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EFFECT OF MINERAL AND BIO-PHOSPHATE FERTILIZATION AND FOLIAR APPLICATION OF MICRONUTRIENTS ON GROWTH, YIELD AND QUALITY OF SWEET POTATO "*Ipomoea batatas*, L.":
1- VEGETATIVE GROWTH, YIELD AND TUBER ROOT CHARACTERISTICS

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ABSTRACT

Two field experiments were carried out at El- Bramoon Agricultural Farm of El-Mansoura Horticultural Research Station, during the summer seasons of 2002 and 2003. The study aimed at investigating the effects of some micronutrients; a mixture of Zn, Fe and Mn, each at 100 ppm; bio-phosphate fertilizers, VAM fungus and Phosphorein, and mineral phosphate fertilizer at 0, 30, 45 and 60 kg P_2O_5/fed., on sweet potato growth, yield and its components, as well as tuber root Characteristics. Results showed that foliar application of micronutrients significantly improved vegetative growth parameters, except number of branches/plant, yield/plant, marketable and total yield/fed., as well as decreasing non-marketable yield/fed. Micronutrients also increased average weight and diameter of tuber roots, but did not affect tuber root shape (length/diameter).

Increasing the supplied phosphate fertilizer level to 45 or 60 kg P_2O_5 /fed. significantly improved vegetative growth parameters, yield/plant and marketable yield/fed., significantly decreased non-marketable yield, and increased average weight, diameter and length of tuber roots, but did not affect tuber root shape.

The addition of bio-phosphorus fertilizers (Phosphorein or mycorrihza) resulted in significant increases in vegetative growth, total marketable yield and its components. Bio-phosphorus fertilizers also increased tuber root weight, diameter and length, but did not affect their shape.

Positive interactions among micronutrients, mineral P-rates and bio-phosphorus fertilizers on studied characters were detected.

INTRODUCTION

Sweet potato (*Ipomoea batatas*, L) is an important and leading vegetable crop of tropical and subtropical countries. Recently, sweet potato received a great attention become of its suitability for exportation. Great efforts have been directed to improve sweet potato production and quality for the purpose of increasing exported yield. Application of adequate amounts of phosphate fertilizer and micronutrients are among factors involved in improving plant growth, tuber roots yield and quality of sweet potato (El-Morsy *et al.*, 2002).

Foliar nutrition of plants is not only an addition channel of nutrients but also a mean of regulating root absorption by such plants. The important of spraying micronutrients, i.e., Fe, Zn and Mn can be accounted by its essential role in respiration, N metabolism, activation of the enzyme, photosynthesis, chloroplast formation, chlorophyll synthesis and natural hormone biosynthesis (Nijjar 1985).

Phosphorus is one of the major elements for plant nutrition and development. It plays an important role in certain essential steps, such as accumulation and release of energy during cellular metabolism. In addition, it is a constituent of many organic compounds in plants (Marschner, 1995).

Nile valley soils faced numerous deteriorating problems during the last decades, among which is shifting the pH value to the alkaline side, rending most plant nutrient in unavailable forms especially phosphorus and micronutrients (El-Morsy and Shokr, 2005).

Fortunately under such conditions, it has become essential to use the untraditional fertilizers as a partial substitute for chemical fertilizers, to reduce production costs yield, limit environmental pollution, increase production and improve quality of vegetable crops (El-Agrodi *et al.*, 2003).

The use of phosphate-dissolving microorganisms, including phosphate-dissolving bacteria (Phosphorin) and fungus (Mycorrhiza), has several benefits such as mobilizing phosphate and micronutrients through the production of organic acid such as formic, acetic, lactic, prop ionic, fumaric and succinic acids. Those acids lower the pH and bring about the dissolution of bounds forms of phosphate and render them available for growing plants (Ibrahim and Abdel-Aziz, 1977). In addition, such microorganisms can secrete growth promoting factors, e.g., gibberellins, cytokinins and auxins (Cacciari *et al.*, 1989).

Accordingly, the present study aims at evaluating the effects of foliar spray with micronutrient and phosphorus fertilizer rates, either alone or in combination with biofertilizers, on plant growth, yield, chemical composition and quality of sweet potato plants cv. Abees.

