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Impact of Microorganisms Activity on Phosphorus Availability and its Uptake by Faba Bean Plants Grown on Some Newly Reclaimed Soils in Egypt

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ABSTRACT

Two field experiments were conducted on two soil types, i.e., calcareous and sand soils located at West Nubaria and El Bostan regions respectively, Egypt, during the growing season of 2004. The current work aims to evaluate the effect of inoculation with Vesicular Arbuscular Mycorrhizal (VAM) and Phosphate Dissolving Bacteria (PDB, cited as a commercial product from Agriculture Research Center and called Phosphorin) on some soil physical properties, availability of P, some micronutrients (Fe, Mn, Zn & Cu) as well as their up-take by faba bean plants (*Vicia faba* L.) grown on the studied soils. VAM or PDB was used solely or in combination with three different levels of P-mineral supply for each of the studied soils (mono-super-phosphate, 15.5% P_2O_5). Some plant parameters such as no. of nodules/plant, weight of nodules/plant, dry weight/plant, 100 seed weight and seed yield were also determined. The results obtained revealed that inoculation with VAM tended to decrease the values of soil bulk density in both the studied soils. It also caused an increase in the infiltration rate of calcareous soil, while an opposite trend was observed in the sandy one. Moreover, inoculation with VAM and PDB as solely or dually under the applied three P-mineral levels supply enhanced P and micronutrients availability in soil, consequently tended to increase their up-take by faba bean plants. These beneficial effects were positively reflected on each of the studied plant parameters of faba bean grown on both calcareous and sandy soils under consideration.

Key Words: Calcareous soil; Sandy soil; Faba bean; P-mineral fertilizer; VAM and PDB

INTRODUCTION

Egypt faces a noticed reduction in fertile cultivated soils in the old Nile Valley and Delta, which represent about 3 - 4% of the total area of Egypt. So, an attention was direct towards the desert soils, either those characterized by sandy or calcareous in nature, reclamation and cultivation. The fertility status of these soils are poor, in turn, application of bio-fertilization by using micro-organisms to improve it through their activities and providing most of the essential nutrients required to plant growth and crop productivity. That can be achieved through nutrients bio-fixation and released from inert state or nutrients bearing minerals. This was a great reflect on the nutritional aspects of both human and animal feeding. The microbial biomass is important in soil through various activities and through the potential to act as nutrients sink/source (Schnürer & Rosswall, 1987).

Phosphorus is the second to nitrogen as a mineral nutrient required by both plants and micro-organisms. The newly reclaimed desertic soils, i.e., calcareous and sandy ones, are of low availability of phosphorus and micronutrients to plant (Koreish *et al.*, 1998). Application of mineral fertilizers to the calcareous and sandy soils proved to be ineffective could be due to alkaline reaction of these soils (Wahba *et al.*, 2000). In addition, sandy soil is poor in its content of nutrients to start with and the low contents of organic matter and clay minerals that prevent the soil from preserving water and nutrients (Abou Hussien *et al.*, 2002).

Biological fertilization becomes an important factor to increase availability of P and micronutrients to improve their up-take deficiencies. Khalafalla *et al.* (1988) reported that actionmycetes have a great effect in dissolving tri-calcium phosphate in calcareous soils of Egypt. Mycorrhizal fungi and P-dissolving bacteria as biological activities have an important role in solubilizing of P and enhancing its absorption as well as improve seed germination and yield of plant, which has been attributed solely to N 2-fixation (Habashy, 2005).

The effect of arbuscular mycorrhizal fungi on plant growth often related to the increase of nutrients availability and up-take. The proposed mechanism is the increase of surface area by growth of mycorrhizal hyphae associated with roots in to soils, the absorption of nutrients by hyphae and their translocation to plant, mobilizing sparingly available nutrients and releasing of chelating compounds or exo-enzymes (Bolan, 1991). The ability of rhizosphere bacteria to solubilize phosphorus may be important in soils of Egypt, where available phosphorus is low. The workers reported that the application of P-solubilizing bacteria increased the efficiency of phosphoric fertilizer through solubilizing the fixed forms by acids produced from bacteria (Attia & Badr El Din, 1999).

The current work aims to evaluate the effect of inoculation with Vascular Arbuscular Mycorrhizal and Phosphate Dissolving Bacteria (PDB, cited in a commercial product from Agriculture Reserch Center and called Phosphorin) used as solely or in combination with three different rates of P-mineral fertilizer (mono-super-phosphate, 15.5% P_2O_5) on some soil physical properties and availability of P or some micronutrients. The micronutrients up-take by faba bean plants (*Vicia faba* L.) grown in both calcareous and sandy soils were also under taken, with special reference to some plant parameters such as weight of nodules/plant, dry weight/plant, 100 seed weight and seed yield.

