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Maximizing Efficiency of Rock Phosphate as a Source of P-Fertilization for Faba Bean (*Vicia faba* L.) Plant

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ABSTRACT

A field experiment was conducted at the experimental farm of faculty of agricultural, Mansoura University, Dakahlia Governorate, Egypt during 2014 /2015 winter season to evaluate the efficiency of phosphate dissolving bacteria (PDB), sulphur (S), as well as foliar application of iron, zinc and Fe + Zn to enhance the availability of phosphorus from rock phosphate and their effects on vegetative growth parameters, chemical composition, yield and yield components of faba bean seeds cv. Giza 461. Twenty treatments were arranged according to complete randomized block design (CRBD) with three replicates; which were the sample possible combination between five treatments as soil addition (super phosphate (SP) , rock phosphate (RP), RP + phosphate dissolving bacteria (PDB) , RP + sulphur (S) and RP + PDB + S) and four spraying treatments; (1) spraying with tap water , (2) spraying with iron at the rate of Fe 300 mg/L, (3) spraying with zinc at the rate of Zn 100 mg/L, (4) spraying with solution containing 300 and 100 mg/L of Fe and Zn thus, the total number of the experimental plots were 60 plots. The results indicated that the highest values of vegetative growth (plant height , fresh and dry weight , chlorophyll a , chlorophyll b , chlorophyll a + b), yield and yield components (number of flowers. plant^{-1}, number of pods. plant^{-1}, fruit setting % , weight of pods. plant^{-1}, 100-seeds weight and seed yield) of faba bean plant as well as nitrogen , phosphorus , potassium and protein contents in faba bean seeds were significantly increased for the plants treated with rock phosphate + PDB + S + (Fe + Zn) as compared to those obtained from the treatment of rock phosphate in single form except Fe content in faba bean seeds, the highest values were recorded when faba bean plants were treated with rock phosphate + PDB + S + Fe, but had no significant effect on K content. Faba bean seeds decreased significantly in their content of Zn as a result of the applied treatments. So, the lowest Zn content in faba bean seeds were recorded from (RP + PDB + S + Fe + Zn) compared with (RP + Zn) because of the dilution caused by growth response of P values which is known as P induced Zn deficiency. Generally, under the conditions of the present study, it can be concluded that adding RP mixed with PDB + S under sprayed of Fe 300 mg/L + Zn 100 mg/L may be the recommended treatment for enhancing the productivity of faba bean crop.

Keywords: Faba bean , rock phosphate , phosphate dissolving bacteria , sulphur , iron , zinc.

INTRODUCTION

Faba bean (*Vicia faba L.*) is one of the most important legumes crops that can be used for human nutrition in Egypt. Faba bean seeds contains higher amount of carbohydrate, protein, high calorific and nutritive value, so it is consumed as an excellent human food especially in the diet of low income people. Phosphorus (P) is an essential macro-nutrient element required for maximizing plant growth and production of faba bean plant. It is involved in several plant functions, including transformation of carbohydrate as well as formation of oils, regulation of metabolic pathways energy transfer, controlling enzyme reactions and transfer energy produced by photosynthesis for use in plant growth (Ahmed and El-Abagy 2007). Phosphorus availability under Egyptian soil conditions is controlled by several factors (pH, organic matter, $CaCO_3$ and clay contents) so; the low availability of phosphorus for plant. The content of available phosphorus in the integrated fertilizer is rapidly converted to unavailable compounds to the plants such as tri-calcium phosphate. Phosphorus recovery efficiency (PRE) is not more than 20 % of applied P in the world soils because of P ion complexes precipitate about 80 % of added P fertilizer. Therefore, the supply of phosphorus is required for the primary objective is improving food security by increasing sustainable crop production. Therefore, the environmental pollution caused by over use the large quantities of fertilizers could be reduced.

Phosphate rock is the natural and economical source of P for production of phosphate fertilizers and has become the subject of investigation in the recent years as a reasonably effective source of P fertilization to crops under natural and alkaline soil environment, (Akintokum *et al.,* 2003). Many studies have been performed in order to evaluate the efficiency of phosphate rock treated with different acidulates at varying degrees of acidulation to excess available and soluble P in alkaline soils (Cordell *et al.,* 2009). Sulphur oxidation in soils is an effective process in the reclamation of sodic soils in addition to providing the sulphur needs for plants. More importantly, this process will lower the pH of the soil resulting in an increased activity of some plant nutrients near the root zone and consequently resulting in an improvement in the yield and quality of agricultural crops (Mohammed, 2004).