MATERIALS AND METHODS

Two field experiments were carried out at El-Bramoom Agricultural Research farm of El-Mansoura Horticultural Research station, during the two successive summer seasons of 2002 and 2003. The experiments were designed to investigate the effects of some micronutrients, mineral and bio-phosphate fertilizer treatments and their interactions, on plant growth, yield and its components, and chemical constituents of tuber roots of sweet potato (*Ipomoea batatas*, L.) cv. Abeese, under clay-loam soil conditions. Physical and chemical properties of experimental soil are presented in Table (1).

Table (1): Some physical and chemical properties of the experimental soil

Parameter	Sand %	Silt %	Clay %	Texture	pH	$CaCO_3$	EC (ds/m)	Organic matter %	Available elements (ppm)					
									N	P	K	Zn	Mn	Fe
Value	25.8	33.7	40.5	Clay loam	8.11	4.55	1.12	1.95	47.2	11.9	379.0	1.35	11.51	8.62

Each experiment was designed as split-split-plot with 4 replicates. The micronutrient mixture (Fe, Zn and Mn) placed in the main plots, which subsequently divided into 4 sub plots, each contained one of the phosphate rates, while biofertilizer treatments were assigned to the sub-sub plots.
Each sub sub plot area was 17.5 m^2 and contained 5 rows; each was 5m in length and 0.7m in width. The experiment included 24 treatments which were the possible combinations of two micronutrient levels (0.0 and 100 ppm of chelated Fe, Zn and Mn mixture), four P_2O_5 rates (0, 30, 45 and 60 kg P_2O_5/fed.), and three biofertilizer treatments, i.e., control, phosphorein and Vesicular Arbuscular Mycorrhizae (VAM). The mixture of chelated micronutrients was applied to plants as foliar spray at 30, 45 and 60 days after transplanting. Calcium superphosphate (15.5%) was used as a source of phosphate (P_2O_5), which was used at 4 different rates, e.g. 0, 30, 45 and 60 kg/fed., at planting time. Phosphorein inoculum which contains active bacteria (*Bacillus megatherium* var. *phosphaticum*) was mixed with wet soft dust at (1:10 ratio). It was applied to the root absorption zone of plants, 30 days after transplanting, at the rate of 3 kg/fed, just before irrigation. As for VAM, a forty grams of inoculum were added to root absorption zone of each plant, 30 days after transplanting, before irrigation.

Sweet potato stem cuttings, about 20 cm length, were transplanted on the third top of slope ridges, at 25 cm apart, in the second week of April of both seasons of the study. Growing plants were fertilized with 200 kg/fed ammonium sulfate, (20.5% N) and 200 kg/fed. Potassium sulfate (48% K_2O). The added amounts were equally divided and applied after planting and 45 days after transplanting.

Recorded Data:

Vegetative growth parameters:

Five representative plants were randomly picked up from sub-sub plot, 100 days after transplanting to measure, plant length, number of branches/plant, leaf area/ plant (according to the method of Koller, 1972), dry weight per plant and
chlorophyll a + b (according to the method of Commar and Zscheile, 1941).

Yield and its components and tuber root characteristics:

At harvest, 140 days from transplanting, all tuber roots of plants of each sub-sub plots were dig up, classified according to the method of Grang (1963) into marketable roots (with a diameter of 3.5 to 6.5 cm) and non-marketable roots (with a diameter of > 3.5 cm or < 6.5)., then weighted to determine the total yield per feddan (tons). In addition, plant yield, as number and weight (kg) of tuber roots, was determined. Samples, each of ten tuber roots, were also randomly chosen at harvesting time to determine average tuber root weight (gm), length (cm), diameter (cm), and shape (length/diameter).

All recorded data were statistically analyzed by Analysis of Variance and least significance differences (LSD) was used to separate means, as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Vegetative growth parameters:

Data presented in Table (2) show that vine length, leaf area, dry weight/ plant and chlorophyll content of leaves were significantly increased, in both seasons, in response to foliar spray of micronutrients, compared with control, while number of branches/plant was not significantly affected by micronutrients. The positive effect of micronutrients on plant vegetative growth parameters might be due to their essential roles in many important metabolic functions such as transport of carbohydrates, regulation of meristematic activity, photosynthesis, respiration, energy production and protein metabolism. Such functions would directly or indirectly contribute to plant growth (Srivastva and Gupta, 1996). The obtained results are in harmony with those of Radwan and Tawfik (2004) on potato, who found that spraying plants with micronutrients increased vegetative growth of plants as compared with the untreated ones.

