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INFLUENCE OF WHEAT INOCULATION WITH MYCORRHIZAL FUNGI, PHOSPHATE SOLUBILIZING BACTERIA AND AZOSPIRILLUM ON ITS GROWTH AND SOIL FERTILITY

BY

Zaghloul, R.A.*; Mostafa, M.H. and Amer, A.A.****

* Agric. Botany Dept., Fac. of Agric. Moshtohor, Zagazig Univ., Egypt.
** Water, Soil and Environment Institute Research, Agric. Res. Center, Ministry of Agriculture, Egypt.

ABSTRACT

The influence of inoculation with mycorrhizal fungi and phosphate solubilizing bacteria in the presence of associative N2-fixers (*Azospirillum brasilense*) on wheat (Sakha 8 cultivar) and soil fertility was studied. Inoculation of wheat grains with phosphate solubilizing bacteria (PSB) gave the highest counts of Azospirilla and inorganic phosphate dissolvers compared with the inoculation with vesicular Arbuscular Mycorrhiza (VAM). Dehydrogenase activity of the soil was higher in the (VAM) treatments than (PSB) treatments. Also, organic carbon, ammoniacal and nitrate nitrogen, total and available phosphorus, nitrogen and potassium were higher in the tested soil when wheat grains were inoculated with VAM compared with its inoculation by phosphate solubilizing bacteria. Soil content from the abovementioned nutritional elements was higher during heading stage of wheat than other plant growth stages. The inoculation with VAM gave higher values of N, P and K concentrations in wheat plants compared with the inoculation with PSB. There was a significant difference in spike weight, grain weight/spike, root system length and dry weight of root and shoot system/plant which were highly significant in the presence of VAM compared with phosphate solubilizing bacteria. In contrary, there is no significant difference in studied growth characters and grain yield of wheat when superphosphate or rock phosphate was used as phosphorus fertilization in the presence of microbial inocula.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops in Egypt. The positive effect of soil nitrogen and phosphorus fertilization on yield of wheat has already been recognized by several investigators. Biofertilizers, either solely or in combination with certain chemical additives proved to be an efficient tool in increasing available nutrients in soil as well as crop yields (Kabesh *et al.*, 1975). Ahmed and Jha (1978) found that mixed inoculation with N_2-fixers and phosphate solubilizing bacteria (PSB) increased dry matter content, grain yield and P uptake in cereal crops. Li (1981) showed that inoculation with phosphate dissolving bacteria (PDB) supply the plant with its needs of phosphorus and increase the yield and its component. Plant may support VA-mycorrhiza and asymbiotic N_2-fixing bacteria simulatneously. The importance of interaction between mycorrhiza and N_2-fixing bacteria has been reported by Daft *et al.*, (1985). Their study showed that the interaction improves plant growth. El-Haddad *et al.*, (1986) reported that grains inoculation with non-symbiotic N_2-fixing bacteria resulted higher yields and reduced N-requirements fertilization to 50%. Azazy *et al.*, (1988) revealed that biofertilization by phosphate dissolving bacteria increased the total bacterial count, fungi, phosphate dissolvers and asymbiotic N_2-fixers in cultivated soil. Cacciari (1988) and Mahmoud *et al.*, (1993) emphasized that auxins, gibberellins and cytokinins are produced by *Azospirillum brasilense* which improve growth of plants and produced high growth parameters, nutrient content, protein content in grains and yield of crop. Blaszkowski (1993) stated that wheat plants inoculated with mycorrhizal fungi were significantly taller than uninoculated, as well as, the root and shoot dry weight, nitrogen, phosphorus and potassium content in soil were significantly increased. Abbas *et al.*, (1993) and Hussein *et al.*, (1993) mentioned that the inoculation with associative N_2-fixers (*Azospirillum brasilense*) had increased dry matter, grain yield, protein yield and nitrogen uptake by wheat over the uninoculated treatment. Ishac *et al.*, (1993) mentioned that wheat inoculation with N_2-fixing bacteria resulted considerable improvement of the plant growth and N-uptake. Also, mixed inoculation with *Azotobacter* and VAM in the presence of rock phosphate increased growth parameters, N-uptake and grain yield of wheat.

This study was done to investigate the influence of inoculation with VAM and phosphate solubilizing bacteria in the presence of *Azos. brasilense* on wheat growth.

