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Effect of Phosphate Solubilizing Bacteria (PSB) and Phosphatic Fertilizer Levels on Yield and Quality of Soybean and Sunflower

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Abstract: Two field experiments were conducted during the two growing summer seasons of 2021 and 2022 on a private farm in Al Aiat District, Giza Governorate. The objective of the study was to investigate the integrated effect of Phosphate Solubilizing Bacteria (PSB) and P level on , yield and chemical constituents of Soybean and sunflower. Three phosphatic fertilizer levels were applied to soybean and sunflower, ie., 0, 240 and 480 kg super phosphate (P0, P1 and P2, respectively). These levels represent 31 and 62 kg P_2O_5/ha. The seeds of both crops were inoculated or non-inoculated with Phosphate Solubilizing Bacteria(PDB). The results showed that significant effects were reported due to inoculation with (PSB) in most of the yield component of each crop except for the number of branches per plant in soybean, plant height, number of pods and seed yield per plant were increased compared to the non- inoculation with (PSB). The same trend was reported for sunflower as significant increases were evident in plant height, head diameter, head weight and seed yield per plant. Seed yield and quality were significantly increased by inoculation with Phosphate Solubilizing Bacteria (PDB). Application of the highest level phosphate (480 kg super phosphate /ha) to both crops gave the highest significant increase in the studied characters. Application of 240 kg phosphatic fertilizer gave the highest percentage of soybean protein %, while oil percentage was increased by applying the highest level of phosphatic fertilizer. The results showed that with the exception of soybean oil content and protein percentages of sunflower application of 240kg super phosphate /ha combined with inoculation with (PSB) could achieve more or similar effect to 480 kg super phosphate application treatment alone in all the studied characters of the two oil corps. The data of relative yield increase over the control treatment showed increases in seed, protein and oil yields by 50.1, 34.7 and68.2 for soybean and 68.2, 53.5 and 54.2 for sunflower, respectively.

Key words: Sunflower · Soybean · P level · PSB · Yield · Quality

INTRODUCTION

In Egypt, one of the most important problems in the agricultural sector is the shortage of oil production. This shortage is approximately 90 percent of the oil consumption and covered by imports from abroad. Alkitkat [1] indicated that, in 2030, the Egyptian population size is expected to reach about 126 million inhabitants, which will put more pressure on food production. Thus, increasing the efficiency of using our natural resources, namely soil, water and weather resources could increase food production and availability, as well as reduce food insecurity

The government targets to raise Egypt's self-sufficiency of oil crops from three percent to 10 percent by 2025. Edible oils are a major constituent of human food. Soybean, sunflower, seeds are the major sources of edible oil in Egypt. Edible oils group comes in second place after wheat, with respect to importation [2]. In 2011, Egypt imported 350, 101 tons of soybean oil and 262, 764 tons of sunflower oil, to fulfill the needs of the Egyptian population [3].

Phosphorus is the second important key element after nitrogen as a mineral nutrient in terms of quantitative plant requirement and also is a major and crucial nutrient for oil crops. Although abundant in soils, in both organic

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and inorganic forms, its availability is restricted as it occurs mostly in insoluble forms [4]. The efficiency of applied P fertilizers in chemical form rarely exceeds 30% due to its fixation, in the form of calcium phosphate in neutral to alkaline soils [5].

Solubilizing Microorganisms (PSM) through various mechanisms of solubilization and mineralization are able to convert inorganic and organic soil P respectively [6] into the bioavailable form facilitating uptake by plant roots. Microbial-mediated P management is an eco-friendly and cost-effective approach for the sustainable development of agricultural crops. Microorganisms are an integral component of the soil P cycle and are important for the transfer of P between different pools of soil P. Phosphate Solubilizing Microorganisms (PSM) through various mechanisms of solubilization and mineralization are able to convert inorganic and organic soil P respectively [6] into the bioavailable form facilitating uptake by plant roots. Therefore, the objective of this study is to investigate the integrated effect of Phosphate Solubilizing Bacteria (PSB) and P level on, yield and chemical constituents of Soybean and sunflower.