Soil organisms play a vital role in P nutrition by improving phosphate uptake by enhancing its availability to plant through release from rock or tri-calcium phosphate to the plants from both inorganic and organic sources by solubilizing and mineralizing complex P compounds and by producing phosphate enzymes. In particular, phosphate dissolving bacteria (PDB) are important for plant nutrition by improving the phosphorus efficiency of both native and applied P and incrementing P uptake by plant, crop growth and production. Many investigators reported that phosphate dissolving bacteria increase the solubilization of insoluble P compounds such as RP through produce large amounts of organic acids and phosphates, enhance crop growth, improve seed, straw yields and an abundant population of active and effective microorganisms to the root activity zone which increases plant ability to uptake more nutrients and increase P uptake was reported by many researchers (El-Gizawy and Mehasen 2009; Khan *et al*., 2014).

Micronutrients are essential for plant growth and have a large impact on balanced crop nutrition. The deficiency of these micronutrients in the soil can limit plant growth and reduces crop yields either due to low available concentration in the soil. Foliar application of microelements such as zinc (Zn), iron (Fe) and their uptake by plants is essential for crop production is more beneficial especially when the roots cannot provide necessary nutrients than soil application. Many researchers found that microelements are used in lower amounts as compared to macronutrients, such as N, P and K. However, they are crucial for crop growth; they have a major role in cell division and development of meristematic tissues, photosynthesis, respiration and acceleration of plant maturity. Foliar spraying of micronutrients at vegetative growth stage significantly increased soybean seed yield by influencing the number of seeds per plant and seed weight (Ghasemi-Fasaei *et al*., 2010 and Salwa *et al*., 2011). El-Gizawy and Mehasen (2009) found that a significant effect on bean grain yield, yield components, nitrogen content, and the level of phosphorus and zinc in the grain by utilization of chemical phosphorus fertilizer with phosphate-solution bacteria

Therefore, the aim of this study was evaluating the efficiency of PDB, sulphur , Fe and Zn on release of phosphorus from rock phosphate and their effects on vegetative growth parameters, chemical composition, and yield of faba bean plants.

MATERIALS AND METHODS

A field experiment was conducted at the experimental farm of faculty of agricultural, Mansoura University, Dakahlia Governorate, Egypt during 2014 /2015 winter season. Soil samples were collected, prior to tillage from surface layer (0 – 20 cm) for soil physical and chemical properties as given in Table (1). The soil used for this experiment was Sandy loam in texture, non saline or alkaline and moderately fertile soil. Soil analysis was determined using the standard methods as follows; particle size distribution and calcium carbonate were determined according to the methods of Piper, (1950). Organic matter, EC, pH, available N, P and K were determined according to the methods described by Jackson, (1973). DTPA extractable Fe and Zn were estimated using an atomic absorption spectrophotometry (Berkin Elmer Model 5100 as described by Lindsay and Norvell (1978).

Table 1. Some physical and chemical properties of the soil used .

Soil properties								
A: Physical analysis					**B: Chemical analysis :**			
Particle size distribution :				***S.P. (%)**				
Sand (%)	**Silt (%)**	**Clay (%)**	**Texture**		****pH (1:2.5)**	*****E.C ($dS.m^{-1}$) (1:5)**	**(O.M %)**	**($CaCO_3$%)**
58.1	23.0	18.9	Sandy loam	56.5	8.07	0.93	1.32	2.96
C: Available macronutrient (mg. kg^{-1}).								
N						51.6		
P						4.93		
K						187.5		
D: DTPA extractable (mg. kg^{-1}).								
Fe						3.16		
Zn						0.76		

***S.P. : Saturation percentage** ****pH : In soil water suspension** ***EC : In soil water extract**

The treatments were as following :