MATERIALS AND METHODS

A pot experiment was carried out under greenhouse conditions. The soil used in this research was loamy sand (organic matter 0.7%, total nitrogen 0.07%, total phosphorus 0.04%, $CaCO_3$ 0.23%, pH 7.44 and E.C. 1.76 m mohs/cm). It was obtained from El-Dir Village, Qualubia governorate and the soil samples were collected from 0-15 cm layer, air dried, ground to pass through a 2 mm sieve and was thoroughly mixed. 30 cm diameter pots were filled with the soil (6 kg/pot) and divided into two groups. Before cultivation, the first group was supplied with calcium superphosphate at a rate of 30 kg phosphorus/feddan, while the second was supplied with rock phosphate at the same rate mentioned above. Except for control treatment, wheat grains were coated by an effective inoculum from *Azospirillum brasilense* and then divided into two groups. The first group was inoculated with an effective strain of *Bacillus megatherium* var. *phosphaticum*, whereas the other was inoculated with vesicular arbuscular mycorrhiza (VAM) (*Glomus mosseae*). For preparation of bacterial inocula. Dobereiner medium (1978) and modified Bunt and Rovira medium (Abdel-Hafez, 1966) were inoculated by effective strains of *Azospirillum brasilense* and *B. megatherium* var. *phosphaticum*, respectively, then incubated at 30°C for 7 days till the viable count reached 10^8 cell/ml. This experiment included the following treatments:

- Control.
- Mycorrhiza (*Glomus mosseae*) + superphosphate.
- Mycorrhiza (*Glomus mosseae*) + rock phosphate.
- *B. megatherium* var. *phosphaticum* as phosphate solubilizing bacteria (PSB) + superphosphate.
- *B. megatherium* var. *phosphaticum* + rock phosphate.
- Only superphosphate.
- Only rock phosphate.

Four pots were used as replicates for every treatment in a randomized complete block design. Cultivation process was performed by sowing ten inoculated or uninoculated grains of wheat (*Triticum aestivum* cv. Sakha 8) in every pot and thinned later to five plants.

All pots were supplemented with a half dose of inorganic nitrogen fertilizer (45 kg N/feddan) in two equal doses at tillering and heading stages.

Sampling and determinations:

After 45, 90, 120 and 180 days from sowing, rhizosphere soil samples of the developed plants were taken. These periods were considered and referred to in the results discussion as the tillering, heading, grain formation and maturity stages, respectively. The samples were microbiologically and chemically analyzed.

1. Microbiological analyses:

1-1- Phosphate dissolving bacteria and *Azospirillum spp.* were chosen as representative of phosphate dissolvers and asymbiotic N_2-fixers respectively. Counts of inorganic phosphate dissolving bacteria and *Azospirillum spp.* were estimated on modified Bunt and Rovira medium (Abdel-Hafez, 1966) and Semi-solid malate medium (Dobereiner, 1978) using plate count and MPN technique, Cochran (1950), respectively.

1-2- Dehydrogenase activity in the soil was assayed by the method described by Casida *et al.*, (1964).

2. Chemical analyses:

2-1- Organic carbon was estimated according to Black *et al.*, (1965).

2-2- Total phosphorus was colorimetrically determined according to Troug and Mayer (1949).

2-3- Ammoniacal and nitrate nitrogen were estimated according to Morkus *et al.*, (1982).

2-4- Total nitrogen was estimated in soil and plant samples using Kjeldahl digestion method as described by Jackson (1973).

2-5- Total potassium was estimated by flame photometer apparatus according to the method described by Brown and Lilliland (1946).

2-6- Available phosphorus was extracted from soil according to Olsen *et al.*, (1954) and colorimetrically determined according to Troug and Mayer (1949).

At the end of the experiment, wheat plants were harvested, then plant height, root length, spike length, spike weight, grain weight/spike, number of spikelets/spike, fresh and dry weight of root and shoot system/plant were measured. Also, nitrogen, phosphorus and potassium were determined in shoot system. The obtained data of growth characters were statistically analysed according to Snedecor and Cochran (1982).

