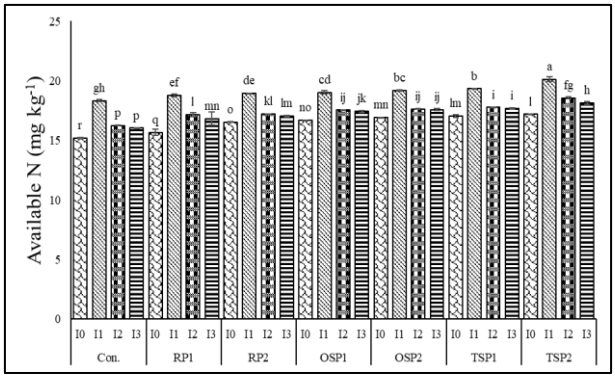
Data illustrated in Table 6 and Fig. 1 represent the values of available nitrogen and phosphorus (mg kg^{-1}) in the treated soil with different sources of phosphate fertilizer and phosphate solubilizing inoculations.

Table 6. Available N and P (mg kg^{-1}) as affected by application of different phosphate fertilizer and phosphate solubilizing inoculations.

Studied factors		Available N	Available P
P sources with different rates effects (A)			
Control	Con.	16.44 ± 1.22 g	4.34 ± 0.21 f
RP at 37 kg P ha^{-1}	RP1	17.1 ± 1.19 f	5.43 ± 0.35 e
RP at 74 kg P ha^{-1}	RP2	17.42 ± 0.94 e	6.74 ± 0.16 d
OSP at 37 kg P ha^{-1}	OSP1	17.66 ± 0.89 d	7.27 ± 0.58 c
OSP at 74 kg P ha^{-1}	OSP2	17.82 ± 0.87 c	7.81 ± 0.09 b
TSP at 37 kg P ha^{-1}	TSP1	17.95 ± 0.88 b	7.93 ± 0.19 ab
TSP at 74 kg P ha^{-1}	TSP2	18.49 ± 1.11 a	8.1 ± 0.24 a
Inoculation effects (B)			
No inoculation	I0	16.44 ± 0.72 d	6.52 ± 1.39 c
R. leguminosarum	I1	19.09 ± 0.53 a	6.62 ± 1.34 c
G. fasciculutum	I2	17.44 ± 0.66 b	7.12 ± 1.32 a
B. megaterium	I3	17.24 ± 0.67 c	6.94 ± 1.39 b
Interaction effects (A×B)			
Con.	I0	15.16 ± 0.06 r	4.12 ± 0.01 l
	I1	18.33 ± 0.09 gh	4.22 ± 0.01 l
	I2	16.25 ± 0.03 p	4.65 ± 0.01 jk
	I3	16.02 ± 0.01 p	4.35 ± 0.06 kl
RP1	I0	15.65 ± 0.26 q	4.98 ± 0.08 ij
	I1	18.76 ± 0.13 ef	5.26 ± 0.02 hi
	I2	17.15 ± 0.19 l	5.85 ± 0.1 g
	I3	16.82 ± 0.54 mn	5.62 ± 0.01 gh
RP2	I0	16.52 ± 0.03 o	6.57 ± 0.04 f
	I1	18.92 ± 0.03 de	6.68 ± 0.03 ef
	I2	17.22 ± 0.01 kl	6.98 ± 0.09 e
	I3	17.03 ± 0.04 lm	6.72 ± 0.01 ef
OSP1	I0	16.68 ± 0.02 no	6.69 ± 0.01 ef
	I1	19.02 ± 0.15 cd	6.73 ± 0.01 ef
	I2	17.53 ± 0.03 ij	7.79 ± 0.01 d
	I3	17.42 ± 0.1 jk	7.85 ± 0.07 d
OSP2	I0	16.9 ± 0.03 mn	7.7 ± 0.01 d
	I1	19.17 ± 0.05 bc	7.75 ± 0.01 d
	I2	17.63 ± 0.01 ij	7.92 ± 0.01 bcd
	I3	17.57 ± 0.09 ij	7.86 ± 0.01 cd
TSP1	I0	17.02 ± 0.1 lm	7.74 ± 0.03 d
	I1	19.32 ± 0.01 b	7.82 ± 0.01 d
	I2	17.76 ± 0.01 i	8.22 ± 0.03 abc
	I3	17.68 ± 0.05 i	7.93 ± 0.01 bcd
TSP2	I0	17.18 ± 0.04 l	7.87 ± 0.05 cd
	I1	20.12 ± 0.2 a	7.88 ± 0.03 bcd
	I2	18.54 ± 0.09 fg	8.4 ± 0.05 a
	I3	18.12 ± 0.1 h	8.24 ± 0.02 ab