1- Super phosphate (SP) (60 kg P_2O_5/fed).
2- SP + Fe 300 mg/L
3- SP + Zn 100 mg/L
4- SP + Fe 300 mg/L+ Zn 100 mg/L
5- Rock phosphate (RP) 116.12 kg P_2O_5/fed).
6-RP+ Fe 300 mg/L
7- RP + Zn 100 mg/L
9- RP + phosphate dissolved bacteria (PDB).
10- RP + PDB + Fe 300 mg/L
11- RP + PDB + Zn 100 mg/L
12- RP + PDB + Fe 300 mg/L + Zn 100 mg/L
13- RP +223.88 kg S/fed
14- RP + S + Fe 300 mg/L
15- RP + S + Zn 100 mg/L
16- RP + S + Fe 300 mg /L + Zn 100 mg /L
17- RP + PDB + S
8- RP + Fe 300 mg/L + Zn 100 mg/L
18- RP + PDB + S + Fe 300 mg/L
19- RP + PDB + S + Zn 100 mg/L
20- RP + PDB + S + Fe 300 mg/L + Zn 100 mg/L

Seeds of faba bean (cv. Giza 461) were planted on 2nd week of November in the 2014 /2015 season. For all treatments, phosphorus of two sources (super phosphate and rock phosphate) and sulphur were applied during seed bed preparation. Each plot was included 5 ridges; 3 m long and 70 cm wide, the plot's area was 10.5 m^2. The recommended dose for faba bean (60 kg P_2O_5/fed) was added before sowing in the form of calcium super phosphate (SP); 15.5 % P_2O_5. Rock phosphate (RP); 30% P_2O_5 applied as soil addition before sowing at the rate of 116 kg P_2O_5/fed. Sulphur was added before sowing at the rate of 224 kg S /fed. Cell suspension of (B. megaterium var. phosphaticum) was kindly provided from by unit of biofertilizers, Fac. of Agric., Ain Shams Univ. Cairo. Egypt. This suspension of cell is containing about 108 colony farming unit (CFU). Seeds of faba bean were soaked with the liquid suspension of (PDB) before sowing. Stock solution from Fe- EDTA and Zn- EDTA was prepared at the rate of 300 and 100 mg/L for Fe and Zn, respectively. Faba bean plants were sprayed three times by using hand sprayer with the aqueous solution of these chelated Zn and Fe at 21, 28 and 35 days after planting, while control treatments were sprayed with tap-water. All other practical treatments were done according to the recommended doses of Ministry of Agricultural and soil reclamation for faba bean plant.

At flowering stage (60 days after sowing) randomly plant samples were taken from each plot to determine; plant height (cm), fresh and dry weight (g. $plant^{-1}$) as well as chlorophyll content (mg. g^{-1} fresh weight) in faba bean leaves according to the method of Goodwine, (1965). Also, data of flowering in expression of number of flowers, number of pods as well as;

Fruit setting % (F.S.) = No. of pods. $plant^{-1}$ / No. of flowers. $plant^{-1}$ x 100 was calculated.

At harvesting stage (130 days after sowing) representative plant sample were taken from each plot and these parameters were determined; weight of pods (g.

plant^{-1}), 100-seeds weight (g) and seed yield (kg/fed). From each plot, samples of faba bean seeds were oven dried at (70 ^{o}C) tell constant weight and digested by a sulphoric-perchloric acid mixture as described by Peterburgski, (1968) to determine N, P, K, Fe and Zn in faba bean seeds. Nitrogen and potassium contents were determined by Kjeldahl and flame photometer in the digested product, respectively according to the methods of Chapman and Pratt (1961). Phosphorus content of faba bean seeds was determined by a colorimetric method Olsen *et al*., (1954). Also, Fe and Zn were determined through atomic absorption spectrophotometer in seeds of faba bean using the methods suggested by Cottenie *et al*., (1982). Moreover, protein percentage in faba bean seeds was calculated by multiplying nitrogen percentage X 6.25 A.O.A.C. (1990).