RESULTS AND DISCUSSION

Effect of inoculation with VAM and PSB on microbial counts and dehydrogenase activity:

1. Changes in *Azospirillum spp.* counts:

Data in Table (1) clearly indicate that inoculation of wheat grains with phosphate solubilizing bacteria (PSB) gave higher counts of *Azospirillum spp.* than its inoculation with vesicular arbuscular mycorrhiza (VAM) and this trend was observed during all growth stages. The lowest counts of *Azospirillum spp.* were recorded in uninoulated treatments where soil only recived superphosphate or rock phosphate fertilizers. The counts of *Azospirillum spp.* increased with increasing the growth period to reach their maximal values during the grain formation stage and decreased thereafter. This was true in all treatments. Also, results showed that there wass no difference in *Azospirillum spp.* counts due to P-fertilization source. These results are in agreement with those obtained by Barea and Conzalez (1986) and Ishac *et al.*, (1993) who reported that rock phosphate could be a useful substance for VAM infected plants even at high pH values.

2- Changes in populations of inorganic phosphate dissolving bacteria:

Data in Table (2) revealed that the inoculation of wheat grains with *B. megatherium* var. *phosphaticum* gave the highest counts of inorganic phosphate dissolvers compared with the other treatments in various growth stages. The counts of inorganic phosphate dissolvers gradually increased with increasing the growth period to reach their maximal values during the grain formation stage. This increase could be attributed to the high beneficial effect of root secretions during the grain formation stage in most cultivated crops. Similar results were observed by Azazy *et al.*, (1988) who reported that biofertilization by phosphate dissolving bacteria increased the total bacterial count, fungi, phosphate dissolvers and asymbiotic nitrogen fixers in cultivated soil.

Table (1): Periodical changes in *Azospirillum spp.* counts ($x10^3$/gram dry weight of soil) during various growth stages of wheat.

Treatments	Plant growth stage			
	Tillering	Heading	Grain formation	Maturity
Control	3	7	22	12
Superphosphate	9	20	50	36
Rock phosphate	7	18	46	32
VAM + superphosphate	13	34	110	94
VAM + rock phosphate	11	30	100	92
PSB + superphosphate	24	38	170	140
PSB + rock phosphate	20	36	160	132

Table (2): Periodical changes in populations of inorganic phosphate dissolvers ($x10^6$/gram dry weight of soil) during various growth stages of wheat.

Treatments	Plant growth stage			
	Tillering	Heading	Grain formation	Maturity
Control	1.8	3.2	5.0	3.6
Superphosphate	5.8	12.2	20.0	15.0
Rock phosphate	4.4	8.0	14.0	10.0
VAM + superphosphate	6.8	14.0	28.0	20.0
VAM + rock phosphate	7.2	16.0	26.0	18.0
PSB + superphosphate	9.6	18.0	38.0	24.0
PSB + rock phosphate	8.8	16.0	36.0	20.0

3. Changes in dehydrogenase activity:

It can be observed from Table (3) that dehydrogenase activity varied according to the phosphorus solubilizing microorganisms as well as the phosphorus fertilization source. VA-mycorrhiza fungi treatments clearly showed higher dehydrogenase activity values than phosphate solubilizing bacteria and this was true in all plant growth stages. Dehydrogenase activity was higher with superphosphate than rock phosphate in the presence of VAM or PSB as well as when was used without microbial inoculation. Also, dehydrogenase activity increased with increasing the growth period to reach their maximum values during the grain formation stage and decreased thereafter. This may be due to the higher counts of Azospirillum spp. and phosphate dissolving bacteria during the grain formation stage which were previously discussed.

Effect of microbial inoculation on nutritional elements in soil:

1. Effect on organic carbon:

Data in Table (4) show that the organic carbon content of the tested soil was higher in the VAM treatments compared with the inoculation with phosphate solubilizing bacteria. Generally, the inoculation of wheat grains with VA-mycorrhiza or phosphate solubilizing bacteria led to increasing the organic carbon percentage compared with the uninoculated treatments. Soil organic carbon percentage gradually decreased with increasing the growth period and this was true in all treatments.

2- Effect on nitrogen forms:

The results presented in Table (5) revealed that the ammonical and nitrate nitrogen content of soil varied according to the phosphorus solubilizing microorganisms and phosphorus fertilization source. The nitrogen forms increased at the commencement of growth period in case of inoculation with (PSB), while, there was an increase in nitrogen forms in the delayed growth periods when wheat grains were inoculated with VAM. Also, data showed that the ammoniacal nitrogen decreased with increasing growth period, while, the nitrate nitrogen increased. Generally, inoculation of wheat grains before cultivation with VAM or PSB in the presence of effective strain of *Azospirillum brasilense* increased the soluble nitrogen forms compared with uninoculated treatments. This increase of ammoniacal and nitrate nitrogen may be due to nitrogen fixation by *Azospirillum brasilense*. These results are in accordance with findings of Cacciari *et al.*, (1988) and Ishac *et al.*, (1993) who reported that biofertilization by VAM in the presence of asymbiotic N_2-fixing bacteria produced high growth parameters and increased nutrients content in the soil.