MATERIALS AND METHODS

Two field experiments were conducted during the two growing summer seasons of 2021 and 2022 on a privit farm in Al Aiat District, Giza Governorate. The objective of the study was to investigate The integrated effect of Posphate Solubilizing Bacteria (PSB) and P level on growth, yield and chemical constituents of Soybean and sun flower. The soil texture of the experimental sites was sandy clay loam soil analysis was done according to [7]. Mechanical and chemical analyses of the soil are presented in the Table (1).

The soil was ploughed twice and levelled and divided into plots. Each plot consists of 5 rows, 7 meters in length and 60 cm apart. The plot area was (21 m^2). During seed-bed preparation, three phosphatic fertilizer levels were applied, Le., 0, 240 and 480 kg super posphate (P0, P1 and P2, respectively. These levels represent 31 and 62 kg P_2 O_5/ha. Treatments were arranged in a split-split plot design with four replications where the crops occupied the main plot , (PSB)to were assigned) treatment and P levels in the sub-sub plots. Then, the two oil crop, i.e., soybean and sunflower were sown by the recommended methods for each crop.

Soybean seeds c.v. Giza-82 were inoculated with specific Rhizobium sown by Herati (wet method), where the plots were irrigated and left until the moisture content of the soil was suitable for sowing. Seeds were treated with the adhesive material Arabic gum to make their surface sticky before adding Phosphate Solubilizing Bacteria. Seeds were inoculated with Phosphate Solubilizing Bacteria(PDB) { Commercial product released by Ministry of Agriculture ARC Giza. }.The seeds were drilled after two hours from inoculation on one side of the ridge at 5 cm spacing.

Sunflower seeds c.v. Giza -102 were inoculated with Phosphate Solubilizing Bacteria (PSB) and planted in hills 25 cm apart within the ridges. Sowing date for the two crops was in the same time on 22 and 15 May in 2021 and 2022 seasons, respectively. Thinning were carried out after 21 days from planting as recommended for both crops. All the traditional agricultural practices of growing soybean and Sunflower were applied as usual.

Table 1: Some physical and chemical properties of the clay soil

Soil characteristics	Value	Soil characteristics	Value
Particle size distribution%:		*Soluble cations* (soil pastem $mole_c\ L^{-1}$):	
Sand	21.7	Ca^{2+}	14.20
Silt	34.4	Mg^{2+}	2.73
Clay	43.9	Na^{+}	16.50
Textural class *Clayey*	K^{+}	0.75	
Soil chemical properties:		*Soluble anions* (soil paste $mole_c\ L^{-1}$):	
pH (1.25 soil water suspension)	7.82	CO_3^{2-}	0.00
$CaCO_3$ %	2.86	HCO_3^-	3.00
Organic carbon %	2.37	Cl^-	18.20
ECe (dS/m, soil paste extract)	3.40	SO_4^{2-}	12.98
Soil physical properties:			
Bulk density g cm^{-3}	1.15	Total aggregate %	2.08
Hydrulic conductivity (cm h^{-1})	1.72	Avail. Water %	26.11
Soil moisture at wilting point %	7.50	Soil moisture at field capacity %	18.61

Available Nutrients mg kg^{-1}

N	P	K	Fe	Mn	Zn	Cu
48.90	8.65	498.00	7.25	1.83	1.40	1.14

At harvest, ten guarded plants were collected from the central ridges of each plot for the measuring plant height, number of branches per plant, number of pods for soybean as well as head diameter and weight per plant for sunflower. Plants were threshed to determine seed yield per plant and weight/l00 seeds. Two central ridges of each plot were harvested to determine the seed yield per unit area, then calculated as seed yield per hectare

The total nitrogen content of seed was detennined for the three oil crops using the micro-kjeldahl method (A.O.A.C., 1990) [8] and crude protein content was calculated by multiplying the N-percent by 6.25 for soybean seeds and by 5.75 for sesame and sunflower seeds. Oil content was determined for almost dry seed by the modified soxhlet method [8].