MATERIALS AND METHODS

Field experiment. Two field experiments were carried out in two locations, i.e., a calcareous soil at West Nubaria region and a sandy one at Experimental Farm of Ali Mobarak, El Bostan regoin. The soils were cultivated with faba bean plants (*Vicia faba* L.) during the growing season of 2004.

Both experiments were designed as a split plot (5 x 5 m area), with four replicates for each main treatment. P-mineral fertilizer was added at rates 24, 48 and 72 kg P_2O_5/fed for calcareous soil and 36, 72 and 108 kg P_2O_5/fed for sandy one in the form of mono-super-phosphate (15.5% P_2O_5) added during soil preparation. N-mineral fertilizer at a rate 50 kg N/fed in the form of ammonium nitrate (33.5% N) was added in two equal doses after 20 and 40 days from planting. K-mineral fertilizer at a rate 24 kg K_2O/fed in the form of potassium sulphate (48% K_2O) was added just after 40 days from planting.

Inocula used. It was represented by a mixture of Vesicular Arbuscular Mycorrhizal (VAM) inoculum in the form of *Glomus macrocarpium*. This inoculum was originally extracted by a wet sieving and decanting technique (Gerdemann & Nicolson, 1963) from rhizosphere soil. The mycorrhizal inoculum consisted of infected root fragments, spores and mycelium. An inoculum of Phosphate Dissolving Bacteria (PDB) was used from a commercial product of Agriculture Research Center and called Phosphorin.

Inoculation. Four groups of phosphorus treatments were distinguished as follows:

1- Un-inoculated seeds (control treatment).
2- Seeds mixed well with Vesicular Arbuscular Mycorrhiza (VAM).
3- Seeds inoculated with Phosphate Dissolving Bacteria (PDB).
4- Seeds inoculated with a mixture of VAM and PDB.

Soil analysis. Soil surface samples (0 - 25 cm) were taken, then air dried, ground, sieved through a 2 mm sieve and then subjected to determine some soil chemical and physical properties (Black, 1965) as well as available phosphorus (Olsen & Sommers, 1982). DTPA extractable of Zn, Fe, Mn and Cu (Lindsay & Norvell, 1978) were also determined using Atomic Adsorption Spectrophotometer.

RESULTS AND DISCUSSION

General view on the experimental soils. Initial state of the two experimental soil sites are shown in Table I, which indicate that calcareous soil is characterized by medium textural grade (sandy clay loam), with a relatively high $CaCO_3$ (35.0%). However, the texture of other soil site is sandy, with a low content of $CaCO_3$ (2.83%). Soil pH values tend to be alkaline side for both the studied soils. The available micronutrient contents of soils under consideration are lower than the critical limits as well as available P, which is lower too. Accordingly, the studied soils are suffering from deficient in plant nutrients.

Effect of inoculation under p levels supply on soil bulk density and infiltration rate. Soil bulk density and infiltration rate are two major functions of the change in the soil conditions, especially soil structure. As for the calcareous soil, data in Table II showed that the values of soil bulk density, as mean values, were significantly

Table I. Some physico-chemical characteristics of the studied soil (0-25 cm).

Soil characteristics	Calcareous soil	Sandy soil	Soil characteristics.	Calcareous soil	Sandy soil
Particle size distribution %:			Soil paste extract:		
Sand	48.23	92.43	ECe (dS/m)	1.32	0.25
Silt	29.12	4.35	Soluble ions (meq/L):		
Clay	22.65	3.22	Ca^{++}	3.79	0.85
Textural class	SCL*	Sandy	Mg^{++}	1.85	0.71
Soil fertility status:			Na^+	6.18	1.25
Available nutrients (mg/kg soil):			K^+	0.72	0.11
N	27.11	9.95	CO_3^{--}	0.00	0.00
P	4.90	3.90	HCO_3^-	1.88	1.25
K	209.88	70.38	Cl^-	7.44	1.15
Fe	4.16	3.72	SO_4^{--}	3.22	0.52
Mn	0.84	0.66	pH (1:5 soil water suspension)	8.44	7.68
Zn	0.48	0.29	Organic matter %	0.67	0.22
Cu	0.32	0.21	$CaCO_3$ %	35.60	2.83

* Sandy clay loam

decreased with inoculation by VAM solely or in combination with PDB (VAM + PDB) as compared to the control treatment. However, inoculation with PDB solely caused an insignificant decrease in soil bulk density. These trends were observed under different applied P-mineral rates.