3- Effect on total and available phosphorus:

Data in Table (6) clearly show that the soil total phosphorus increased with inoculation of wheat grains with VAM in all growth stages of wheat compared with the inoculation with PSB. The inoculated treatments showed

Table (3): Changes in dehydrogenase activity in soil during various growth stages of wheat (μLH/g dry soil/24 hrs).

Treatments	Plant growth stage			
	Tillering	Heading	Grain formation	Maturity
Control	166	195	206	82
Superphosphate	183	298	309	128
Rock phosphate	176	218	293	114
VAM + superphosphate	365	396	437	298
VAM + rock phosphate	302	343	376	276
PSB + superphosphate	316	386	408	228
PSB + rock phosphate	296	315	326	186

Table (4): Periodical changes in soil organic carbon percentage during various growth stages of wheat.

Treatments	Plant growth stage			
	Tillering	Heading	Grain formation	Maturity
Control	0.640	0.528	0.472	0.302
Superphosphate	0.654	0.572	0.512	0.432
Rock phosphate	0.611	0.538	0.482	0.417
VAM + superphosphate	0.909	0.834	0.698	0.612
VAM + rock phosphate	0.931	0.870	0.793	0.615
PSB + superphosphate	0.833	0.717	0.584	0.456
PSB + rock phosphate	0.897	0.787	0.542	0.481

Table (5): Periodical changes in nitrogen forms concentration in soil during various growth stages of wheat (concentration, ppm).

Treatments	Plant growth stage							
	Tillering		Heading		Grain formation		Maturity	
	NH_4^+	NO_3^-	NH_4^+	NO_3^-	NH_4^+	NO_3^-	NH_4^+	NO_3^-
Control	18	11	13	17	11	23	8	30
Superphosphate	23	20	20	30	18	38	16	45
Rock phosphate	21	17	18	27	16	33	14	41
VAM + superphosphate	25	26	21	43	17	57	13	69
VAM + rock phosphate	29	23	22	38	15	55	11	61
PSB + superphosphate	37	31	28	42	24	53	13	63
PSB + rock phosphate	33	29	27	40	22	47	17	58

Table (6): Periodical changes in total and available phosphorus in soil during various growth stages of wheat (concentration, ppm).

Treatments	Plant growth stage					
	Tillering		Heading		Maturity	
	TP	AP	TP	AP	TP	AP
Control	392	16.2	562	25.4	309	13.8
Superphosphate	620	48.2	939	84.6	546	51.8
Rock phosphate	560	43.6	872	88.8	490	47.2
VAM + superphosphate	1020	133.0	1366	197.2	957	96.6
VAM + rock phosphate	980	124.0	1280	184.6	886	104.8
PSB + superphosphate	906	94.6	1046	132.4	846	86.2
PSB + rock phosphate	668	87.6	922	126.4	725	78.9

TP : Total phosphorus AP : Available phosphorus higher values of total phosphorus than uninoculated treatments. Superphosphate was more effective than rock phosphate. Soil phosphorus content was higher during heading stage compared with other growth stages of wheat and this trend occurred in all treatments. Also, data indicate that the inoculation of wheat grains with VAM gave higher values of available phosphorus in soil than when inoculated with PSB, and this trend was obtained in all plant growth stages. This result indicated the very important role of Mycorrhiza in the availability of phosphorus from the unavailability sources like rock phosphate. Then, rock phosphate could be a useful substance for VAM infected plants even at high pH values. Also, this result showed the importance of inoculation with VAM in case of soils with high pH values even when superphosphate was used as a phosphorus fertilizer to increase its availability in this environment. Available phosphorus content of soil was higher at heading stage than other wheat growth stages. Taking the P-source into account, available phosphorus concentration slightly differed according to phosphorus fertilizer source and this trend occurred when wheat grains were inoculated with VAM or PSB. Similar results were obtained by Ahmed and Jha (1978) and Blaszkowski (1993) who reported that the inoculation of wheat grains with mycorrhizal fungi and phosphate solubilizing bacteria, nitrogen, phosphorus and potassium content in soil were significantly increased. Also, they found that the effect of VAM was much more pronounced than of PSB. Moreover, Barea *et al.*, (1986) concluded that rock phosphate could be a useful substance for VAM infected plants even at high pH values.

