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EFFECT OF PHOSPHORUS AND SOME BIOSTIMULANTS ON GROWTH, YIELD, PHOSPHORUS USE EFFICIENCY AND TUBER QUALITY OF POTATO PLANTS GROWN IN SANDY SOIL

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ABSTRACT

This experiment was carried out during two successive summer seasons of 2009 and 2010 at private farm in El-Salhyia El-Gadida region, Sharkia Governorate on potato plants, to study the effect of phosphorus fertilizer (20, 40, 60 and 80 kg/fed.) and some biostimulants (phosphorein and mycorrhiza) as well as their interactions on growth, yield, phosphorus use efficiency and tuber quality under sandy soil conditions using drip irrigation system.

Plant height, number of both aerial stems and leaves/ plant, shoot dry weight, P and K percentages, and number of tubers/ plant, average tuber weight and yield / plant as well as total yield/fed., phosphorus use efficiency by potato plants, chlorophyll concentration in leaf tissues, N, P and K uptake by shoot, N, P, K and dry matter percentage in tubers were significantly increased with increasing phosphorus levels up to 80 kg/feddan.

Inoculation of potato tuber seeds with phosphorein or mycorrhiza significantly increased plant height, number of leaves/ plant, shoot dry weight, chlorophyll concentration in leaf tissues, N,P % in shoots and their uptake, average tuber weight, yield/ plant as well as total yield/ fed., N, P and dry matter(%) in tubers. Moreover, phosphorus use efficiency by potato plants recorded the maximum values when tuber seeds were treated with mycorrhiza.

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Interaction effect between phosphorus at 60 kg/fed. and inoculation of tuber seeds with mycorrhiza was the superior treatment for enhancing plant height, number of leaves and concentrations of chlorophyll a, b and total (a+b) as well as phosphorus use efficiency by potato plants. Treating potato plants with 80 kg phosphorus /fed. and inculcation with mycorrhiza gave the highest values of shoot dry weight/ plant, and concentration of N, P in shoots and their uptake, number of tuber/ plant, average tuber weight, yield/ plant as well as total yield/fed., N,P, K and dry matter (%) in tubers.

Keywords: Potato, phosphorus, mycorrhiza, phosphorein, phosphorus use efficiency (PUE), tuber yield and quality.

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important vegetables in Egypt. It gained a considerable importance as an export crop to European markets and one of the national income resources.

Potato needs high P requirement for optimum growth and yield; thus, when grown on P deficient soils, considerable yield losses are apparent (Dechassa *et al.*, 2003). Plant height, number of branches, foliage dry weight of potato plants were significantly increased by increasing phosphorus rate (Bardisi, 2000; Balemi, 2009). Tuber yield of potato plants were markedly increased by application of P-fertilizer as compared with control (Kamla and Singh, 1999). Dry matter and starch percentage, N, P and K contents in tubers of potato were increased with increasing P-rate (Mahendran and Chandramani, 1998).

Arbuscular mycorrhizal fungi (AMF) form a symbiotic association with more than 80% of land plant families. AMF consists of an internal phase inside the root and an external phase, or extraradical mycelium (ERM) phase, which can form an extensive network within the soil (Gosling *et al.*, 2006). AMF benefit their host principally by increasing uptake of relatively immobile phosphate ions, due to the ability of the fungal ERM to grow beyond the phosphate depletion zone that quickly develops around the root (Smith and Read, 1997).

Biostimulants (microbial and fungi inoculation), which contain efficient strain of phosphate solubilizing bacteria and mycorrhiza could be used partially instead of chemical fertilizers. Moreover, these bacteria cells or fungi hyphat increase the availability of nutrients in form, which can be easily assimilated or to make them absorbable by plants (Subba Rao, 1993). Inoculation of potatoes with mycorrhiza fungi increased and improved plant growth (Iqbal *et al.*, 1990; Niemira *et al.* 1995 and Awad 2002). Also, Ghosh and Das (1998) found that plant height and number of shoots/plant of potato were considerably increased when plants were inoculated with both mycorrhiza fungi and phosphate solubilizing bacteria. Treated tuber seeds of potato with mycorrhiza recorded higher total tuber yield. (Atimanav *et al.*, 2000 and David *et al.*, 2007).

Thus, this work aimed to study the effect of phosphorus fertilizer and inoculation with phosphorein or mycrrohiza on growth, yield, phosphours use efficiency and tuber quality of potato grown in sandy soils under drip irrigation system.

MATERIALS AND METHODS

This work was carried out during two successive summer seasons of 2009 and 2010 at private farm in El-Salhyia El-Gadida region, Sharkia Governorate, on potato plant, to study the effect mineral phosphorus and some biostimulants (phosphorein and mycrrohiza) as well as their interactions on growth, yield, phosphours use efficiency and tuber quality under sandy soil conditions using drip irrigation system. The physical and chemical properties of the used experimental soil were: sandy in texture, while it had 0.05 and 0.06% organic matter, 8.02 and 8.07 pH, 2.11 and 2.04 mmhos/cm (EC), 4.61 and 4.82 ppm available N, 3.24 and 3.57 ppm available P and 9.63 and 9.21 ppm available K during the 1^{st} and 2^{nd} seasons, respectively.

This experiment included twelve treatments, which were the combinations between four mineral phosphorus rates (20, 40, 60 and 80 kg/fed.) and two biostimulants (phosphorein and mycrrohiza) beside control. These treatments were arranged in a split plot system in a complete randomized block design (CRBD) with three replicates. Phosphorus rates were randomly arranged in the main plots and biostimulants were randomly distributed in the sub plots. Tuber seeds of potato cv. Diamant were sown on January 7th and 10th in both seasons at 25 cm apart.