Data in Table (2) also show that vegetative growth of sweet potato plants that received P_2O_5 fertilizer was generally improved compared with control plants. It is also clear from the obtained data that increasing the rate of applied P_2O_5 from 30 to 60 kg/fed was associated with marked simulative effects on plant growth. The application of 45 and 60 kg P_2O_5/ fed. to plants were significantly superior in increasing vine length, number of branches, leaf area, canopy dry weight per plant and total chlorophyll content of leaves, compared with control treatment, in both seasons. These increases may be due to the beneficial effect of p-element on the activation of photosynthesis and metabolic processes of organic compounds in plants and hence increasing plant growth (Gardener *et al.*, 1985). These results are in agreement with those of Abdel-Fattah and Abdel-Hameid (1997) who indicated that increasing the applied P-rate to sweet potato plants significantly increased plant length, plant leaf area, canopy fresh weight and total chlorophyll in plant leaves.

Data presented in Table (2) reveal that inoculation of sweet potato with VAM fungi or phosphorein led to significant increases in vine length, number of branches/plant, leaf area, plant dry weight and total chlorophyll contents of leaves as compared with the uninoculated treatment, in both seasons. The superiority effect of VAM-fungi could be explained based on their role in supplying the growing plants with available phosphorus needs, some micronutrients and phytohormones, such as gibberllins, auxins and cytokinins which promoted plant growth, in addition to root development and thereby enhanced nutrient uptake (Marschner., 1995). Similar results were reported by El-Morsy *et al.* (2002) on sweet potato, which showed that the use of VAM-fungi as biofertilizer to sweet potato plants markedly increased shoot growth, fresh and dry weight of plants compared with untreated plants.

Table (2): Vegetative growth parameters and chlorophyll contents of sweet potato plants as affected by micronutrients, P_2O_5 rates and biofertilizers, during 2002 and 2003 seasons.

Parameters / Treatments	Vine length (cm)		Number of branches/ plant		Leaf area/ plant (m^2)		dry weight / plant (gm)		chlorophyll (A + B) (mg/g F.W)	
	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
a- Effect of micronutrients										
Without	132.4	128.0	15.43	14.94	0.82	0.69	118.94	109.21	1.20	0.90
With	140.4	136.0	17.16	16.82	1.04	0.96	131.34	129.86	1.41	1.17
LSD (5%)	4.36	5.30	N.S	N.S	0.04	0.11	1.71	7.68	0.016	0.040
b- Effect of P-rates										
Control	120.8	122.9	13.66	13.72	0.74	0.68	109.77	107.39	0.89	0.84
30 kg	139.4	129.9	15.62	15.77	0.84	0.76	121.20	116.53	1.21	1.02
45 kg	141.5	135.9	17.43	16.65	1.04	0.90	132.66	125.69	1.47	1.19
60 kg	143.9	139.4	18.53	17.38	1.12	0.95	136.89	128.53	1.65	1.26
LSD (5%)	6.09	8.23	2.59	1.26	0.03	0.12	1.90	2.17	0.012	0.02
c- Effect of biofertilizers										
Control	125.6	127.2	19.65	14.65	0.89	0.75	120.83	101.60	1.21	0.89
VAM[1]	147.6	136.5	24.31	16.94	0.97	0.92	129.87	125.67	1.40	1.32
Phosphorein	135.9	132.5	21.28	16.04	0.93	0.80	124.68	120.26	1.29	1.03
L.S.D (5%)	4.84	3.15	1.43	1.40	0.03	0.08	3.92	4.95	0.007	0.03

1- VAM = Vascular Arbuscular Mycorrhiza.