4- Effect on total nitrogen:

Data in Table (7) indicate that the inoculation of wheat grains with VAM fungi was highly effective with regard to the nitrogen content of soil compared with the inoculation with PSB. Also, the nitrogen content of soil in the presence of superphosphate tended to be higher than rock phosphate. Generally, the inoculation of wheat grains by VAM or PSB showed increase in total nitrogen compared with the uninoculated ones. The nitrogen content of soil during heading stage was higher than other plant growth stages. This may be due to the beneficial effect of roots exudates which increase during heading or flowering stage in various cultivated plants. These results are in harmony with those reported by Hussein *et al.*, (1993) and Blaszkowski (1993).

5- Effect on potassium concentration:

The effect of inoculation with phosphate solublilizing bacteria and mycorrhizal fungi on potassium status in soil, is presented in Table (8). The inoculation of wheat grains with mycorrhizal fungi led to increase of potassium content in the investigated soil compared with the inoculation with phosphate solubilizing bacteria. Potassium concentration slightly differed according to the type of P-source in both treatments and growth stages. The potassium content of soil during the heading stage was higher than other plant growth stages and this trend was noticed in all treatments.

Table (7): Periodical changes in total nitrogen in soil during various growth stages of wheat (concentration, ppm).

Treatments	Plant growth stage		
	Tillering	Heading	Maturity
Control	680	941	730
Superphosphate	962	1340	1040
Rock phosphate	945	1120	980
VAM + superphosphate	1890	2290	2100
VAM + rock phosphate	1460	1980	1750
PSB + superphosphate	1280	1830	1620
PSB + rock phosphate	1100	1700	1630

Table (8): Periodical changes in total potassium in soil during various growth stages of wheat (concentration, ppm).

Treatments	Plant growth stage		
	Tillering	Heading	Maturity
Control	672	1240	1180
Superphosphate	920	1420	1310
Rock phosphate	840	1400	1280
VAM + superphosphate	1200	1880	1650
VAM + rock phosphate	1150	1820	1655
PSB + superphosphate	1120	1680	1510
PSB + rock phosphate	1100	1650	1490

Effect of microbial inoculation on chemical components of wheat plants:

Data in Table (9) show the N, P and K concentrations of wheat plants during heading and maturity stages. Data indicated that the N, P and K concentrations in wheat plants slightly differed during both growth stages in all treatments. Also, data revealed that the grains of wheat inoculated with mycorrhizal fungi gave the highest values of N, P and K concentrations compared with that inoculated with phosphate solubilizing bacteria. The inoculation of wheat grains at just sowing with VAM or PSB showed an increase in N, P and K compared with the uninoculated treatments. These results are in accordance with those reported by Barea *et al.*, (1986) who concluded that VAM are able to increase N and K concentrations in plant shoots indirectly by increasing the P-supply and directly by the uptake of N compounds from soil by VAM hyphae and the ability of mycorrhizal roots to assimilate nitrate or ammonium ions. Superphosphate was more effective than rock phosphate on N, P and K uptake. The superphosphate or rock phosphate application improved N-uptake as well as P and K by VAM infected plants. These results agreed with those reported by Mosse *et al.*, (1976), Barea and Conzalez (1986) and Ishac *et al.*, (1986). Such effects may be attributed to an indirect enhancement of associative N_2-fixation as a result of increased P-supply by VAM from insoluble P and/or direct uptake of N-compounds from soil by VAM hyphae.