Statistical Analysis:

All data were statistically analyzed according to the technique of analysis variance (ANOVA) by means of COSTATE software program. Means of treatments were considered significantly when they were more than the least significant differences (LSD) at significance of ($p \leq 0.05$) difference at according to Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Plant growth parameters and chlorophyll content in leaves :

Data presented in Table (2) show that the interaction effects between rock phosphate as a source of P-fertilization combined with different amendments; PDB, sulphur application and foliar spraying with Fe, Zn and (Fe + Zn) improved vegetative growth parameters; plant height (cm), fresh and dry weight (g. plant^{-1}) and chlorophyll a, b and a + b (mg. g^{-1} F.W) as compared to rock phosphate treatment. The statistical analysis of the obtained data shows that; the most suitable treatment which realized the highest mean values of all parameters of faba bean plants (123.00 cm) for plant height, (218.7 and 43.46 g. plant^{-1}) for fresh and dry weight and (0.638, 0.492 and 1.130 mg.g^{-1} F.W for chlorophyll a, b and a + b, respectively) were recorded with the treatment of rock phosphate + PDB + S + foliar applied of Fe and Zn. The increments of plant height, fresh and dry weight. plant^{-1} and chlorophyll a, b and a + b were 39.77, 54.12, 73.42, 24.6, 37.8 and 30.03 % over those obtained from the plants treated with rock phosphate individually, which realized the lowest mean values of these parameters. The previous results revealed that application of phosphorus plays a great role in activation of photosynthesis, respiration and other metabolic processes of organic compounds in plant and hence increasing plant growth. The performance of adding rock phosphate for legume crops significantly lower growth parameters than that of super phosphate, because it could possibly maintain more phosphorus in soil solution due to its lower solubility (Mohammed, 2004; Awad and Tahir 2011).

Phosphorus application combined with PDB + sulphur + foliar applied of Fe + Zn induced significant increase in the vegetative growth characters of faba bean plant. The enhancement in plant growth parameters may be due the role played by PDB in stimulation plant hormones production, such as auxins, cytokines, gibberellins and also some volatile compounds. Sulphur application helps in increasing the plant growth hence increased the uptake of the nutrients at higher levels of sulphur application. These results are in agreement with those obtained by (Mohammed, 2004; El-Gizawy and Mehasen 2009; Shirish and Popat 2013).

Table 2. Plant growth parameters of faba bean plant as affected by SP, RP, PDB, S, Fe and Zn applications.

Treatments	Plant height (cm)	Fresh weight (g. plant^{-1})	Dry weight (g. plant^{-1})	Chl a (mg.g^{-1}F.W)	Chl b (mg.g^{-1}F.W)	Chl a + b (mg.g^{-1} F.W)
SP	107.00	157.5	23.18	0.540	0.384	0.924
SP + Fe	108.66	190.8	29.41	0.591	0.436	1.028
SP + Zn	110.00	174.4	26.34	0.565	0.408	0.973
SP + Fe+Zn	112.66	208.5	32.55	0.622	0.472	1.094
RP	88.00	141.9	19.87	0.512	0.357	0.869
RP + Fe	93.00	149.7	21.44	0.530	0.374	0.905
RP + Zn	96.00	145.8	20.65	0.520	0.365	0.885
RP + Fe + Zn	99.00	153.6	22.26	0.538	0.378	0.917
RP + PDB	108.33	162.1	24.02	0.545	0.389	0.934
RP + PDB + Fe	109.66	194.9	30.27	0.598	0.446	1.044
RP + PDB + Zn	111.00	178.5	27.19	0.569	0.410	0.979
RP + PDB + Fe +Zn	112.33	211.8	33.08	0.631	0.476	1.107
RP + S	111.66	166.2	24.71	0.551	0.391	0.942
RP + S + Fe	113.66	199.1	30.95	0.604	0.454	1.059
RP + S + Zn	114.33	182.6	27.87	0.576	0.414	0.99
RP + S + Fe + Zn	115.66	214.2	33.66	0.632	0.486	1.118
RP + PDB + S	117.00	170.3	25.53	0.556	0.398	0.954
RP + PDB +S +Fe	118.33	203.8	31.74	0.614	0.461	1.076
RP + PDB + S +Zn	121.33	186.7	28.63	0.584	0.420	1.004
RP+ PDB +S +Fe+Zn	123.00	218.7	34.46	0.638	0.492	1.130
LSD at 5%	5.66	5.45	0.92	0.123	0.126	0.238

SP = superphosphate , RP = rock phosphate , PDB = phosphate dissolving bacteria and S = sulphur
Chl a = chlorophyll a , Chl b = chlorophyll b , Chl a + b = chlorophyll a + b.