The effect of interaction of micronutrients x P-rates on plant vegetative growth parameters of sweet potato is presented in Table (3). The interaction exerted positive significant effects on leaf area/plant, plant dry weight and chlorophyll content in plant leaves in both seasons. However, it didn't significantly affect vine growth or number of branches/plant, in both seasons. Results also indicated that plants treated with foliar micronutrient and P_2O_5 at 45 or 60 kg P_2O_5/fed gave the highest values of vegetative growth parameters in both seasons, while the untreated plants followed by plants received only P_2O_5 at 30 kg P_2O_5/fed., yielded the lowest values in both seasons, respectively. The obtained results are in agreement with those of Abdel-Fattah *et al.* (2002), on garlic.

The interaction of micronutrients x VAM fungi or phosphorein resulted in a non-significant increase in vegetative growth of sweet potato plants,in both seasons, except for chlorophyll content of plant leaves, in both seasons, where the increase was significant (Table 3). The interaction of micronutrients with VAM fungi resulted in the highest values of vegetative growth parameters, compared with the interactions at any other level.

The effect of interaction of P-rates x biofertilizers on vegetative growth of sweet potato plants is shown in Table (4). Results show that there is a positive effect for this interaction on most of the studied vegetative growth characteristics of sweet potato plants. Data also point out that the interaction had no significant effect on vine length, and number and branches/plant, in the two seasons. However, significantly the highest leaf area/plant resulted from the interaction of 60 kg P_2O_5/fed with VAM or phosphorein biofertilizers, in the first season and from the interaction of 45 kg P_2O_5/fed with VAM only, in the second season. Plant dry weight and leaf chlorophylls significantly increased to the highest values when of 60 kg P_2O_5 per fed. interacted with VAM biofertilizer, in both seasons. The obtained results could be explained by the results of Negeve and Roncadori (1985) who showed that phosphate fertilization was more effective in stimulating growth of sweet potato plants in the presence of VAM fungi. Furthermore, El-Dahtory *et al.* (1989) mentioned that use of mineral phosphorus fertilizer in combination with phosphorein may activate P-solubilizing bacteria in soil and consequently increase available phosphorus and plant growth promoting substances. The obtained results are also in agreement with those of El-Morsy *et al* (2002), and EL-Shimi (2003), on sweet potato

Table (3): Vegetative growth parameters and chlorophyll content of sweet potato plants as affected by the interactions of micronutrients × P_2O_5 rates and micronutrients x biofertilizers during 2002 and 2003 seasons.

Treatments	Parameters	Vine length (cm)		Number of branches/ plant		Leaf area/ plant (m^2)		dry weight/ plant (gm)		chlorophyll (A + B) (mg/g F.W)	
		2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Micro.[1]	P-rates	a- Interaction of P rates x micronutrients									
Without	Control	112.6	118.8	12.79	13.26	0.62	0.59	104.33	96.67	0.84	0.86
	30 kg P_2O_5/fed	135.2	125.7	14.42	14.32	0.70	0.60	114.96	108.39	1.08	0.93
	45 kg P_2O_5/fed	138.8	131.5	16.37	15.37	0.88	0.65	125.11	109.28	1.31	1.15
	60 kg P_2O_5/fed	143.1	136.2	18.26	16.61	1.09	0.89	131.26	122.50	1.56	1.25
With	Control	128.9	127.1	14.52	14.18	0.85	0.76	115.20	118.10	0.94	0.99
	30 kg P_2O_5/fed	143.7	134.1	16.82	17.22	0.97	0.93	127.44	124.67	1.34	1.11
	45 kg P_2O_5/fed	144.2	140.3	18.49	17.73	1.20	1.15	140.21	142.11	1.63	1.24
	60 kg P_2O_5/fed	144.7	142.6	18.79	18.14	1.15	1.02	142.52	134.55	1.72	1.32
LSD (5%)		N.S	N.S	N.S	N.S	0.04	0.17	5.42	8.11	0.017	0.05
Micro.	Biofertilizers	b-interaction of micronutrients x biofertilizers									
Without	Control	121.9	123.6	14.34	14.43	0.79	0.63	115.36	92.66	1.11	0.84
	VAM[2]	145.4	132.5	16.95	15.58	0.85	0.80	122.69	127.54	1.29	1.19
	Phosphorein	130.0	127.9	15.09	14.81	0.83	0.63	118.70	107.42	1.18	0.94
With	Control	129.3	130.7	15.13	14.88	1.01	0.86	126.31	110.55	1.30	0.94
	VAM	149.9	140.3	19.51	18.30	1.08	1.08	132.05	145.93	1.51	1.44
	Phosphorein	141.9	137.1	16.83	17.28	1.04	0.98	130.67	133.09	1.40	1.10
LSD (5%)		N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	0.08	0.04

1- Micro = Micronutrients 2-VAM = Vascular Arbuscular Mycorrhiza.