Effect of microbial inoculation on growth charaters and yield of wheat:

It is clearly indicated from data in Table (10) that studied growth parameters were significantly increased with inoculation of wheat grains with mycorrhizal fungi or phosphate solubilizing bacteria compared with uninoculated treatments. No significant differences had been observed concerning plant height, number of spikelets/spike and spike length when wheat grains were inoculated with VAM or PSB. On the other hand, spike weight, grain weight of spike, root system length and fresh and dry weight of root and shoot system/plant were significantly increased with VAM treatments. Similar results were obtained by many investigators. Abdel-Monem *et al.*, (1992) indicated that mycorrhizal fungi had significantly increased plant growth characters and attributed this increase to capability of mycorrhizal mycelia to absorb nutrients from soil and transfer them to plants and improve of plant water relationship. Blaszkowski (1993) stated that wheat plants inoculated with mycorrhizal fungi were significantly taller than uninoculated as well as, the root and shoot dry weight were significantly increased. No significant difference had been observed in studied growth characters and grain yield of wheat with application of superphosphate or rock phosphate alone as a source of phosphorus. These results are in harmony with those obtained by Ishac *et al.*, (1993) who reported that there is no significant difference in wheat growth characters due to P-source fertilization.

Table (9): N, P and K concentration in wheat plants (ppm) during heading and maturity stages.

Treatments	Ingredients					
	Nitrogen		Phosphorus		Potassium	
	Heading stage	Maturity stage	Heading stage	Maturity stage	Heading stage	Maturity stage
Control	1980	2100	250	273	1240	1500
Superphosphate	2090	2226	406	432	2840	3130
Rock phosphate	2010	2158	390	313	2660	2850
VAM + superphosphate	3890	4031	580	613	5880	6800
VAM + rock phosphate	3630	3740	568	587	5060	5200
PSB + superphosphate	3505	3610	529	544	4600	4900
PSB + rock phosphate	3490	3510	490	518	4150	4550

Table (10): Effect of microbial inoculation on growth characters and yield of wheat.

Treatments	Growth characters									
	Plant height (cm)	Spike length (cm)	No. of spikelets/ spike	Spike weight (gm)	Grain weight of spike (gm)	Root system length (cm)	Fresh weight of root system (gm)/plant	Dry weight of root system (gm)/plant	Fresh weight of shoot system (gm)/plant	Dry weight of shoot system (gm)/plant
Control	43.00	5.13	7.66	0.96	0.57	14.00	1.83	1.05	5.16	3.86
Super phosphate	56.00	7.23	11.33	1.92	1.15	20.66	2.80	1.96	8.83	6.50
Rock phosphate	53.33	6.26	9.33	1.66	1.01	18.66	2.53	1.60	7.43	5.46
VAM + super phosphate	67.33	11.33	17.00	4.93	3.53	26.66	5.06	3.20	12.66	9.56
VAM + rock phosphate	66.66	9.33	15.66	4.13	3.06	26.66	4.53	3.06	11.33	8.13
PSB + super phosphate	66.00	9.26	17.33	3.60	2.50	23.00	3.86	2.87	10.05	8.16
PSB + rock phosphate	66.33	8.13	16.00	3.26	2.13	23.33	3.63	2.62	11.33	7.94
L.S.D. at 5%	3.18	1.24	1.98	0.32	0.24	2.30	1.18	0.01	0.13	0.56
L.S.D. at 1%	4.47	1.73	2.74	0.45	0.33	3.18	1.65	0.02	0.18	0.79

REFERENCES

Abbas, M.T.; Rammah, A.; Monib, M.; Ghanem, E.H.; Eid, M.A.M.; Emara, M.F.Z. and Hegazi, N.A. (1993): Wheat cultivation in sand soils as affected by N-fertilization and composite inoculation with associative diazotrophs. Proc. of 6th Inter. Sym. on N_2-Fixation With Non-Legumes. Ismailia, Egypt, 6-10 September: 485-486.

Abdel-Hafez, A.M. (1966): Some studies on acid producing microorganisms in soil and rhizosphere with special reference to phosphate dissolvers. Ph.D. Thesis, Fac. Agric., Ain Shams Univ.

Abdel-Monem, M.; Kassem, K. and El-Ghandour, I. (1992): Response of lentile to Rhizobium and V.A-mycorrhizal fungi as affected by drought stress. Proc. of Inter. Conf. on supplementry Irrigation and Drought water Management. Bari, Italy, 27th Sept., 2nd Oct.

Ahmed, N. and Jha, K.J. (1978): Effect of inoculation with phosphate solubilizing organisms on the yield and P-uptake of grains. Soil and Fertility 41(8): 4562.

Azazy, M.A.; Saber, M.S.M. and Boutros, B.N. (1988): The use of biofertilizers and conditioners in citrus nurseries in relation to microflora contributing to soil fertility. Egypt. J. Microbiol. 23(3): 389-402.