The experimental unit area was 12.6 m^2 . It contained three dripper lines with 6m length each and 70 cm distance between each two drippers lines. One line was used to measure the morphological and physiological traits and the other two lines were used for yield determinations. In addition, one row was left between each two experimental units as guard area to avoid the overlapping infiltration of irrigation water. The source of mineral phosphours was calcium superphosphate (15.5 %P_2O_5)

Biostimulants (phosphorein or mycorrhiza) were added at the rate of 5 kg of each/fed. and mixed with wet tubers by adding Arabic Gum solution before sowing and the treated tubers were directly sown in the same day. Phosphorein biofertilizer, contains *Bacillus megatherium* phosphate-dissolving bacteria. The source of phosphorein was Ministry of Agriculture, Egypt. While mycorrhiza was supplied by Agricultural Microbiology Department, National Research Center, Egypt. The mycorrhiza fungi are the most widespread associations between fungi and plant. There are three species of indomycorrhizal fungi ; i.e., *Glomus fasciculatum, Glomus mosseae* and *Glomus monosporum.*

All experimental units received equal amounts of commercial fertilizers at the rates of 120 kg N/fed. as ammonium sulfate (20.6% N) and 100 kg K_2O/fed. as potassium sulfate (48-52 % K_2O). One third of N and K fertilizers were added at soil preparation with all amounts of mineral phosphorus and 30 m^3/fed. FYM. The rest amount of commercial fertilizers (two-thirds) were added as fertigation by four days intervals beginning one month after planting. The normal agricultural practices were carried out as commonly followed in the district.

Data Recorded

Plant Growth

A random sample of five plants was randomly taken from every plot at 90 days after planting, in both seasons of study, for measuring the growth characters of potato plants expressed as follows: Plant height, number of both aerial stems and leaves/ plant and dry weight of shoots (aerial stems + leaves).

Photosynthetic Pigments

Discs sample from the fourth upper leaf of potato plant was randomly taken from every experimental unit at 90 days after planting, in the two growing seasons, to determine chlorophyll a and b as well as carotenoides according to the method described by Wettestein (1957).

Contents of N, P and K

The dry weight of shoots (leaves and aerial stems) at 90 days after planting were finely ground and wet digested for N, P and K determination. Total Nitrogen, phosphorus and potassium were determined according to the methods described by A.O.A.C (1990). Uptake of N, P and K by shoots were calculated.

Yield and its Components

At harvesting time (115 days after planting) tubers from each plot were harvested and the following data were recorded: Number of tubers/plant, average tuber weight (gm), tuber yield per plant (gm), total yield (ton/fed.) and relative yield (%).

Phosphorus Use Efficiency (PUE)

It was calculated according to Shah *et al.* (2002) as follows:

$$PUE = \frac{\text{Yield of fertilized} - \text{yield of control}}{\text{Fertilized P applied}} \text{(kg yield//kgP)}$$

Tuber Quality

NPK Contents

Total nitrogen, phosphorous and potassium were determined as previously mentioned in the dry weight of shoots.

Total carbohydrate (%)

It was determined colorimetrically in dry tubers as (gm/100gm) according to the methods described by A.O.A.C. (1990).

Starch content

It was determined by the method described by A.O.A.C. (1990).

Specific gravity

It was determined according to the method of Murphy and Govern (1959). The tubers were weighed in the air and then in water and specific gravity was calculated.

Dry matter (%)

One hundred grams of the grated mixture were dried at 105 ^{0}C till constant weight and DM (%) was recorded.

Statistical analysis

The data were subjected to proper statistical analysis of variance according to Snedecor and Cochran (1980) and means separation were done according to L.S.D. at 5 % level of probability.

RESULTS AND DISCUSSION

Plant Growth

Effect of phosphours

Data in Table 1 show that mineral phosphorus at different rates reflected significant differences on plant height, number of leaves / plant and shoot dry weight of potato plant in both seasons. Fertilization of potato plants with phosphorus at 80 kg/fed. gave the tallest plants with no significant differences with 60 kg P_2O_5/fed. and recorded the maximum values of number of both aerial stems and leaves/ plant and shoot dry weight/ plant followed by 60 kg /fed.. Such results could be explained on the basic that phosphorus element had beneficial effect on the activation of photosynthesis and metabolic processes of organic compounds in plants and hence increasing plant growth (Gardener *et al.*, 1985). These results agree with those reported by Bardisi (2000) and Balemi (2009).

Effect of some biostimulants

Data given in Table 1 show that treated potato seeds with some biostimulants (phosphorein and mycorrhiza) had a significant effect on plant height and shoot dry weight of potato in both seasons and number of leaves/ plant in the 1st season, but had no significant effect on number of aerial stems/ plant in both seasons. Treated seed tubers with mycorrhiza or phosphorein gave the tallest plants and application with mycorrhiza increased shoot dry weight in both seasons. The superiority effect of arbuscular mycorrhiza fungi (AMF) could explained based on their role in supplying the growing plants with available phosphorus needs, some micronutrients such as Zn, Cu, Mn and Fe and phytohormones, such as gibberllins, auxins and cytokinins which promoted plant growth, in addition to root development and thereby enhanced photosynthesis and biosynthesis of proteins and nutrient uptake (Marschner, 1995). These results agreed with Ghosh and Das (1998) who found that plant height and number of shoots/plant of potato were considerably increased when plants inoculated with both vesicular – arbuscular mycorrhiza (VAM) fungi and phosphate solubilizing bacteria.

Effect of interaction

The interaction between phosphors application and

Table 1. Effect of phosphorus and some biostimulants on plant growth of potato plants during summer seasons of 2009 and 2010 under sandy soil conditions

Treatments	Plant height (cm)		Number/ plant: Aerial stems		Number/ plant: Leaves		*Shoots dry weight (gm)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
P_2O_5 (kg/fed.)				**Effect of phosphorus**				
20	44.22	37.11	3.22	3.67	30.22	30.22	19.46	19.22
40	44.56	40.00	3.45	3.89	31.00	30.67	20.31	19.79
60	49.22	41.34	3.89	4.00	36.67	30.66	21.30	20.62
80	51.22	44.67	4.22	4.56	39.11	36.34	22.71	21.89
LSD at 0.05 level	**4.28**	**4.14**	**0.42**	**0.28**	**6.42**	**5.17**	**1.13**	**1.18**
				Effect of some biostimulants				
Without	45.42	39.17	3.75	4.09	34.09	32.25	17.48	17.77
Phosphorein	48.50	41.50	3.67	3.84	36.09	30.84	18.74	18.19
Mycorrhiza	51.56	42.34	3.78	4.00	37.00	32.11	20.66	20.54
LSD at 0.05 level	**3.52**	**1.52**	**NS**	**NS**	**2.14**	**NS**	**0.86**	**0.51**

* Shoots (aerial stems +leaves) , NS: Not significant at 5 % of probability

inoculation with some biostimulants (mycorrhiza or phosphorein) reflected a significant effect on plant height, number of leaves/ plant and shoot dry weight/ plant in both seasons (Table 2). Fertilization of potato plants with 80 kg P_2O_5/fed. with or without mycorrhiza significantly increased plant height and number of leaves/ plant with no significant differences with the interaction between P_2O_5 at 60 kg/fed. and phosphorein with respect to plant height, whereas the interaction between of 80 kg P_2O_5/fed. and inoculation of seed tubers with mycorrhiza increased shoot dry weight/ plant.