The data were statistically processed using software package (MSTAT-C) [9]. After testing the homogeneity of the error according to Bartlett's test, combined analysis for both seasons was done. Treatment means were compared using the Least Significant Difference test (L.S.D.) at 5 % level.

RESULTS AND DISCUSSION

Effect of Inoculation with (PSB): Data presented in Table (2) show significant effect, of inoculation with (PSB) in most of the yield component of each crop except for the number of branches per plant in soybean, plant height, number of pods and seed yield per plant were increased compared to the non- inoculation with (PSB). The same trend was reported for sunflower as significant increases in plant height, head diameter, head weight and seed yield per plant were exhibited. Inoculation with (PSB) is supposed to increase the mobility of the fixed phosphate, in the soil which has an alkaline reaction (pH 8.1). Similar results were reported by [4-6].

Concerning seed yield and quality, the data in Table (3) show that inoculation with (PSB)) resulted in higher seed index and higher seed yield /ha as well as seeds with higher protein and oil percentage. Soybean seed yield increased by 20.4 %, whereas oil content increased by 3.7% due to inoculation with (PSB). Similar results were obtained for sunflower seeds. Seed yield increased 15.4% above the control.. Seed oil content was increased due to inoculation with (PSB) by 8.5 % over the control trearment. Such increases in both yield and seed quality of both oil crops reveal the importance of microorganisms in mobilizing fixed phosphate to a from available for plant absorption which is clearly reflected in these criteria. In this respect, several, investigators came to similar conclusions The growth of phosphate-solubilizing bacteria (PSB) are playing a key role in phosphorus solubilization in the soil[10] that they can transform the insoluble phosphorus to soluble forms HPO-2 and H2PO-4 by acidification, chelation, exchange reactions and polymeric substances formation [11]. The association of PSB with sunflower roots and screening of the potential of these PSB for enhancing the growth and yield of sunflower plants has not as yet been completely studied. Inoculation with PDB solely or in combination with super phosphate and rock phosphate significantly affected on growth parameter, yield and yield component of peanut and faba bean crops, the highest values obtained by applying P fertilizer at rate 30.98 Kg ha^{-1} [11]. Park *et al*. [12] Painted out that phosphate ssolubilizing bacteria (PSB) increase the ssolubilization of insoluble P compounds such as RPs through the production of organic acids and phosphates. Increasing bioavailability of P in soil with inoculation of PSB and rock materials, which may lead to increased P uptake and plant growth, was reported by many researchers [13, 14].

Increasing growth and yield of several crop plants due to inoculation by PDB have been reported in a number of studies, [15-18]. The increase in growth parameters, yield and yield components of peanut plant inoculated with PDB could be attributed to increase uptake of P. However phosphate solubilization is not the only way for promoting plant growth by PDB but also help plant growth by stimulating the efficiency of plant hormone production such as auxiens, cytokines, gibberellins and also some volatile compound (Podile and Kishore 2006 and Ali *et al*., 2010 [19, 20].

Effect of P Level: Results given in Table (2) and (Figs. 1, 2) emphasize the importance of phosphatic fertilization to the studied oil crops. In general, the application or the highest level phosphate (480 kg super phosphate /ha) to both crops gave the highest significant increase in the studied characters. Such increases were were observed in soybean plants in terms of plant height and number of branches per plant as compared to control treatment. Moreover, number of pods and seed yield per plant were also increased by phosphatic application and the greatest response occurred when plants were fertilized with 240 kg super posphate per hectare (Fig. 1). Table (3) also shows the effect of phosphatic fertilization on soybean seed

Table 2: Effect of Phosphatic Fertilizer level and Phosphate Soubilizing Bateria (PSB)inoculation on soybean and sunflower yield components characters (Combined mean of 2012 and 2022 seasons