Also, soil infiltration rate, as mean values, showed a significantly increased with inoculation by VAM added as solely or in combination with PDB (VAM + PDB) in the calcareous soil as compared to the control treatment. The infiltration rate was un-affected with inoculation by PDB solely under different levels of P fertilizer. As for the infiltration rate in sandy soil, the values obtained exhibited an opposite trend.

The beneficial effects of inoculation by both VAM and PDB on the values of soil bulk density and infiltration rate might be related to continuous activities of these micro-organisms, which built up surface area by growth of mycorrhizal phases associated with roots in to soil. These conditions enhanced the formation of false soil aggregates that caused a reduction in soil bulk density for both studied soils as well as infiltration rate of sandy soil. On the other hand, these favorable conditions encouraged the formation of conductive pores in calcareous soil that enhancing the movement of excess water under flooding system, and in turn increasing the infiltration rate (Frighettc *et al.*, 1999).

Effect of inoculation under p levels supply on soil availability of P and_micronutrients. The availability of soil phosphorus and micronutrients in the studied calcareous and sandy soils were greatly affected by inoculation, as shown in Table III. The data obtained indicate that soil available P was significantly increased with inoculation, with a superior effect for the combined treatment of VAM + PDB followed by VAM or PDB when added solely. The higher values of available P in sandy soil in all treatments as compared to calcareous one has been reported by Rausschkolb *et al.* (1976) and O'Neill *et al.* (1979) who found an increase in soil P content to 50 cm in calcareous supernatant. It is worthy to mention that the Ca-phosphate precipitation occurs in calcareous soil after the initial phosphate adsorption reaction is a function of pH and of the concentrations of both Ca and P present in soil solution. Also, the depletion in soil moisture content towards harvest time might affect in sandy soil than calcareous one. Daniels and Trappe (1980) reported that spore germination was favored in soil at or above field capacity, but it decreased with decreasing water potentials below field capacity.

Similar trend to soil available P and the DTPA extractable Fe, Mn, Zn and Cu were also significantly increased with inoculation than the control treatment. Both Fe and Mn were more affected by the different P additives and inoculation for growth, where their values reached the significance levels at the combined treatment of VAM + PDB.

Effect of inoculation under P levels supply on faba bean yield and its components. Effect of inoculation and applied P levels on faba bean yield and its components were tabulated in Table IV. A significant nodulation occurred in both the studied calcareous and sandy soils infected with mycorrhizal inoculation. Mycorrhizal inoculation was more positively affected the values of nodulation in the sandy soil as compared to the calcareous one, may due to the sensitivity of faba bean to a relatively high pH and other adverse environmental factors that characterized calcareous soil. Similar observation was recorded by Bond *et al.* (1985) and Schubert (1995).

In sandy soil, nodulation was also achieved a significant effect, due to the released P, in addition to common relatively low soil pH. These results are in agreement with those obtained by Giller and Wilson (1991). The effects of mycorrhizal inoculation under P levels supply on dry weight, 100 seed weight and seed yield were significantly enhanced at all applied treatments in both calcareous and sandy soils under investigation. Hamdi (1982) observed that application of P without mycorrhizal inoculation increased faba bean yield, but the increase was

Table II. Effect of inoculation under P levels supply on the values of soil bulk density and infiltration rate at both the studied soil sites.

Treatments of inoculation with VAM or PDB		Calcareous soil		Sandy soil	
		Bulk density (g/cm^3)	Infiltration rate (cm/h)	Bulk density (g/cm^3)	Infiltration rate (cm/h)
Control	P1	1.364	5.55	1.644	8.48
	P2	1.368	5.53	1.641	8.44
	P3	1.374	5.50	1.633	8.32
VAM	P1	1.284	6.32	1.562	7.36
	P2	1.281	6.36	1.538	7.22
	P3	1.279	6.39	1.524	7.15
PDB	P1	1.326	5.50	1.626	8.40
	P2	1.310	5.45	1.613	8.23
	P3	1.303	5.40	1.605	8.12
VAM+PDB	P1	1.265	6.48	1.532	7.13
	P2	1.260	6.54	1.517	7.08
	P3	1.256	6.60	1.504	7.01
L.S.D. at 0.05		0.12	0.05	0.70	0.88

Table III. Effect of inoculation under P levels supply on soil availability of P and micronutrients in the studied soils.