Photosynthetic Pigments

Effect of phosphours

Presented data in Table 3 indicate that, application of mineral phosphorus to potato plants showed a significant effect on concentration of chlorophyll a (Chl a), chlorophyll b (Chl b) and total Chl (a+b) in both seasons, but had no significant effect on carotenoides in leaf tissues. Soil application with phosphorus at 80 kg /fed. gave the highest values of Chl a, b and total Chl (a+b) in leaf tissues in both seasons with no significant differences with 60 kg/fed. with respect to Chl a in the 1st season and total Chl (a+b) in both seasons. Phosphorus is constituent of nucleic acids, phospholipids and ATP energy, phosphorus activates amino acids to synthesis of protein (Devlin and Witham, 1972).

Effect of some biostimulants

From data in Table 3 show a significant effect for some biostimulants (phosphorein or mycorrhiza) on Chl a, Chl b and total Chl (a+b) in leaf tissues of potato in both seasons, except Chl a in the 1st season. Inoculation of potato seeds with mycorrhiza recorded the maximum concentration of Chl a, b and total Chl (a+b) compared with the other treatments. These results are in line with those obtained by Saif El-Deen (2005) who found that, inoculation of sweet potato with VAM fungi or phosphorein led to significant increases in total chlorophyll content of leaves as compared with the uninoculated treatment

Effect of interaction

The interaction between mineral phosphours and some biostimulants showed a significant effect on concentration of Chl a, b and total Chl (a+b) in leaf tissues

Table 2. Effect of interaction between phosphorus and some biostimulants on plant growth of potato plants during summer seasons of 2009 and 2010 under sandy soil conditions

Treatments		Plant height (cm)		Number/ plant				*Shoots dry weight (gm)	
P_2O_5 X (Kg/fed.)	Biostimulants			Aerial stems		Leaves			
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
20	Without	40.33	33.67	3.33	3.67	27.00	32.67	14.99	15.74
	Phosphorein	45.00	39.00	3.00	3.67	35.33	29.67	16.92	16.98
	Mycorrhiza	47.33	38.67	3.33	3.67	28.33	28.33	16.17	18.1
40	Without	40.33	34.67	3.00	3.67	28.67	27.33	15.53	16.48
	Phosphorein	49.67	40.67	3.67	3.67	33.67	29.67	17.63	16.05
	Mycorrhiza	43.67	44.67	3.67	4.33	30.67	35.00	19.86	20.16
60	Without	50.67	41.67	4.00	4.33	38.00	31.33	19.01	17.92
	Phosphorein	51.67	43.67	4.00	3.67	41.67	30.33	18.33	18.19
	Mycorrhiza	45.33	38.67	3.67	4.00	30.33	30.33	20.96	20.67
80	Without	50.33	46.67	4.67	4.67	42.67	37.67	20.38	20.93
	Phosphorein	47.67	42.67	4.00	4.33	33.67	33.67	22.09	21.52
	Mycorrhiza	55.67	44.67	4.00	4.67	41.00	37.67	25.65	23.23
LSD at 0.05 level		6.68	2.88	NS	NS	4.06	4.09	1.63	0.96

* Shoots (aerial stems +leaves) , NS: Not significant at 5 % of probability

Table 3. Effect of phosphorus and some biostimulants on photosynthetic pigments (mg/100 gm DW) of potato leaves during summer seasons 2009 and 2010 under sandy soil conditions

Treatments	Chlorophyll (mg/100 gm DW)						Carotenoides (mg/100 gm DW)	
	Chl (a)		Chl (b)		Total Chl (a+b)			
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
P_2O_5 (kg/fed.)				**Effect of phosphorus**				
20	121.56	109.70	85.23	55.92	206.79	165.63	96.54	100.81
40	129.74	125.88	95.06	57.98	224.80	183.87	96.82	101.14
60	136.89	129.75	95.53	61.89	232.42	191.64	98.72	104.69
80	146.47	143.09	100.65	65.44	247.12	208.53	96.24	104.39
LSD at 0.05 level	**17.44**	**6.90**	**12.79**	**5.59**	**9.26**	**9.74**	**NS**	**NS**
				Effect of some biostimulants				
Without	128.75	119.08	88.94	57.87	217.70	176.95	96.93	101.59
Phosphorein	132.39	127.55	94.02	59.80	226.40	187.35	96.55	103.11
Mycorrhiza	139.86	134.69	99.39	63.25	239.25	197.94	97.78	103.58
LSD at 0.05 level	**NS**	**3.86**	**9.47**	**2.99**	**5.15**	**5.24**	**NS**	**NS**

Chl : chlorophyll; NS: Not significant at 5 % of probability of potato plants, except Chl a in the 1st season and carotenoides in both seasons (Table 4). The interaction between P_2O_5 at 60 kg /fed. and inoculation of tuber seeds with mycorrhiza gave the highest concentration of Chl a , b and total Chl (a+b) followed by the interaction between P_2O_5 at 80 kg/fed. and inoculation of seed tubers with phosphorein. These results agree with those obtained by Anwar (2005) on potato.

N, P and K Content and Uptake

Effect of phosphours

Soil application with mineral phosphorus at different rates showed a significant differences on content and uptake of N, P and K by shoots of potato in both seasons (Table 5). Contents of N, P and K in shoots were significantly increased with increasing phosphorus rates up to 80 kg/fed. with no significant differences with 60 kg/fed. with respect to P and K contents. Also soil phosphorus application at 80 kg /fed. gave the highest values of N,P and K uptake by shoots in both seasons compared with the other treatments. Under clay soil, NPK contents increased with increasing phosphorous fertilizer at level 75 kg P_2O_5/fed. (Awad, 2002).

Effect of some biostimulants

Presented data in Table 5 show that, treating seed tubers of potato with some biostimulants (phosphorein or mycorrhiza) reflected a significant effect on contents and uptake of N, P and K by shoots, except K content in both seasons. Inoculation of seed tubers with mycorrhiza recorded the maximum values of N and P contents and N, P and K uptake by shoots.