Fruit setting , yield and yield components :

The interaction effects between rock phosphate as a source of P-fertilization combined with different amendments; PDB, sulphur applications and foliar spraying with Fe, Zn and (Fe + Zn) on number of flowers. plant^{-1} , number of pods. plant^{-1}, fruit setting % (F.S.), weight of pods

g. plant^{-1}, 100-seeds weight (g) and seed yield (kg/fed) of faba bean plant during the winter season 2014 /2015 are presented in Table 3. Results showed that an application of used amendments with rock phosphate such as PDB, S as soil addition and foliar spraying with (Fe + Zn) resulted in a high significant increase in the studied plant growth parameters compared to the application of different P sources in single form. However, an application of combined treatment of (RP + PDB + S + Fe + Zn) obtained the maximum number of flowers. plant^{-1} (32.6), number of pods. plant^{-1} (25.6), fruit setting (79.4 %), weight of pods. plant^{-1} (39.07 g), 100-seeds weight (64.00 g) and seed yield (1133.03 kg/fed) while, the lowest values were connected with the treatment of rock phosphate treatment in single form. The corresponding relative increments due to an addition of phosphate dissolving bacteria (PDB), sulfure (S) and Fe + Zn combination treatments for number of flowers.plant^{-1}, number of pods.plant^{-1}, fruit setting % (F.S.), weight of pods (g.plant^{-1}), 100-seeds weight (g) and seed yield (kg/fed) were 115.89, 175.26, 29.11, 56.46, 138.09 and 51.06 %, respectively over those obtained from the plants treated with rock phosphate in single form.

These increases in yield and its components of faba bean plants may be attributed to the increases in photosynthesis, both cell division and cell elongation due to sulphur application and inoculation with PDB in foliar way with Fe+Zn in the presence of RP. In addition; the vital role of combined treatments in increase the proportion or protoplasm to cell wall, and it is a part of the molecular structure of nucleic acids DNA and RNA. It also increases respiration, photosynthesis rate, chlorophyll formation, and it is also essential for division and development of meristematic tissues which impacted vegetative growth and yield. Also; sulphur is important for a good vegetative growth particularly the chlorophyll formation as well as leading to a high yield. Seed inoculation with the PDB produces organic acids and may also produce growth promoting substances such as auxins, gibberellins and cytokinins. Such substances could influence the plant growth and alter phosphate ions to be chemically liberated from the P- source. These results were agreement with the previously reported by Zeidan *et al*., (2006); El-Habbasha *et al*., (2007); Bozoglu *et al*., (2007) and El-Gizawy and Mehasen (2009) who found that plant height, 100-seed weight, number of pods/plant, seed yield/plant, seed and straw yields/fed were increased by adding 30 kg P_2O_5 mixed with PDB to soil markedly. Thus, adding 30 kg P_2O_5 mixed with PDB might be the recommended for faba bean production, where phosphorus is an essential element for root development, cell division and seed formation. This might be due to combined stimulating effect of phosphate dissolving bacteria and P fertilizer levels in supplying the growing plants with their phosphorus requirements. The increment in seed yield might be associated with high number of pods /plant, 100-seed weight and seed yield/plant.

Table 3. Flowering , yield and its components of faba bean as affected by SP, RP, PDB, S, Fe and Zn applications.