		Soybean				Sunflower			
Phosphatic Fertilizer level	Phosphate Soubilizing Bateria (PSB)	Plant height (cm)	No of branches/ plant	No of pods /plant	Seed yield (g/plant)	Plant height (cm)	Head diameter (cm)	Head weight (g)	Seed yield (g/plant)
P0	-	80.7	3.2	67.3	18.8	198.9	12.4	179.4	26.5
	+	82.4	3.5	79.5	24.1	202.5	13.9	235	37.9
Mean		81.6	3.4	73.4	21.5	200.7	13.2	207.2	32.2
P1	-	83.4	3.7	86.5	25.2	205.6	14.9	242.9	43.9
	+	86.1	3.5	92.6	26.8	223.5	15.3	263.7	47.4
Mean		84.9	3.6	89.6	26	214.6	15.1	253.3	45.7
P2	-	85.9	3.5	80.6	24.2	207.8	15.2	252.6	47.4
	+	87.3	3.8	97.3	27	218.3	17.8	275.6	62.3
Mean		86.6	3.7	89	25.6	213.1	16.5	264.1	54.9
PDB Mean	-	83.3	3.5	78.1	22.7	204.1	14.2	225	39.3
	+	85.3	3.6	89.8	26	214.8	15.7	258.1	49.2
LSD0.05	P	1.6	0.2	6.3	3.1	5.7	1.4	9.8	8.4
	PSB	1	NS	4.7	2.3	7.6	1.3	22.1	7.3
	Interaction	1.8	0.3	2.1	0.7	5.4	1.5	10.2	3.2

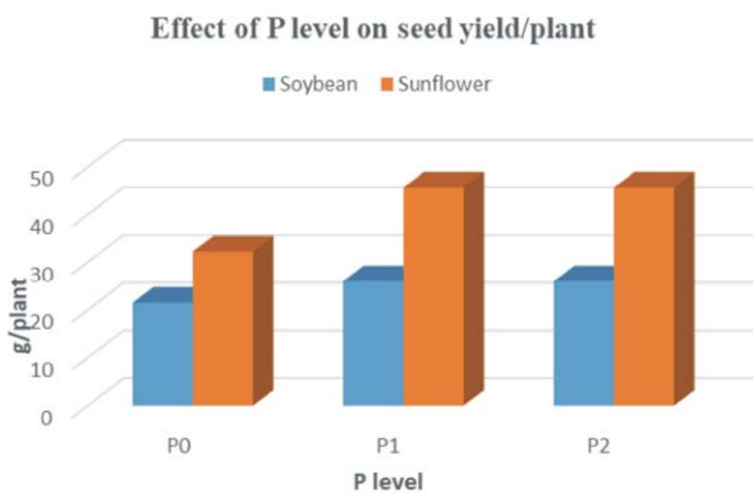

Fig. 1: Effect of P level on soybean and sunflower seed yield/plant (g/plant)

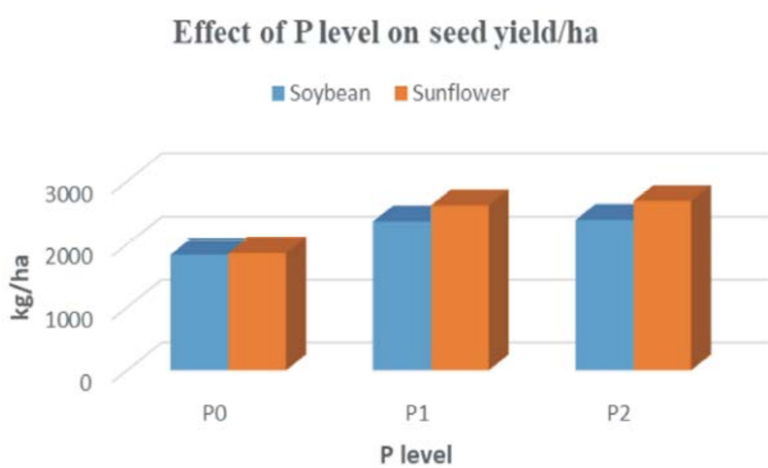

Fig. 2: Effect of P level on soybean and sunflower seed yield (kg/ha)