Effect of interaction

In general, the interaction between mineral phosphorus at 80 kg /fed. and inoculation of seed tubers with mycorrhiza gave the highest values of N,P and K contents and their uptake by shoots of potato plants, except K content in both seasons and K uptake in the 2nd season with no significant differences with some treatments (Table 6). For most mineral soils a pH range for optimum phosphate availability is 6 to 7. The rate of phosphate uptake was declined rapidly with increasing pH (Mengel and Kirkby, 1987). For this reason soil application of phosphatic fertilizer beside inoculation with phosphorein and mycorrhiza seem to be favorable for absorption.

Table 4. Effect of interaction between phosphorus and some biostimulants on photosynthetic pigments (mg/100 gm DW) of potato leaves during summer seasons of 2009 and 2010 under sandy soil conditions

Treatments		Chlorophyll (mg/100 gm DW)						Carotenoides (mg/100 gm DW)	
P_2O_5 (Kg/fed.) X	Biostimulants	Chl (a)		Chl (b)		Total Chl (a+b)			
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
20	Without	114.14	96.22	80.19	51.86	194.33	148.08	92.07	96.84
	Phosphorein	126.24	119.78	89.60	57.56	215.84	177.34	98.39	104.29
	Mycorrhiza	124.30	113.12	85.91	58.34	210.21	171.45	99.17	101.29
40	Without	119.13	111.48	83.01	53.10	202.14	164.58	98.37	100.35
	Phosphorein	116.43	107.48	81.90	52.44	198.33	159.93	94.06	99.20
	Mycorrhiza	153.66	158.68	120.26	68.42	273.91	227.10	98.02	103.87
60	Without	136.91	128.49	95.83	62.07	232.73	190.57	98.69	104.66
	Phosphorein	137.68	134.42	96.94	62.48	234.62	196.89	98.77	104.74
	Mycorrhiza	136.10	126.35	93.82	61.11	229.92	187.47	98.71	104.68
80	Without	144.84	140.12	96.75	64.46	241.59	204.58	98.56	104.50
	Phosphorein	149.20	148.53	107.63	66.73	256.82	215.26	94.97	104.20
	Mycorrhiza	145.37	140.62	97.57	65.13	242.94	205.75	95.20	104.47
LSD at 0.05 level		NS	7.33	17.98	5.67	9.77	9.95	NS	NS

Chl : chlorophyll; NS: Not significant at 5 % of probability

Table 5. Effect of phosphorus and some biostimulants on N, P and K contents and uptake of shoots of potato plants during summer seasons of 2009 and 2010 under sandy soil conditions

Treatments	Mineral contents (%)						Uptake (mg/ plant)					
	N		P		K		N		P		K	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
P_2O_5 (Kg/fed.)	**Effect of phosphorus**											
20	5.49	4.99	0.523	0.445	4.39	4.08	1011.61	846.97	96.42	75.46	812.43	693.28
40	5.72	5.21	0.557	0.473	4.54	4.22	1188.07	919.73	115.71	83.43	940.96	745.36
60	5.92	5.39	0.597	0.507	4.96	4.62	1149.14	1018.27	116.00	95.98	964.00	873.31
80	6.32	5.75	0.612	0.520	5.24	4.87	1435.91	1258.76	139.48	114.08	1187.27	1065.94
LSD at 0.05 level	**0.32**	**0.28**	**0.036**	**0.024**	**0.68**	**0.47**	**176.15**	**136.18**	**18.53**	**8.25**	**96.48**	**118.25**
	Effect of some biostimulants											
Without)	5.76	5.24	0.564	0.479	4.76	4.43	1043.40	937.75	102.11	85.61	865.88	795.50
Phosphorein	5.86	5.33	0.563	0.479	4.78	4.45	1186.59	975.85	114.12	87.48	967.01	813.94
Mycorrhiza	5.96	5.43	0.591	0.502	4.82	4.48	1358.57	1119.20	134.48	103.63	1095.61	923.97
LSD at 0.05 level	**0.11**	**0.10**	**0.014**	**0.015**	**NS**	**NS**	**112.18**	**118.25**	**10.25**	**5.24**	**74.15**	**NS**

NS: Not significant at 5 % of probability

Table 6. Effect of interaction between phosphorus and some biostimulants on N, P and K contents and uptake of shoots of potato plants during summer seasons of 2009 and 2010 under sandy soil conditions

Treatments		Mineral contents (%)						Mineral uptake					
P_2O_5 X (Kg/fed.)	Biostimulants	N		P		K		N		P		K	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
20	**Without**	5.23	4.76	0.504	0.428	4.00	3.72	783.98	749.22	75.55	67.37	599.60	585.53
	Phosphorein	5.70	5.19	0.521	0.443	4.76	4.43	1135.44	881.26	103.78	75.22	948.19	752.21
	Mycorrhiza	5.53	5.03	0.545	0.463	4.41	4.10	1115.40	910.43	109.93	83.80	889.50	742.10
40	**Without**	5.63	5.12	0.532	0.452	4.60	4.28	986.94	843.78	93.26	74.49	806.38	705.34
	Phosphorein	5.38	4.90	0.554	0.471	4.20	3.91	1109.89	786.45	114.29	75.60	866.46	627.56
	Mycorrhiza	6.15	5.60	0.585	0.497	4.82	4.48	1467.39	1128.96	139.58	100.20	1150.05	903.17
60	**Without**	5.96	5.42	0.627	0.533	4.97	4.62	1133.00	971.26	119.19	95.51	944.80	827.90
	Phosphorein	6.04	5.50	0.569	0.484	5.02	4.67	1107.13	1000.45	104.30	88.04	920.17	849.47
	Mycorrhiza	5.76	5.24	0.594	0.505	4.90	4.56	1207.30	1083.11	124.50	104.38	1027.04	942.55
80	**Without**	6.23	5.67	0.591	0.502	5.46	5.08	1269.67	1186.73	120.45	105.07	1112.75	1063.24
	Phosphorein	6.31	5.74	0.607	0.516	5.13	4.77	1393.88	1235.25	134.09	111.04	1133.22	1026.50
	Mycorrhiza	6.41	5.83	0.639	0.543	5.13	4.77	1644.17	1354.31	163.90	126.14	1315.85	1108.07
LSD at 0.05 level		**0.20**	**0.18**	**0.026**	**0.028**	**NS**	**NS**	**212.68**	**224.55**	**19.46**	**9.95**	**140.80**	**NS**