Treatment		Calcareous soil					Sandy soil				
		P	Fe	Mn	Zn	Cu	P	Fe	Mn	Zn	Cu
Control	P1	4.86	4.54	0.86	0.42	0.34	3.71	3.55	0.67	0.28	0.24
	P2	5.01	4.86	0.91	0.48	0.39	3.86	3.75	0.75	0.34	0.26
	P3	5.24	4.97	0.94	0.51	0.41	4.02	3.91	0.78	0.36	0.29
VAM	P1	7.11	6.18	0.90	0.64	0.61	8.44	4.22	0.84	0.61	0.30
	P2	7.60	6.65	0.98	0.83	0.78	8.89	4.70	0.87	0.70	0.36
	P3	7.96	6.81	1.15	0.95	0.81	9.12	4.88	0.95	0.78	0.45
PDB	P1	5.78	5.18	0.89	0.56	0.45	6.15	3.75	0.70	0.39	0.28
	P2	6.05	5.79	0.97	0.60	0.53	6.22	3.97	0.79	0.45	0.31
	P3	6.34	6.09	1.03	0.67	0.57	6.65	4.05	0.81	0.56	0.34
VAM	P1	8.44	7.14	1.18	0.87	0.75	8.93	5.43	1.00	0.79	0.53
+ PDB	P2	8.81	7.26	1.67	0.94	0.86	9.11	5.69	1.09	0.83	0.60
	P3	9.00	7.55	1.99	1.10	0.90	9.64	5.99	1.17	0.92	0.68
L.S.D. at 0.05		1.41	0.83	0.38	0.18	0.40	1.30	0.30	0.29	0.09	0.20

Table IV. Effect of inoculation on under P levels supply faba bean parameters in the studied soils.

Treatments		Calcareous soil						Sandy soil					
		No. of nodules/ plant	Weight of nodules/plant (g)	Dry weight/plant (g)	100 seed weight (g)	Crop yield (ton/fed)	Crop yield Relative increase %	No. of nodules/ plant	Weight of nodules/plant (g)	Dry weight/plant (g)	100 seed weight (g)	Crop yield (ton/fed)	Crop yield Relative increase %
Control	P1	40.54	2.35	110.12	75.66	2.65	--	41.73	1.19	71.66	82.22	2.62	--
	P2	43.11	2.40	112.16	76.96	2.73	--	44.66	1.26	72.70	84.65	2.66	--
	P3	45.99	2.46	113.95	79.59	2.77	--	46.82	1.35	75.88	88.75	2.68	--
VAM	P1	45.88	2.47	136.71	97.99	3.36	22.26	46.67	1.77	84.99	98.11	2.97	12.03
	P2	46.92	2.49	138.78	98.44	3.40	23.31	49.72	1.82	86.45	98.99	2.98	13.36
	P3	47.89	2.50	140.50	99.78	3.45	24.55	52.96	1.91	88.00	99.14	3.06	14.16
PDB	P1	47.88	2.49	135.00	98.78	2.98	12.45	47.22	1.79	85.39	98.65	2.85	7.14
	P2	47.98	2.56	138.22	98.93	3.10	13.55	49.00	1.84	86.35	98.93	2.86	8.78
	P3	49.91	2.59	139.35	99.24	3.19	15.16	51.11	1.89	88.21	99.51	2.97	10.82
VAM + PDB	P1	47.90	2.62	139.70	99.53	3.40	22.06	50.67	1.99	97.22	99.73	3.09	16.16
	P2	50.99	2.69	140.61	100.06	3.45	26.37	54.56	2.03	99.11	99.98	3.22	22.90
	P3	55.71	2.73	141.45	101.51	3.59	29.60	59.72	2.10	100.00	100.11	3.33	24.25
L.S.D. at 0.05		3.75	0.09	19.00	12.11	0.22	--	4.73	0.33	12.22	10.88	0.30	--

Table V. Effect of inoculation under P levels supply on phosphorus and micronutrients in mg/g dry weight of plant.