Table 3: Effect of Phosphatic Fertilizer level and Phosphate Soubilizing Bateria (PSB)inoculation on soybean and sunflower yield components characters (Combined mean of 2012 and 2022 seasons

Phosphatic Fertilizer level	Phosphate Soubilizing Bateria (PSB)	Soybean Seed Index	Soybean Seed yield	Soybean Protein	Soybean Oil	Sunflower Seed Index	Sunflower Seed yield	Sunflower Protein	Sunflower Oil
P0	-	18.1	1548	28.2	18.4	4.2	634.5	19.1	29.2
	+	18.9	2121.6	29.8	19.6	4.9	915.9	21.1	30.7
Mean		18.5	1834.8	29.0	19.0	4.6	775.2	21.1	30.0
P1	-	19.0	2272.8	30.2	19.2.	5.5	1047.4	21.0	30.1
	+	19.4	2450.4	31.1	18.9	.9	1134.6	20.8	35.0
Mean		19.2	2361.6	30.65	19.1	5.7	1091.0	20.9	32.6
P2	-	19.5	2152.8	29.1	19.0 I	5.9	1089.5	22.1	32.2
	+	19.9	2620.8	28.0	20.0	6.1	1148.6	21.9	33.7
Mean		19.7	2386.8	28.55	19.6	6.0	1119.1	22.0	32.9
PDB Mean	-	18.87	1991.208	29.27	18.87	5.2	923.8	20.7	30.5
	+	19.40	239760	29.63	19.57	5.6	1066.4	21.3	33.1
LSD0.05	P	0.4	76.8	0.9	0.3	0.3	284.88	0.7	0.8
	PSB	0.3	60	n.S	0.6	0.2	155.04	0.4	0.9
	Interaction	0.2	45.6	0.7	0.2	0.4	143.52	0.6	0.7

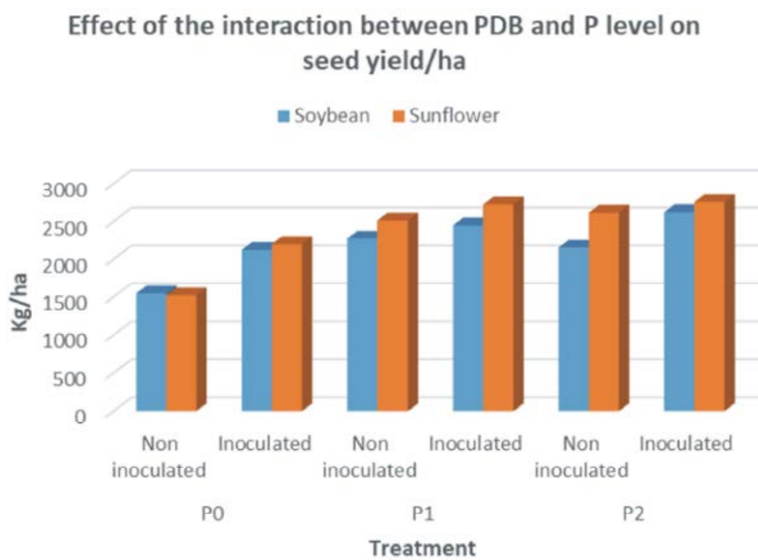

Fig. 3: Effect of the interaction between PDB and P level on seed yield/ha

quality, where 480 kg super phosphate gave the highest seed index (100-seed weight) and seed yield per hectare which was 30% over control treatment (Fig. 2). Concerning protein soybean protein %, application of 240 kg phosphatic fertilizer gave the highest percentage, while oil percentage was increased by applying the highest level of phosphatic fertilizer.

Table (2) shows that similar results were obtained for sunflower, data in Table (2) show the same effect of phosphatic fertilizer on plant height, head diameter, head weight and seed yield per plant. Application of phosphatic fertilizer up to the highest level gave the highest increase in head diameter head weight and seed yield per plant compared with the control treatment. Seed yield and quality were also affected by phosphatic application, i.e., seed index, seed yield /ha as well as protein and oil percentages. These data are in harmony with those obtained by [19, 20].