NS: Not significant at 5 % of probability

Yield and its Components

Effect of phosphours

The obtained results from data in Table 7 show that phosphorus application to potato plants reflected a significant effect on number of tubers/ plant, average tuber weight, yield/ plant and total yield/fed. of potato in both seasons. Phosphorus application at 40, 60 and 80 kg/fed. significantly increased number of tubers/ plant, average tuber weight, yield/ plant and total yield/fed. compared with 20 kg P_2O_5, wherever, P_2O_5 at 80 kg/fed. recorded the maximum values of total yield in both seasons (11.889 and 11.539 ton/fed. in the 1st and 2nd seasons, respectively). The increases in total yield /fed. were about 65.60 and 82.26% for the phosphorus at 80 kg/fed. over the 20 kg P_2O_5/fed. in the 1st and 2nd seasons, respectively. The role of phosphorus as an essential component of many organic compounds in plant, such as phosphoproteins, phospholipids, nucleic acids and nucleotides, which indirectly may reflect positively on yield (Marschner, 1995). Potato has high P requirement for optimum growth and yield; thus, when grown on P deficient soils, considerable yield losses are apparent (Dechassa *et al.*, 2003). Potato plants require a good soil texture and low pH for increasing its productivity. These results are coincided with those reported by Kamla and Singh (1999), Bardisi (2000) and David *et al.* (2007) on potato.

Effect of some biostimulants

Treating tuber seeds with some biostimulants showed a significant effect on average tuber weight, yield/ plant and total yield/fed. in both seasons (Table 7). Inoculation of tuber seeds with phosphorein or with mycorrhiza increased average tuber weight, yield/ plant and total yield/fed. with no significant differences between them (10.301 and 9.900 ton /fed. for phosphorein and 10.729 and 10.175 ton/fed. for mycorrhiza in the 1st and 2nd seasons, respectively). The increases in total yield /fed. were about 14.52 and 16.87% for phosphorein and 19.28 and 20.12 (%) for mycorrhiza over the control in the 1st and 2nd seasons, respectively. In this regard, Atimanav *et al.* (2000) studied the effect of endogenous endomycorrhizal fungi for its ability to promote growth and yield of potato. They found that inoculation of tuber seeds recorded relative increase in yield by 48%.

Table 7. Effect of phosphorus and some biostimulants on yield and its components of potato plants during summer seasons of 2009 and 2010 under sandy soil conditions

Treatments	Number of tubers/plant		Average weight of tubers (gm)		Yield / plant (kg)		Total yield (ton/fed.)		Relative yield (%)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
P_2O_5 kg/fed.					**Effect of phosphorus**					
20	7.62	7.07	48.54	46.13	0.370	0.326	7.179	6.331	100.00	100.00
40	8.99	8.91	55.62	51.94	0.500	0.464	9.809	9.106	136.63	143.89
60	9.85	10.29	57.43	54.72	0.568	0.564	11.156	11.084	155.39	175.07
80	9.67	9.96	61.83	58.25	0.598	0.581	11.889	11.539	165.60	182.26
LSD at 0.05 level	**1.14**	**2.10**	**9.62**	**6.57**	**0.140**	**0.120**	**1.564**	**1.926**	--	--
					Effect of some biostimulants					
(Without)	8.70	8.52	52.15	49.96	0.456	0.429	8.995	8.471	100.00	100.00
Phosphorein	9.23	9.34	56.48	53.55	0.527	0.506	10.301	9.900	114.52	116.87
Mycorrhiza	9.17	9.31	58.93	54.77	0.544	0.516	10.729	10.175	119.28	120.12
LSD at 0.05 level	**NS**	**NS**	**4.28**	**3.78**	**0.072**	**0.076**	**1.040**	**1.280**	--	--

NS: Not significant at 5 % of probability

Effect of interaction

Presented data in Table 8 show that the interaction between P_2O_5 at 40 or 60 or 80 kg/fed. and inoculation with phosphorein or with mycorrhiza significantly increased number of tubers/ plant, average tuber weight and yield/ plant compared with the interaction between P_2O_5 at 20 kg/ fed. and some biostimulants. The interaction between 80 kg/fed. P_2O_5 and treating tuber seeds with mycorrhiza gave the highest value of total yield/fed. (12.584 and 12.226 ton/fed. in the 1^{st} and 2^{nd} seasons, respectively). The increases in total yield /fed. were about 84.17 and 94.46 % for the interaction between 80 kg P_2O_5/fed. and phosphorein and 85.09 and 102.32% for the interaction between 80kg P_2O_5/fed. and mycorrhiza over the control (20 kg P_2O_5/fed. and without biostimulants) in the 1^{st} and 2^{nd} seasons, respectively.

Rates of phosphorus and inoculation of seed tubers with phosphorein and mycorrhiza are considered of the most important factors which may affect plant growth, yield and tuber quality of potato under sandy soil conditions. It is well know that sandy soil is very poor in phosphorus and high pH value.

Crops grown in soils high in available P may respond more favourably to inoculation than those grown in soil low in available P, because the native AM community is likely to be suppressed on soils high in available P (Hamel *et al.*, 1997). These results agreed with those reported by Singh *et al.* (2002) who found that crop yield and tuber size were increased with increasing rates of P and were higher with phosphate–solubilizing bacteria inoculation also the interaction effect of P rate and phosphate sulblizating bacteria inoculation was significant.

Phosphorus Use Efficiency (PUE)

Effect of phosphours

The highest utilization of P-efficiency by fertilization of potato plants with phosphorus at 60 kg P_2O_5/fed. (62.62 and 84.02 kg tubers/ one kg P_2O_5 in the 1^{st} and 2^{nd} seasons,respectively). These treatments produced higher total yield /feddan (Table 9).