Table (4): Vegetative growth parameters and chlorophyll content of sweet potato plants as affected by the interaction of P_2O_5 rates × biofertilizers during 2002 and 2003 seasons.

Treatments / Parameters		Vine length (cm)		Number of branches/ plant		Leaf area/ plant (m^2)		dry weight/ plant (gm)		Chlorophyll (A + B) (mg/g F.W)	
P-rates	Biofertilizers	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Control	Control	108.0	117.2	11.48	12.03	0.69	0.59	107.17	91.66	0.82	0.73
	VAM[1]	131.8	126.9	15.66	14.90	0.77	0.76	112.5	119.07	0.97	0.96
	Phosphorein	122.5	124.6	132.8	14.21	0.74	0.68	109.63	111.42	0.89	0.82
30 kg P_2O_5/fed	Control	133.7	123.3	13.50	14.08	0.79	0.72	118.18	104.55	1.12	0.82
	VAM	147.9	134.4	17.92	17.10	0.88	0.82	124.55	129.38	1.31	1.25
	Phosphorein	136.7	131.8	15.45	16.13	0.83	0.75	120.87	115.66	1.20	0.99
45 kg P_2O_5/fed	Control	130.2	129.2	15.22	15.03	0.99	0.69	125.16	105.08	1.36	0.95
	VAM	153.0	142.5	20.02	18.08	1.09	1.07	139.99	149.09	1.56	1.51
	Phosphorein	141.2	136.1	17.05	16.83	1.04	0.94	132.82	122.90	1.48	1.12
60 kg P_2O_5/fed	Control	130.4	138.9	18.75	17.46	1.11	0.97	132.83	105.13	1.55	1.07
	VAM	157.7	141.7	19.32	17.68	1.12	1.05	142.42	149.39	1.77	1.55
	Phosphorein	143.5	137.6	17.52	16.98	1.12	0.84	135.42	131.04	1.60	1.16
L.S.D at 5 %		N.S	N.S	N.S	N.S	0.06	0.16	7.06	8.90	0.013	0.07

1- VAM =Vvascular Arbuscular Mycorrhiza

As for the interaction effect of the three studied factors on plant vegetative growth, data in Table (5) reveal that vine length, number of branches/plant, leaf area and plant dry weight, were not significantly influenced by the three ways interaction, in both seasons. However, leaf chlorophyll content was significantly affected by the interaction, in both seasons. Generally, plants received micronutrients, 45 kg P_2O_5/fed and treated with VAM-fungi had the highest vegetative growth and chlorophyll content values, in the two seasons, compared with control plants.

Yield and its components:

Concerning the effect of micronutrients on yield and its components, data presented in Table (6) indicate that application of micronutrient mixture as foliar spray was generally more effective than the control, where it exerted significant increases on total yield by 30, 11.19% and marketable yield by 31.84, 12.57%, in the first and second seasons, respectively. Micronutrients, also significantly increased total yield/plant, in both season, and significantly reduced non-marketable yield by 8%, in the second season only. However, number of tubers/plant was not significantly influenced by micronutrients in both seasons. The improving effect of Zn, Mn and Fe on yield and its components might be attributed to their positive role on enhancing photosynthesis, biosynthesis of proteins and carbohydrate assimilation diverted to the tuber roots (Nijjar, 1985). This is in coincidence with the findings of Badillo and Lopez (1976) on sweet potato and Nofal (1998) on potato plants, where they found that yield and its components were increased markedly by foliar spray of micronutrients compared with the untreated plants.

Table (5): Vegetative growth parameters and chlorophyll content of sweet potato plants as affected by the interactions of micronutrients, P_2O_5 levels and biofertilizers, during 2002 and 2003 seasons.