Treatment		Calcareous soil					Sandy soil				
		P	Fe	Mn	Zn	Cu	P	Fe	Mn	Zn	Cu
Control	P1	0.25	211.55	77.19	18.46	4.22	0.24	200.14	67.44	19.00	3.94
	P2	0.28	239.11	77.66	22.81	5.39	0.26	222.11	69.11	20.98	4.22
	P3	0.29	240.22	82.12	25.29	5.57	0.28	230.29	70.22	25.00	4.33
VAM	P1	0.35	330.22	80.98	50.17	6.22	0.33	321.17	69.29	43.33	5.00
	P2	0.36	350.81	84.18	55.32	6.96	0.34	340.22	72.32	44.82	5.97
	P3	0.38	362.73	89.44	60.19	7.93	0.35	351.11	77.79	76.77	6.22
PDB	P1	0.33	320.99	92.69	40.96	5.99	0.29	360.88	80.84	57.33	5.22
	P2	0.34	324.18	94.65	44.22	6.50	0.30	375.81	84.91	59.82	5.40
	P3	0.36	341.22	99.15	49.28	6.94	0.33	380.12	88.95	60.79	5.93
VAM + PDB	P1	0.44	37.92	80.17	64.22	9.22	0.43	221.00	74.12	40.22	7.89
	P2	0.46	385.27	83.76	68.29	11.17	0.45	311.55	79.81	43.52	8.11
	P3	0.49	399.18	85.12	69.12	1180	0.49	330.12	82.22	50.21	8.99
L.S.D. at 0.05		0.09	88.66	3.11	14.66	0.88	0.05	77.24	6.61	14.82	0.77

Table VI. Effect of inoculation under P levels supply on phosphorus and micronutrients in kg/fed.

Treatment		Calcareous soil					Sandy soil				
		P	Fe	Mn	Zn	Cu	P	Fe	Mn	Zn	Cu
Control	P1	28.50	24114	8054	2104	481	17.25	14386	4847	1365	283
	P2	30.80	26340	8503	2512	593	19.68	16138	5102	1588	314
	P3	48.17	27894	9535	2936	646	20.34	17432	5231	1816	319
VAM	P1	49.20	46395	11377	7048	873	29.04	28.174	6097	3813	440
	P2	49.90	48685	11682	7677	965	29.39	29412	6252	3874	518
	P3	51.90	49587	12227	8228	1084	29.74	29840	6611	3975	529
PDB	P1	45.90	31239	11171	5707	834	24.73	18849	6321	3430	446
	P2	46.90	44367	11491	6112	898	25.79	26790	6862	3742	464
	P3	48.60	46064	11577	6654	936	28.22	29119	7252	4429	522
VAM + PDB	P1	62.00	52466	13103	9083	1304	41.62	35766	8012	5681	782
	P2	64.30	53826	13223	9540	1560	42.77	36536	8254	5815	788
	P3	66.60	56128	13941	9718	1659	47.00	38012	8895	6079	899
L.S.D. at 0.05		6.22	22122	488	4322	366	10.77	13699	1230	2423	143

greater at inoculation in combination with P application. Similar results were reported by Ibrahim *et al.* (1982), Koreish *et al.* (1998) and Amanuel *et al.* (2000).

Effect of inoculation under P levels supply on P and micronutrient contents and their up-take by faba bean. Data illustrated in Tables V and VI indicate that the concentrations of P, Fe, Mn, Zn and Cu up-take were significantly increased by inoculation as compared to the control treatment. Higher values of P, Fe, Mn, Zn and Cu up-take, as means, were observed by inoculation with VAM + PDB, while inoculation by VAM or PDB solely recorded relatively lesser values. In this connection, Elwan and El Sharawy (1994) and Koreish *et al.* (2001) showed that concentrations of nutrients up-take by maize and faba bean were increased by mycorrhizal inoculation. El Sharawy *et al.* (1995) found a similar trend for VAM, PDB added as solely and dual inoculation. The relative low Mn concentration in mycorrhizal plants has been observed by

Arimes *et al.* (1989) and Kothari *et al.* (1991).

Moreover, results tabulated in Tables V and VI revealed that P and micronutrient contents and up-take with PDB inoculation was lower than mycorrhizal inoculation in both studied types of soils. This indicates the importance of VAM for improving of adsorption and accumulation of elements in higher plants.

In conclusion, from the aforementioned results, it could be concluded that mycorrhizal or phosphate dissolving bacteria application improved P and micronutrients availability and their up-take by plants. The dual application of mycorrhizal and P dissolving bacteria present in phosphorin have greater impact due to synergestic effect of both fungi and bacteria on soil fertility, and in turn on plant productivity. So, it is recommended by inoculating faba bean in both calcareous and sandy soils with both VAM and phosphorin dually.

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