Effect of some biostimulants

Treating of tuber seeds with mycorrhiza recorded the maximum values of PUE (84.38 and 90.97 kg tubers/ one kg P_2O_5

Table 8. Effect of interaction between phosphorus and some biostimulants on yield and its components of potato plants during summer seasons of 2009 and 2010 under sandy soil conditions

Treatments		Number of tubers/plant		Average weight of tubers (gm)		Yield / plant (kg)		Total yield (ton/fed.)		Relative yield (%)	
P_2O_5 (Kg/fed.)	Biostimulants	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
20	Without	7.46	6.84	47.03	45.65	0.351	0.312	6.799	6.043	100.00	100.00
	Phosphorein	7.49	7.12	48.49	46.17	0.363	0.329	7.028	6.369	103.37	105.39
	Mycorrhiza	7.90	7.26	50.09	46.57	0.396	0.338	7.710	6.581	113.40	108.90
40	Without	8.76	8.3	52.87	46.85	0.463	0.389	9.140	7.679	134.43	127.07
	Phosphorein	9.14	9.16	55.22	54.55	0.505	0.500	9.832	9.735	144.61	161.10
	Mycorrhiza	9.06	9.26	58.76	54.42	0.532	0.504	10.454	9.904	153.76	163.89
60	Without	9.23	9.33	52.19	51.92	0.482	0.484	9.481	9.520	139.45	157.54
	Phosphorein	10.26	10.9	58.95	55.11	0.605	0.601	11.822	11.744	173.88	194.34
	Mycorrhiza	10.07	10.63	61.14	57.14	0.616	0.607	12.166	11.988	178.94	198.38
80	Without	9.34	9.61	56.51	55.41	0.528	0.532	10.560	10.640	155.32	176.07
	Phosphorein	10.02	10.19	63.27	58.38	0.634	0.595	12.522	11.751	184.17	194.46
	Mycorrhiza	9.64	10.09	65.71	60.95	0.633	0.615	12.584	12.226	185.09	202.32
LSD at 0.05 level		2.04	3.32	8.12	7.17	0.136	0.144	1.974	2.430	--	--

Table 9. Effect of phosphorus some biostimulants and their interactions on the phosphorus use efficiency (kg tuber/ one kg P_2O_5) of potato during summer seasons of 2009 and 2010 under sandy soil conditions

Biostimulants / P_2O_5 (kg/fed.)	Without		Phosphorein		Mycorrhiza		Average	
	1^{st}	2^{nd}	1^{st}	2^{nd}	1^{st}	2^{nd}	1^{st}	2^{nd}
20 (control)	-	--	--	--	--	--	--	--
40	58.53	40.90	75.83	92.30	91.38	96.53	**68.77**	**75.85**
60	44.70	57.95	83.72	95.02	89.45	99.08	**72.62**	**84.02**
80	47.01	57.46	71.54	71.35	72.31	77.29	**63.62**	**68.70**
Average	**50.08**	**52.10**	**77.03**	**86.22**	**84.38**	**90.97**	--	--

in the 1st and 2nd seasons, respectively), followed by treated with phosphorein, being 77.03 and 86.22 kg tuber/one kg P_2O_5 in the 1st and 2nd seasons, respectively (Table 9). AMF can play a significant role in crop P nutrition, increasing total uptake and in some cases P use efficiency. This may be associated with the increment in growth and yield (Koide *et al.*, 2000).

Effect of interaction

The interaction between 60 kg P_2O_5/fed. and treating tuber seeds with mycorrhiza recorded the maximum values of PUE (89.45 and 99.08 kg tubers/ one kg P_2O_5) followed by the interaction between 60 kg P_2O_5/fed. and treating tuber seeds with phosphorein (83.72 and 95.02 kg tuber/ one kg P_2O_5) in the 1st and 2nd seasons, respectively (Table 9).

In general, PUE was increased with increasing P_2O_5 up to 60 kg/fed. alone or with phosphorein or mycorrhiza, after that it decreased with increasing P_2O_5 up to 80 kg/fed. alone or with phosphorein or mycorrhiza.

Tuber Quality

Effect of phosphours

Fertilization of potato plants with P_2O_5 at different rates showed a significant effect on N,P , K and DM (%) in tubers in both seasons (Table 10). Application of P_2O_5 at 80 kg /fed. was the superior treatment for enhancing N, P, K and DM (%) in tubers compared with the other treatments. On the other hand, P_2O_5 had no significant effect on total carbohydrates, starch content and specific gravity in potato tubers. These results are in good line with those reported by Mahendran and Chandramani (1998) on potato

Effect of some biostimulants

Inoculation of seed tuber seeds with some biostimulants reflected a significant effect on tuber contents of N,P and K as well as DM (%) in tubers (Table 10). Inoculation of tuber seeds with mycorrhiza was the best treatment for increasing N, P and K contents and DM (%) compared with the control or phosphorein. Biostimulants of tuber seeds tubers had no significant effect on total carbohydrates, and starch content as well as specific gravity of tubers. These results are coincided with those reported by Ashour (1998) who found that treating potato tuber seeds with phosphorein exerted significant increases in tuber contents of starch, total soluble sugars and P concentration, compared with the control.

Table 10. Effect of phosphorus and some biostimulants on tuber quality at harvest of potato during summer seasons of 2009 and 2010 under sandy soil conditions

Treatments	N (%)		P (%)		K (%)		Carbohydrates (%)		Starch (%)		DM (%)		Specific gravity	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
P_2O_5 kg/fed.							**Effect of phosphorus**							
20	1.68	1.44	0.171	0.147	2.34	2.01	79.09	72.76	65.24	60.02	20.19	18.57	1.03	1.01
40	1.87	1.61	0.179	0.154	2.49	2.14	78.80	72.50	65.04	59.84	20.02	18.41	1.03	1.01
60	1.87	1.61	0.179	0.154	2.49	2.14	78.80	72.50	65.04	59.84	20.02	18.41	1.03	1.01
80	2.55	2.19	0.193	0.166	2.72	2.34	79.87	73.48	66.06	60.77	21.07	19.38	1.04	1.02
LSD at 0.05 level	**0.19**	**0.27**	**0.010**	**0.011**	**0.25**	**0.18**	**NS**	**NS**	**NS**	**NS**	**0.32**	**0.39**	**NS**	**NS**
							Effect of some biostimulants							
(Without)	1.83	1.57	0.176	0.151	2.43	2.09	78.92	72.61	65.15	59.94	20.34	18.71	1.03	1.01
Phosphorein	1.92	1.65	0.179	0.154	2.47	2.12	79.03	72.71	65.24	60.03	19.67	18.10	1.03	1.01
Mycorrhiza	2.24	1.92	0.187	0.161	2.64	2.27	79.46	73.11	65.64	60.38	20.96	19.28	1.04	1.01
LSD at 0.05 level	**0.12**	**0.14**	**0.006**	**0.004**	**0.11**	**0.08**	**NS**	**NS**	**NS**	**NS**	**0.13**	**0.26**	**NS**	**NS**

NS: Not significant at 5 % of probability

Table 11. Effect of interaction between phosphorus and some biostimulants on tuber quality at harvest of potato during summer seasons of 2009 and 2010 under sandy soil conditions