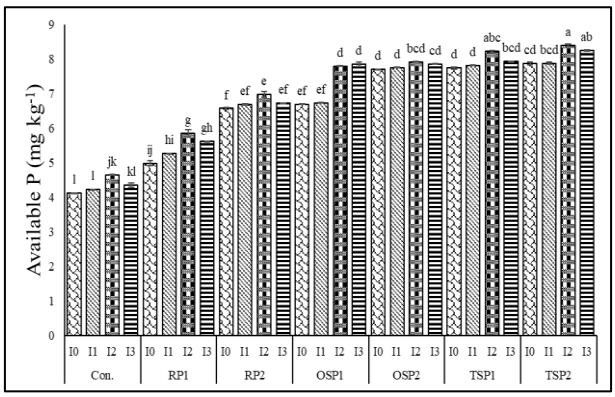


Fig.1. Available N and P (mg kg^{-1}) as affected by application of different phosphate fertilizer and phosphate solubilizing inoculations.

The treatments of TSP2 + *R. leguminosarum* and TSP2 + *G. fasciculutum* gave the highest values of available N and P (20.12 and 8.40 mg kg^{-1}, respectively), while the lowest ones (15.15 and 4.12 mg kg^{-1}, respectively) were obtained with untreated soil. These results are in agreement with those obtained by (Zaki and Radwan, 2006). Principal mechanism in soil for mineral

phosphate solubilization is lowering of soil pH by microbial production of organic acids and mineralization of organic P by acid phosphatases (Khan *et al.*, 2009).

CONCLUSION

Results showed that the application of different phosphate fertilizers as individual application or inoculated with phosphorus solubilizing bacterial gave increase in nodules numbers plant^{-1}, nodules dry weight plant^{-1}, phosphatase activity, biomass plant^{-1}, yield, protein, N and P content of faba bean plants as well as available N and P as compared to untreated soil. The highest values of studied attributes were obtained due to addiction treatment TSP at 74 kg P ha^{-1} and *G. fasciculutum* inoculation.

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تأثير بعض الكائنات الحية الدقيقة المذيبة للفوسفور والأسمدة الفوسفاتية المختلفة على محتوى العناصر الغذائية ومحصول الفول البلدي في التربة الرملية

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أجريت تجربة حقلية تحت ظروف الأراضي الملحية في مزرعة الخطارة بمحافظة الشرقية – مصر خلال موسم ٢٠١٧/٢٠١٦ لدراسة تأثير التسميد الفوسفاتي من مصادر مختلفة (صخر الفوسفات RP، سوبر الفوسفات العادي OSP، وسوبر فوسفات الثلاثي TSP) وبعض الميكروبات المذيبة للفوسفور (*Rhizobium leguminosarum*، *Glomus fasciculatum*، *Bacillus megaterium*) علي محتوي عناصر ومحصول نبات الفول البلدي. تم إضافة المصادر المختلفة للفوسفور بالمعدلات التالية: ٣٧، ٧٤ كجم فوسفور للهكتار.أظهرت النتائج أن إضافة الأسمدة الفوسفاتية من مصادرها المختلفة وحدها أو بعد التلقيح بالميكروبات المذيبة للفوسفور أدي إلى حدوث زيادة معنوية في عدد العقد البكتيرية لكل نبات، والوزن الجاف للعقد البكتيرية لكل نبات وكذا زيادة نشاط إنزيم الفوسفاتيز والكتلة الحيوية لكل نبات بالإضافة إلي زيادة محصول نبات الفول البلدي وزيادة محتواه من النيتروجين والفوسفور وكذلك زيادة تيسر كل من النيتروجين والفوسفور في التربة مقارنة بالقطع التجريبية غير المعاملة (الكنترول). وكانت أفضل النتائج هي معاملة TSP بمعدل ٧٤ كجم فوسفور للهكتار مع التلقيح بميكروب *Glomus fasciculatum*