Treatments	No. of flowers.plant^{-1}	No. of pods. plant^{-1}	Fruit setting (F.S.) %	Weight of pods (g.plant^{-1})	100-seeds weight (g)	Seed yield (kg/fed)
SP	3.33	0.444	2.61	44.54	26.82	20.81
SP + Fe	3.47	0.457	3.13	51.23	25.51	21.68
SP + Zn	3.42	0.332	2.86	47.23	23.91	21.37
SP + Fe+Zn	3.55	0.464	3.43	50.62	22.63	22.18
RP	2.94	0.345	2.36	43.50	27.53	18.37
RP + Fe	3.04	0.381	2.48	49.13	27.32	19.00
RP + Zn	2.98	0.304	2.39	46.23	28.17	18.62
RP + Fe + Zn	3.11	0.412	2.57	49.06	27.93	19.43
RP + PDB	3.58	0.364	2.62	44.85	26.42	22.37
RP + PDB + Fe	3.74	0.398	3.16	52.19	25.19	23.37
RP + PDB + Zn	3.69	0.338	2.92	47.36	23.73	23.06
RP + PDB + Fe +Zn	3.78	0.431	3.52	51.56	22.40	23.62
RP + S	3.89	0.389	2.73	45.36	26.00	24.31
RP + S + Fe	4.04	0.403	3.21	53.16	24.39	25.25
RP + S + Zn	3.94	0.372	2.98	48.21	23.52	24.62
RP + S + Fe + Zn	4.12	0.434	3.56	52.07	22.09	25.75
RP + PDB + S	4.20	0.410	2.77	45.88	25.77	26.25
RP + PDB +S +Fe	4.36	0.451	3.01	54.34	24.21	27.25
RP + PDB + S +Zn	4.25	0.377	3.26	48.68	22.88	26.56
RP+ PDB +S +Fe+Zn	4.44	0.477	3.66	53.78	21.92	27.75
LSD at 5%	0.38	0.05	NS	0.77	0.15	2.39

N, P, K, Fe, Zn and protein contents in faba bean seeds:

Effect of super phosphate (SP), rock phosphate (RP), phosphate dissolving bacteria (PDB), sulphur (S) as well as foliar application of iron and zinc on N, P, K, Fe and Zn concentrations in faba bean seeds are presented in Table 4. Data revealed that faba bean seeds significantly were affected ($p \leq 0.05$) in their contents of N, P, Fe and Zn in faba bean seeds due to an addition of RP in combination with PDB and S either added individually or in combinations with foliar applications of Fe, Zn and (Fe + Zn). The K content did not significantly affected by all studied treatments. The highest N, P and K contents in faba bean seeds were obtained from the treatment of RP + PDB + S + Fe + Zn comparing with the plants treated with RP in single form. The corresponding relative increments were accounted to be (51.02, 56.90 and 55.08 %) for N, P and K contents in faba bean seeds except Fe content in faba bean seeds, the highest values were recorded when faba bean plants were treated with rock phosphate + PDB + S + Fe. The maximum increase percentage was obtained by RP +

PDB + S + Fe , which resulted in increments of 24.91 % in Fe of faba bean seeds as compared with the RP in a single form. The analysis in Table 4 shows that P fertilization, phosphate dissolving bacteria (PDB) , sulphur (S) either added individually or in combinations with foliar applications of Fe , Zn and (Fe + Zn) on Zn content in faba bean seeds had a significant effect ($P \leq 0.05$). The content of Zn in the seeds of faba bean plant decreased significantly from 28.17 $mg.kg^{-1}$ (RP + Zn) to 21.92 $mg.kg^{-1}$ (RP + PDB + S + Fe + Zn) where increased P content lead to growth enhancement and therefore the dilution of zinc content. The main reasons for effect of increment of phosphorus content on zinc deficiency can pointed to the following: increase concentrations of phosphorus lead to decrease zinc transmission of plant roots to shoot, so zinc accumulated in roots or its uptake reduces by roots. Zinc concentrations in shoots of plants reduces by effect of induced growth response (dilution effect); means that amount of zinc uptake in plant increases by increasing plant growth but its concentration decreases in plant tissues..

As shown in Table 4, data reveal that the average values of protein % of faba bean seeds were significantly increased as affected by the studied treatments investigated as compared to super phosphate or rock phosphate application treatments. The highest value of protein (27.75 %) was obtained due to the treatment of RP combined with (PDB + S + Fe + Zn). While the lowest value was (18.37 %) were recorded with rock phosphate in the absence of other amendments.

From previous results, it is clear that when phosphorus availability was increased, the N, P, K, Fe and protein contents in faba bean seeds were observed to increase except Zn content. Due to an increase in iron content in faba bean seeds which contributes in increasing nitrogen fixation by legumes then increase in protein content and seed quality. Also, phosphorus has the effect of control in photosynthetic carbon assimilation where the need for N reduces with p deficiency. The results agreed with the finding of Richards *et al.,* (2011); Weldu and Habtegriel (2013).

Table 4. Nitrogen, phosphorus, potassium, iron, zinc and protein contents in faba bean seeds as affected by studied treatments.