Treatments P_2O_5 (Kg/fed.)	X Biostimulants	N (%)		P (%)		K (%)		Carbohydrates (%)		Starch (%)		DM (%)		Specific gravity	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
20	Without	1.41	1.21	0.166	0.143	2.17	1.87	79.56	73.20	65.63	60.38	20.49	18.85	1.032	1.011
	Phosphorein	1.87	1.61	0.169	0.145	2.44	2.10	79.05	72.72	65.19	59.98	19.21	17.67	1.029	1.009
	Mycorrhiza	1.76	1.51	0.178	0.153	2.40	2.06	78.65	72.36	64.89	59.70	20.86	19.19	1.033	1.012
40	Without	1.82	1.57	0.175	0.150	2.42	2.08	78.06	71.82	64.49	59.33	19.93	18.33	1.033	1.012
	Phosphorein	1.59	1.37	0.178	0.153	2.36	2.03	78.72	72.43	64.95	59.76	19.48	17.92	1.031	1.010
	Mycorrhiza	2.21	1.90	0.185	0.159	2.69	2.31	79.61	73.24	65.68	60.42	20.64	18.98	1.036	1.015
60	Without	1.82	1.57	0.175	0.150	2.42	2.08	78.06	71.82	64.49	59.33	19.93	18.33	1.033	1.012
	Phosphorein	1.59	1.37	0.178	0.153	2.36	2.03	78.72	72.43	64.95	59.76	19.48	17.92	1.031	1.010
	Mycorrhiza	2.21	1.90	0.185	0.159	2.69	2.31	79.61	73.24	65.68	60.42	20.64	18.98	1.036	1.015
80	Without	2.26	1.94	0.187	0.161	2.69	2.31	80.00	73.60	66.00	60.72	20.99	19.31	1.036	1.015
	Phosphorein	2.62	2.25	0.191	0.164	2.71	2.33	79.64	73.26	65.88	60.61	20.52	18.87	1.037	1.016
	Mycorrhiza	2.76	2.37	0.201	0.173	2.76	2.38	79.98	73.58	66.29	60.98	21.70	19.97	1.037	1.016
LSD at 0.05 level		0.22	0.26	0.012	0.008	0.20	0.15	NS	NS	NS	NS	0.24	0.49	NS	NS

NS: Not significant at 5 % of probability

Effect of interaction

The interaction between P_2O_5 at 80 kg /fed. and inoculation of tuber seeds with phosphorein or mycorrhiza gave the highest values of N,P and K contents in tubers with no significant differences between such interaction treatment and with the interaction between P_2O_5 at 60 kg /fed. and phosphorein or mycorrhiza with respect to K contents in tubers . Whereas, the interaction between P_2O_5 at 80 kg /fed. and inoculation with phosphorein or mycorrhiza gave the highest values of DM% in tubers (Table 11).

Conclusion

From foregoing results, it could be concluded that, the interaction treatment between P_2O_5 at 80 kg/fed. and inoculation of tuber seeds with mycorrhiza was the superior treatment for enhancing shoot dry weight and total yield /fed. and the interaction between 60 kg P_2O_5 fed. and mycorrhiza gave the highest value of phosphorus use efficiency.

REFERENCES

A.O.A.C. Association of Official Agricultural Chemists.1990. Official methods of analysis. 10th. ed. A.O.A.C., wash., D.c

Anwar, R.S. 2005. Response of potato crop to biofertilizers, irrigation and antitranspiration under sandy soil conditions. Ph.D. Thesis, Fac. Agric., Zagazig Univ., Egypt.

Ashour, S.A. 1998. Influence of biofertilization and phosphorous application on growth and yield of potato (*Solanum tuberosum*, L.). J. Agric. Sci., Mansoura Univ., 23 (7): 3351-3358.

Atimanav, G., A. Alok, A. Goaur, and A. Adholeya. 2000. Response of three vegetable crops to VAM fungal inoculation in nutrient deficient soils amended with organic matter. Symbiosis Rehovot., 29 (1):19 – 31 (C.A. CAB International Abstr.: 03345114).

Awad, E.M. 2002. Growth, yield and quality of potato crop as affected by the inoculation with vesicular arbuscular mycorrhizal (VAM) fungi under different levels of phosphorus. J. Agric. Sci., Mansoura Univ., 27 (8): 5593 – 5605.

Balemi, T. 2009. Effect of phosphorus nutrition on growth of potato genotypes with contrasting phosphorus efficiency. African Crop Science Journal, 17 (4): 199 – 212.

Bardisi, A. 2000. Response of potato plants to method and rate of phosphorus application under sandy soil conditions. Egypt. J. Appl. Sci.,15 (7):285-304.

David, D.D., J.G. Nagahashi, C. Reider, and P.R. Hepperly. 2007. Inoculation with arbuscular mycorrhizal fungi increases the yield of potatoes in a high P soil. Biological Agriculture and Horticulture, 25: 67-78.

Dechassa, N., M.K. Schenk, N. Claassen, and B. Steingrobe. 2003. Phosphorus efficiency of cabbage (*Brassica oleraceae* L. var. *Capitata*), carrot (*Daucus carota* L.), and potato (*Solanum tuberosum* L.). Plant and Soil, 250:215-224.

Devlin, R.M. and F.H. Witham. 1972. Functions of essential mineral elements and symptoms of mineral deficiency. Wilard Grant Press, Boston P. 140 (577 pages).

Gardener, F.D., R.B. Pearce and R.L. Mitchell. 1985. Physiology of crop plants. The Iowa State Univ. Press, pp. 327.

Ghosh, D.C. and A.K. Das. 1998. Effect of biofertilizers and growth regulators on growth and productivity of potato (*Solanum tuberosum*, L.). Indian Agriculturist, 42 (2): 109 – 113.

Gosling, P., A. Hodge, G. Goodlass, and G.D. Bending. 2006. Arbuscular mycorrhizal fungi and organic farming. Agric., Ecos. and Environ. ,113 : 17–35.

Hamel, C., Y. Dalpe, V. Furlan, and S. Parent. 1997. Indigenous populations of arbuscular mycorrhizal fungi and soil aggregate stability are major determinants of leek (*Allium porrum* L.) response to inoculation with *Glomus intraradicies* Schenck and Smith or *Glomus versiforme* (Karsten) Berch. Mycorrhiza 7, 187–196.