Effect of the Interaction Between PDB and P Level on Soybean and Sunflower Yield and Chemical Constituents: Data in Tables (2 and 3 and Fig. 3) show significant interaction in all the studied characters between inoculation with (PSB) and the phosphatic fertilizer level for both oil crops. Soybean gave its highest seed yield and oil content when the plants were inoculation

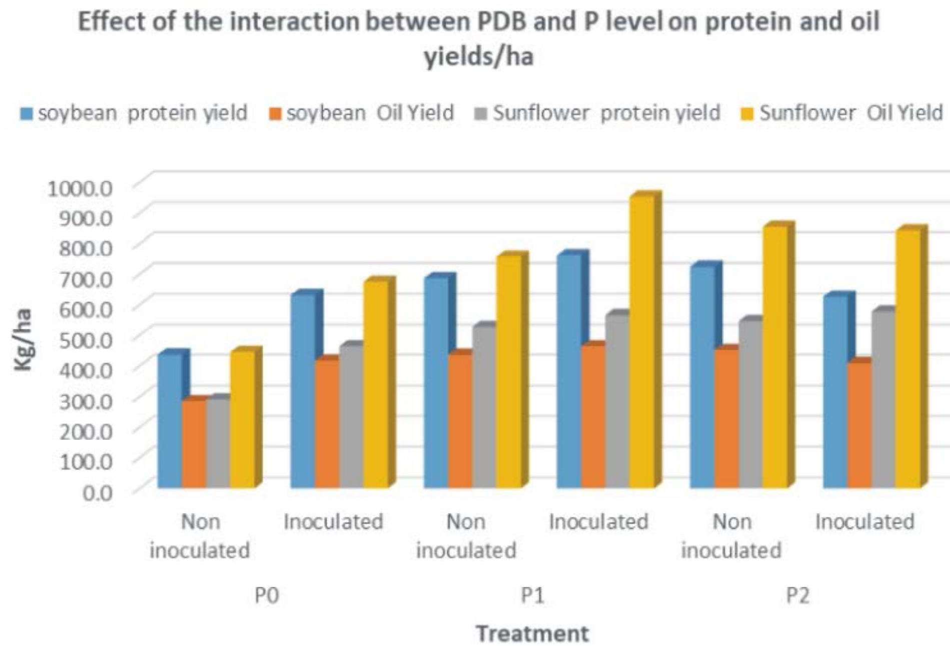

Fig. 4: Effect of the interaction between PDB and P level on protein and oil yields/ha

Table 4: Effect of Phosphatic Fertilizer level and Phosphate Soubilizing Bateria (PSB)inoculation on soybean and sunflower Protein &oil yields kg/ha (Combined mean of 2012 and 2022 seasons

		Protein &oil yields kg/ha			
		Soybean		Sunflower	
Phosphatic Fertilizer level	Phosphate Soubilizing Bateria (PSB)	Protein yield	Oil yield	Protein yield	Oil yield
P0	-	436.5	284.8	290.9	444.7
	+	632.2	415.8	463.8	674.8
Mean		532.1	348.6	392.6	558.1
P1	-	686.4	#VALUE!	527.9	756.6
	+	762.1	463.1	566.4	953.1
Mean		723.8	451.1	547.2	853.6
P2	-	626.5	409.0	577.9	842.0
	+	733.8	524.2	603.7	929.0
Mean		681.4	467.8	590.9	883.6
PSB	-	582.8	375.7	458.9	676.2
	+	710.4	46921.0	545.1	847.1
LSD	P	69	23	99	228
	PSB	NS	36	62	40
	Interaction	31.92	32	9	86

with (PSB)and fertilized with 480 kg super phosphate while the lower level (240 kg) with inoculation with (PSB) resulted in the highest seed protein percentage.