Treatment	N (%)	P (%)	K (%)	(Fe $mg.kg^{-1}$)	(Zn $mg.kg^{-1}$)	Protein (%)
SP	3.33	0.444	2.61	44.54	26.82	20.81
SP + Fe	3.47	0.457	3.13	51.23	25.51	21.68
SP + Zn	3.42	0.332	2.86	47.23	23.91	21.37
SP + Fe+Zn	3.55	0.464	3.43	50.62	22.63	22.18
RP	2.94	0.345	2.36	43.50	27.53	18.37
RP + Fe	3.04	0.381	2.48	49.13	27.32	19.00
RP + Zn	2.98	0.304	2.39	46.23	28.17	18.62
RP + Fe + Zn	3.11	0.412	2.57	49.06	27.93	19.43
RP + PDB	3.58	0.364	2.62	44.85	26.42	22.37
RP + PDB + Fe	3.74	0.398	3.16	52.19	25.19	23.37
RP + PDB + Zn	3.69	0.338	2.92	47.36	23.73	23.06
RP + PDB + Fe +Zn	3.78	0.431	3.52	51.56	22.40	23.62
RP + S	3.89	0.389	2.73	45.36	26.00	24.31
RP + S + Fe	4.04	0.403	3.21	53.16	24.39	25.25
RP + S + Zn	3.94	0.372	2.98	48.21	23.52	24.62
RP + S + Fe + Zn	4.12	0.434	3.56	52.07	22.09	25.75
RP + PDB + S	4.20	0.410	2.77	45.88	25.77	26.25
RP + PDB +S +Fe	4.36	0.451	3.01	54.34	24.21	27.25
RP + PDB + S +Zn	4.25	0.377	3.26	48.68	22.88	26.56
RP+ PDB +S +Fe+Zn	4.44	0.477	3.66	53.78	21.92	27.75
LSD at 5%	0.38	0.05	NS	0.77	0.15	2.39

The results mentioned previously can be discussed as follow; phosphorus plays a role in protoplasm formation, photosynthesis energy storage and transfer and protein synthesis. It may increase the proportion or protoplasm to cell wall, and it is a part of the molecular structure of nucleic acids RNA and DNA resulting in an increment in vegetative growth characters like increased cell division, cell enlargement. The obtained results agreed with these of Abdalla, (2002); Ahmed and El-Abagy (2007); El-Habbasha *et al*., (2007); El-Gizawy and Mehasen (2009); Nyoki and Patrick (2014).

Rock phosphate combined with PDB affected yield and yield components, it may be due to PDB has significant role in making phosphorus more available to plant by bringing about favorable change in soil reaction in the soil microenvironment leading to solubilizing of inorganic phosphate sources. This increment might be due to the production of growth promoting substances such as indol acetic acid, gibberellic acid and ouxin in rhizospher and could increase root growth and nutrient absorption from solution resulting in gave positive effect on accumulation of more N, P and K in the leaves and seeds. Similar results were obtained by Nassar *et al*., (2000); Abdalla (2002); Abo El-Soud *et al*., (2003); Akintokum *et al*., (2003); Hamed (2003); Ahmed and El-Abagy (2007); El-Habbasha *et al*., (2007); Awad and Tahir (2011); Shirish and Virkar (2013) and Khan *et al*., (2014).

Sulphur is important for good vegetative growth leading to a high yield and increasing absorption of macro and micronutrients. Sulphur can be oxidized in soil and produce sulphoric acid which resulted in the reduction of soil pH consequently releases the fixed nutrients such as Zn and makes them available and facilitates their absorption by plant roots. These results in agreement with the findings of Cazzato *et al*., (2012); Evans *et al*., (2006); Mohammed, (2004).

Furthermore, iron and zinc are essential micro-nutrient for plant growth, quality and yield because of functions such as enzyme activation ability , its activity in biological membrane stability and auxin synthesis and a key element for root and shoots growth during the growing season. Foliar spraying of iron and/or Zn significantly affected chemical constituents including protein content and NPK%. Such findings were reported by Mirvat *et al*., (2006); Zeidan *et al*., (2006); Bozoglu *et al*., (2007); El-Tohamy and El-Greadly (2007); Khorgamy and Farnia (2009); Ghasemian *et al*., (2010); Salwa *et al*., (2011); Keram *et al*., (2012); Gianquinto *et al*., (2014).