Barea, J.M. and Conzalez, S.B. (1986): VAM as modifiers of soil fertility. In Proc. Transaction of the XIII Congress of the International Society of Soil Science. Hamburg, 582.

Barea, J.M.; Azcon, C. Aguilar and Azcon, R. (1986): The role of mycorrhiza in improving the establishment and function (BNF) of Rhizobium-legume system under field conditions. In Proc. Biological Nitrogen Fixation Workshop. Aleppo, Syria.

Black, C.C.; Evans, D.D.; Ensminger, F.E.; White, J.L.; Clark, F.E. and Dinauer, R.C. (1965): Methods of soil analysis. II. Chemical and microbiological properties. Amer. Soc. Agron. Inc. Madison. Wisconsin, U.S.A.

Blaszkowski, J. (1993): Effect of five *Glomus spp.* (Zygomycetes) on growth and mineral nutrition of *Triticum aestivum* L. Acta Mycologica 28(2): 201-210.

Brown, J.B. and Lilliland, L.I. (1946): Rapid determination of potand sodium in plant material and soil extract by flame photometer. Proc. Amer. Soci. Hort. Sci., 48: 301-346.

Cacciari, D. Lippi; Pietrosanti, T. and Pietrosanti, W. (1988): Phytohormone-like substances produced by single and mixed diazotrophic culture of Azospirillum and Arthrobacter. Plant and Soil 115: 151-153.

Casida, L.E.; Klein, D.A. and Santoro, T. (1964): Soil dehydrogenase activity. Soil Sci. 98: 371-378.

Cochran, W.G. (1950): Estimation of bacterial densities by means of the "most probable number". Biometrics 6: 105-116.

Daft, M.J.; Clelland, D.M. and Gardner, I.C. (1985): Symbiosis with endomycorrhiza and nitrogen fixing organisms. Proc. of the Royal Society of Edinburge 85B: 283-298.

Dobereiner, J. (1978): Influence of environmental factors on the occurrence of *S. lipoferum* in soil and roots. Ecol. Bull. (Stockholm) 26: 343-352.

El-Haddad, M.E.; Ishac, Y.Z.; Saleh, E.A.; El-Borollosy, M.E.; Reffat, A.A. and El-Demerdash, M.A. (1986): Comparison of different methods of inoculation with a symbiotic N_2-fixers on plant growth. Proc. 2nd AABNF, Cairo, Egypt, Dec. 15-19.

Hussein, K.R.F.; Omar, M.N.A.; Zaher, E.A. and Abou-Zeid, M.Y. (1993): Effect of Azospirillum brasilense on yield and some chemical constituents of wheat grains. Proc. of 6th Inter. Sym. on N_2-Fixation with Non-Legumes. Ismailia, Egypt, 6-10 September: 481-482.

Ishac, Y.Z.; Elgla, A.M.; Soliman, S.M.; Abdel-Monem, M.; Massoud, M.A. and El-Ghandour, I.A. (1993): Evaluation of N_2-fixed by wheat plants grown in sandy soils using tracer techniques. Proc. of 6th Inter. Sym. on N_2-Fixation with Non-Legumes. Ismailia, Egypt, 6-10 September: 77-82.

Ishac, Y.Z.; El-Haddad, M.E.; El-Gharbawy, M.I.; Saleh, E.A.; El-Borollosy, M.A. and El-Demerdash, M.E. (1986): Effect of seed bacterization and phosphate supplementation on wheat yield and mycorrhizal development. In Proc. Transaction of the XIII Congress of International Society of Soil Science, Hamburg, 588.

Jackson, M.L. (1973): Soil chemical analysis. Prentice-Hall of India Private. New Delhi.

Kabesh, M.O.; Saber, M.S.M. and Yousry, M. (1975): Effect of phosphate fertilization on the P-uptake by pea plants cultivated in a calcareous soil. Egypt. J. of Microbiology 3: 605-611.

Li, S.G. (1981): Studies on phosphorite decomposing microorganisms. J. Soil Sci. 5: 33-35.

Mahmoud, S.A.Z.; Mehreshan T. El-Mokadem and Maha A. Heweidy (1993): Effect of inoculation with gamma irradiated *Azospirillum brasilense* on growth, yield and nutrient content of wheat. Proc. of 6th Inter. Sym. on N2-Fixation with Non-Legumes. Ismailia. Egypt, 6-10 September: 479-480.