The results showed that with the exception of soybean oil content and protein percentages of sunflower application of 240kg super phosphate /ha combined with inoculation with (PSB) could achieve more or similar effect to 480 kg super phosphate application treatment alone in all the studied characters of the two oil corps. Such results emphasize that biofertilization is not a substitue but a partial supphnent mineral phosphatic fertilizer which could be ascribed partaily to the increased mobility of fixed phosphatein the soil.

Effect of the Interaction Between PDB and P Level on Protein and Oil Yields/ha: Data presented in Table 4 and Fig. 4 reveal significant effects due to the interaction between PDB and P level on protein and oil yields/ha.

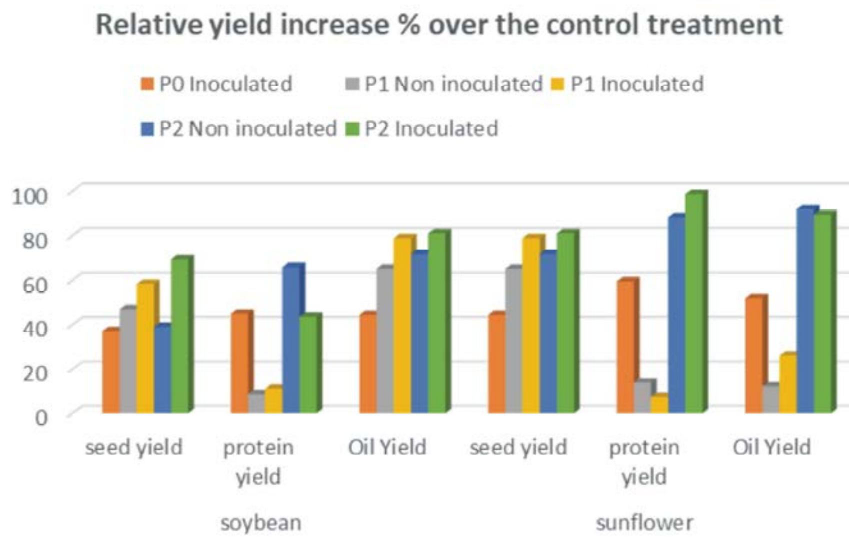

Fig. 5: Relative yield increase of seed, protein and oil yields % over the control treatment

Table 5: Relative yield increase of seed, protein and oil yields % over the control treatment

		Soybean			Sunflower		
		Seed yield	Protein yield	Oil yield	Seed yield	Protein yield	Oil yield
P0	Non inoculated	0	0	0	0	0	0
	Inoculated	37.1	44.8	46.0	44.3	59.5	51.8
P1	Non inoculated	46.8	8.6	-16.2	65.1	13.8	12.1
	Inoculated	58.3	11.0	32.8	78.8	7.3	26.0
P2	Non inoculated	39.1	65.8	58.4	71.7	88.2	92.0
	Inoculated	69.3	43.5	43.6	81.0	98.7	89.4
Mean		50.1	34.7	68.2	68.2	53.5	54.2

The combined application of PDB and P increased protein and oil yields. Such effect was more pronounced for sunflower than that obtained by soybean especially at the lower P level applied. On contrast, soybean gave the greatest protein and oil contents at the higher level of P (P2) and inoculation with PDB.

Relative Yield Increase % over the Control Treatment: The data of relative yield increase over the control treatment are shown in Table 5 and Fig. 5. The results showed relative increases over the control treatment (P0 without inoculation with PSB) in mean seed, protein and oil yields by 50.1, 34.7 and 68.2 for soybean and 68.2,53.5 and 54.2 for sunflower, respectively. The combined application of PDB and P increased seed protein and oil yields. The relative increases in the economic yield was obvious in sunflower than that obtained by soybean especially at the lower P level applied. On contrast, soybean gave the greatest protein and oil contents at the higher level of P (P2) and inoculation with PDB.

CONCLUSION

It can be concluded from this study that Inoculation of oil crops with PDB (soybean and sunflower) have beneficial role in solubilizing P which enhance yield and quality of both crops

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