CONCLUSION

It can be concluded that, under the same condition of this investigation; the most suitable treatment which realized the highest economic yield, yield components as well as seed chemical composition of faba bean plants was associated with the plants treated with inoculation of faba bean seeds with phosphate dissolving bacteria (PDB) before sowing, soil addition of rock phosphate at the rate of 116 kg P_2O_5/fed and sulphur addition at the rate of 224 kg S/fed as well as foliar application of Fe and Zn at the rates of 300 and 100 mg/L, respectively.

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تعظيم كفاءة صخر الفوسفات كمصدر للتسميد الفوسفاتي لنبات الفول البلدي

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أجريت تجربة حقلية بالمزرعة البحثية بكلية الزراعة جامعة المنصورة – محافظة الدقهلية – مصر خلال الموسم الشتوي 2015/2014 لدراسة كفاءة استخدام البكتريا المذيبة للفوسفات , الكبريت , الاضافة الورقية لكل من الحديد والزنك مع صخر الفوسفات بهدف زيادة المتاح من الفوسفور عند استخدام صخر الفوسفات وتأثير ذلك علي صفات النمو- التركيب الكيماوي – المحصول ومكوناته في نبات الفول (جيزة 461). أجريت التجربة في تصميم كامل العشوائية بثلاث مكررات اشتملت التجربة علي 20 معاملة تمثل التفاعل بين خمس معاملات تسميد أرضي (سوبرفوسفات, صخر فوسفات, صخر فوسفات + بكتريا مذيبة للفوسفات, صخر الفوسفات + الكبريت,صخر الفوسفات + بكتريا مذيبة للفوسفات + الكبريت) مع أربعة معاملات اضافة ورقية (1) الرش بماء الصنبور, (2) الرش بالحديد بمعدل 300 ملليجرام حديد/ لتر، (3) الرش بالزنك بمعدل 100 ملليجرام زنك / لتر، (4) الرش بمحلول يحتوي علي 300 ملليجرام حديد/ لتر و 100 ملليجرام زنك / لتر وبذلك يكون اجمالي عدد الوحدات التجريبية 60 وحدة. أظهرت النتائج أن اضافة صخر الفوسفات + البكتريا المذيبة للفوسفات + الكبريت مع الرش بالحديد والزنك معا كان له تأثير معنوي حيث سجلت أعلي قيم لصفات النمو الخضري (طول النبات, الوزن الطازج والجاف, الكلوروفيل أ,ب, أ+ب) وصفات المحصول ومكوناته (عدد الازهار/نبات, عدد القرون/نبات, النسبة المئوية للعقد, وزن القرون/نبات, وزن 100 حبة, محصول الحبوب) لنبات الفول البلدي. كذلك لوحظ زيادة معنوية في محتوي النيتروجين , الفوسفور , البوتاسيوم بالاضافة الي النسبة المئوية للبروتين في حبوب الفول البلدي وذلك مقارنة بأقل القيم التي سجلت عند استخدام صخر الفوسفات بصورة فردية باستثناء محتوى الحديد في حبوب الفول قد سجل أعلى القيم عند معاملة نباتات الفول البلدي بـ صخر الفوسفات + البكتريا المذيبة للفوسفات + الكبريت + حديد . ولكن لم يكن هناك تأثير معنوي علي محتوي حبوب الفول البلدي من البوتاسيوم. انخفض محتوى الزنك في حبوب نبات الفول البلدي بشكل ملحوظ لذلك سجلت أقل قيم محتوي الزنك في حبوب الفول البلدي مع صخر الفوسفات + البكتريا المذيبة للفوسفات + الكبريت + حديد + زنك مقارنة بـ صخر الفوسفات + زنك بسبب التخفيف الناتج عن استجابة النمو لقيم الفوسفور والتي تعرف باسم نقص الزنك الناتج عن الفوسفور. عموما تحت نفس ظروف هذه الدراسة، يمكن الاستنتاج أن اضافة صخر الفوسفات مع البكتريا المذيبة للفوسفات + الكبريت مع الرش بمعدل 300 ملليجرام حديد / لتر + 100 ملليجرام زنك / لتر قد تكون المعاملة الموصي بها لتعزيز انتاجية محصول الفول البلدي.