Morkus, D.K; Mckinnon, J.P. and Buccafuri, A.F. (1982): Automated analysis of nitrite, nitrate and ammonium nitrogen in soils. New Jersy Agric. Exp. Stn., Publication No. D15117-84 Supported by State Funds. Presented in Part before Div. 5-4. Soil Science Soc. of Amer.. Anaheim, C.A., Dec. 1982.

Mosse, B.; Powell, C.L. and Hayman, D.S. (1976): Plant growth response to vesicular arbuscular mycorrhiza. IX- International Between VAM. Rockphosphate and Symbiotic nitrogen fixation. New Phytol. 76: 331.

Olsen, S.R.; Cole, O.V.; Watanabe, F.S. and Dee, A.L. (1954): Estimation of available phosphorus in soil by extraction with sodium bicarbonate. U.S. Dept., Agric. Circ.: 939.

Snedecor, G.W. and Cochran, W.G. (1982): Statistical methods. 6th Ed. Iowa State Univ. Press, Iowa, U.S.A.

Troug, E. and Mayer, A.H. (1949): Improvements in the Denig's colorimeteric method for phosphorus and arsenic. Ind. Eng. Chem. Anal., 1: 136-139.

تأثير تلقيح نبات القمح بالميكورهيزا والبكتريا المذيبة للفوسفات والأزوسبيريللام على نموه وخصوبة التربة

راشد عبدالفتاح زغلول* - محمود حلمى مصطفى ** - على الدين أحمد عامر**

* قسم النبات الزراعى - كلية الزراعة بمشتهر - جامعة الزقازيق - مصر.

** معهد بحوث الأراضى والمياه والبيئة - مركز البحوث الزراعية - وزارة الزراعة - مصر.

أجرى هذا البحث بصوبة قسم النبات الزراعى بكلية الزراعة بمشتهر عام ١٩٩٤ لدراسة تأثير التلقيح بفطريات الميكورهيزا (*Glomus mosseae*) والبكتريا المذيبة للفوسفات *B. megatherium* var. *phosphaticum* على نمو نبات القمح (صنف سخا ٨) وخصوبة التربة فى وجود البكتريا المثبتة لأزوت الهواء الجوى *Azos. brasilense*. ولقد أظهرت الدراسة النتائج التالية:

- أدى التلقيح بواسطة البكتريا المذيبة للفوسفات إلى زيادة أعداد الأزوسبيريللا والبكتريا المذيبة للفوسفات فى التربة بالمقارنة بالتلقيح بفطريات الميكورهيزا.
- بالنسبة لنشاط أنزيم الديهيدروجينيز فقد أوضحت النتائج زيادة نشاط هذا الإنزيم فى التربة عند التلقيح بفطريات الميكورهيزا بالمقارنة بالتلقيح بالبكتريا المذيبة للفوسفات.
- كذلك أدى التلقيح بفطريات الميكورهيزا إلى زيادة محتوى التربة من الكربون العضوى، الأمونيا والنترات، النيتروجين الكلى وكذلك البوتاسيوم والفوسفور (الكلى والميسر) بالمقارنة بالتلقيح بالبكتريا المذيبة للفوسفات. وكذلك أوضحت الدراسة أن محتوى التربة من هذه العناصر المغذية كان أعلى فى طور طرد السنابل بالمقارنة ببقية أطوار نمو النبات.
- بالنسبة لتأثير التلقيح الميكروبى على محتوى نباتات القمح من النيتروجين والفوسفور والبوتاسيوم فقد أظهرت الدراسة أن التلقيح بفطريات الميكورهيزا أعطى أعلى تركيز من هذه العناصر بالمقارنة بالتلقيح بواسطة البكتريا المذيبة للفوسفات.
- كان هناك فرق معنوى فى وزن السنبلة، وزن حبوب السنبلة وكذلك طول المجموع الجذرى والوزن الجاف لكل من المجموع الجذرى والخضرى لكل نبات حيث إزدادت هذه القياسات فى وجود التلقيح بفطريات الميكورهيزا.
- لم يشاهد فرق معنوى فى الصفات الخاصة بالنمو التى درست وكذلك المحصول وذلك بين إضافة السوبر فوسفات وإضافة صخر الفوسفات فى وجود التلقيح الميكروبى.