Iqbal, S.H., S. Rana, A.N. Khalid, M. Khan, S. Rana, and M. Khan. 1990. The influence of vesicular-arbuscular mycorrhiza (VAM) and *Aspergillus niger* deterrents against *Rhizoctonia solani* in potatoes. Sarhad J. Agric., 6 (5): 841–454.

Kamla, S. and K. Singh. 1999. Effect of biofertilizers and phosphorus levels on the production of potato (*Solanum* *tuberosum*, L.) crop under Northeast hill conditions. Indian J. Agric. Sci.,69 (10): 746– 749.

Koide, R.T., M.D. Goff, and I.A. Dickie. 2000. Component growth efficiencies of mycorrhizal and nonmycorrhizal plants. New Phytol., 148: 163 – 168.

Mahendran, P.P. and P. Chanderamani. 1998. NPK uptake, yield and starch content of potato cv. kufri Jyoti as influenced by certain biofertilizers. J. Indian Potato Assoc., 25 (1-2): 50-52.

Marschner, H. 1995. Mineral Nutrition of Higher Plants. 2nd (ed.), Academic Press Limited, Text Book.

Mengel, K. and E.A. Kirkby. 1978. Principles of Plant Nutrition. International Potash Institute, P. O. Box. CH. 3048, Worblaufen Bern, Switzerland.

Murphy, H.G. and M.J. Govern. 1959. Factors affecting the specific gravity of white potato in main Agr.Exp.Sta.Bull.583.

Niemira, B.A., G.R. Safir, R. Hammerschmidt, and G.W. Bird. 1995. Production of prenuclear minitubers of potato with peat-based arbuscular mycorrhizal fungal inoculum. Agron. J., 87 (5): 942–946.

Saif El-Deen, U.M. 2005. Effect of phosphate fertilization and foliar application of some micronutrients on growth, yield and quality of sweet potato *Ipomoea batata,* L. Ph.D. Thesis, Fac. Agric., Mansoura Univ., Egypt.

Shah, P., K.M. Kakar, and K. Zada. 2002. Phosphorus use-efficiency of soybean as affected by phosphorus application and inoculation. Developments in Plant and Soil Sciences, 92 (9): 670-671.

Singh, S.K., S.M.P. Khurana, G.S. Shekhawat, S.K. Pandey, and B.P. Singh. 2002. Efficiency of phosphate solubilizing biofertilizer with phosphorus on potato yield. Potato Global Res. and Dev. Proceedings of the Global Conf. on Potato, New Delhi, India, 6-11 Dec., 1999, Vol. 2: 908-911.

Smith, S.E. and D.J. Read. 1997. Mycorrhizal Symbiosis. Academic Press, London.

Snedecor, G.W. and W.G. Cochran. 1980. Statistical Methods.7th ed., Iowa State Univ., Press, Ames., Iowa, U.S.A.

Subba Rao, N.S. 1993. Biofertilizers in agriculture. 3rd ed., Oxford, IBH Publishing Co. Ltd., New Delhi, Bombay, Calcutta, 219 pp.

Wettestein, D. 1957. Chlorophyll. Lethale under Submikroskopische Formwechsel der Plastiden. Exp. Cell Reso, 12: 427-506.

تأثير التسميد الفوسفاتى وبعض المنشطات الحيوية على النمو، المحصول وكفاءة استخدام الفوسفور وجودة الدرنات لنباتات البطاطس النامية فى الأراضى الرملية

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أجريت هذه التجربة خلال الموسمين الصيفيين المتتاليين لعامي ٢٠٠٩ ، ٢٠١٠ في مزرعة خاصة – بمنطقة الصالحية الجديدة – محافظة الشرقية على نبات البطاطس النامي في ارض رمليه باستخدام نظام الري بالتنقيط بهدف دراسة تأثير معدلات الفوسفور (٢٠ ، ٤٠ ، ٦٠ ، ٨٠ كجم/ فدان) وبعض المنشطات الحيوية (الفوسفورين، الميكورهيزا) والتفاعل بينهما على النمو والمحصول وكفاءة استخدام الفوسفور وجودة الدرنات.

ازداد كل من ارتفاع النبات، وعدد السيقان الهوائية والأوراق/ نبات، والوزن الجاف للمجموع الخضري،ومحتوى المجموع الخضرى من الفوسفور والبوتاسيوم، وعدد الدرنات /نبات، ومتوسط وزن الدرنة،ومحصول النبات والفدان، ومحتوى أنسجة الورقة من الصبغات، والممتص من النتروجين والفوسفور والبوتاسيوم بواسطة المجوع الخضرى، ومحتوى الدرنة من النتروجين والفوسفور والبوتاسيوم وكذلك المادة الجافة بزيادة التسميد الفوسفاتى حتى ٨٠ كجم/ فدان، بينما ازدادت كفاءة استخدام الفوسفور مع ٦٠ كجم فوسفور/ فدان.

أدى معاملة درنات البطاطس بالمنشطات الحيوية الفوسفورين او الميكورهيزا لزيادة كل من ارتفاع النبات، وعدد الأوراق/ نبات، والوزن الجاف للمجموع الخضري، ومحتوى أنسجة الورقة من الصبغات، ومحتوى المجموع الخضري والممتص من النتروجين والفوسفور، ومتوسط وزن الدرنة، ومحصول النبات والفدان، والنسبة المئوية لمحتوى الدرنات من النتروجين والفوسفور وكذلك المادة الجافة، علاوة على ذلك فقد لوحظ أعلى كفاءة لاستخدام الفوسفور بمعاملة التقاوى بالميكورهيزا.

كان للفعل المشترك بين الفوسفور بمعدل ٦٠ كجم /فدان ومعاملة تقاوى البطاطس بالميكورهيزا أكبر الأثر في زيادة كل من ارتفاع النبات، وعدد الأوراق/ نبات، ومحتوى أنسجة الورقة من كلوروفيل أ ، ب ، (أ+ب) ، وكفاءة أستخدام الفوسفور، وقد أدى تسميد البطاطس بالفوسفور بمعدل ٨٠ كجم /فدان ومعاملة تقاوى البطاطس بالميكورهيزا لزيادة كل من الوزن الجاف للمجموع الخضرى، ومحتوى النتروجين والفوسفور والممتص منهما بواسطة المجموع الخضرى، وعدد الدرنات /نبات، ومتوسط وزن الدرنة، ومحصول النبات والفدان،و محتوى الدرنة من النتروجين والفوسفور والبوتاسيوم وكذلك المادة الجافة.