Treatments (Parameters)			Vin length (cm)		Number of branches/ plant		Leaf area/ plant (m^2)		dry weight/ plant (gm)		chlorophyll (A + B) (mg/g F.W)	
Micro[3]	P-rates	Bio[1].	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Without	Control	Cont[2]	99.9	113.9	11.03	12.33	0.58	0.45	101.00	85.67	0.75	0.65
		VAM[4]	124.6	122.5	14.13	13.76	0.66	0.74	108.34	108.33	0.92	0.70
		Phos.[5]	113.4	120.0	13.20	13.67	0.62	0.60	103.64	96.00	0.85	0.69
	30 kg P_2O_5/fed	Cont.	126.9	119.4	12.72	13.10	0.66	0.55	112.33	91.83	1.01	0.74
		VAM	150.3	130.7	16.37	15.23	0.74	0.68	117.59	121.33	1.16	1.11
		Phos.	128.3	126.9	14.17	14.63	0.70	0.56	114.96	112.00	1.08	0.94
	45 kg P_2O_5/fed	Cont.	132.5	126.3	14.63	14.87	0.83	0.54	120.21	90.33	1.21	0.93
		VAM	145.9	137.3	18.37	16.57	0.93	0.79	130.02	133.15	1.39	1.46
		Phos.	134.9	131.0	16.10	15.27	0.88	0.63	126.1	104.33	1.34	1.05
	60 kg P_2O_5/fed	Cont.	128.3	134.9	18.97	17.40	1.09	0.97	128.88	102.83	1.47	1.05
		VAM	157.7	139.6	18.93	16.77	1.08	0.99	134.81	147.30	1.72	1.49
		Phos.	143.3	134.0	16.90	15.67	1.10	0.71	130.09	117.33	1.49	1.08
With	Control	Cont.	116.2	120.6	11.93	11.73	0.82	0.73	113.33	97.65	0.85	0.81
		VAM	139.1	131.4	17 20	16.03	0.88	0.79	116.66	129.81	1.03	1.21
		Phos.	131.6	129.2	14.43	14.77	0.85	0.76	115.62	126.85	0.93	0.90
	30 kg P_2O_5/fed	Cont.	140.5	127.3	14.27	15.07	0.92	0.89	124.03	117.26	1.23	0.89
		VAM	145.6	138.2	19.47	18.97	1.03	0.95	131.52	137.43	1.45	1.41
		Phos.	145.1	136.8	16.73	17.63	0.96	0.94	126.78	119.32	1.33	1.04
	45 kg P_2O_5/fed	Cont.	127.9	132.1	15.80	15.20	1.14	0.85	131.45	119.84	1.52	0.97
		VAM	157.2	147.7	21.67	19.60	1.26	1.35	149.97	165.01	1.73	1.56
		Phos.	147.5	141.2	18.00	18.40	1.20	1.26	139.54	141.47	1.63	1.19
	60 kg P_2O_5/fed	Cont.	132.5	142.9	18.53	17.53	1.14	0.98	132.12	107.44	1.63	1.10
		VAM	157.7	143.8	19.70	18.60	1.16	1.10	153.37	151.46	1.82	1.61
		Phos.	143.7	141.2	18.13	18.30	1.15	0.97	140.77	144.75	1.72	1.24
LSD (5)			N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	0.09	0.10

1- Bio. = biofertilizers   2- Cont.= control   3- Micro. = micronutrients
4- VAM = vascular arbuscular mycorrhiza   5- Phos.= phosphorein

Data in Table (6) also show that irrespective of the unfertilized plants, increasing the supplied p-rate from 30 to 60 kg P_2O_5/fed significantly increased total yield by 19.16% and 16.22%, in the first and second seasons respectively, marketable yield/fed and tuber yield/plant, in both seasons. Non-marketable yield was significantly reduced, in both seasons, by increasing P-rate from 30 to 60 kg P_2O_5, whereas, number of tuber roots/plant was significantly increased, in the second season only. These increases may be due to 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 be reflected positively on yield (Marschner, 1995). Similar results were reported by Abdel-Fattah and Abdel-Hamed (1997) and El- Morsy *et al.* (2002), who found that fertilization of sweet potato plants with P-fertilizer caused significant increases in total and marketable yield.

Table (6): Yield and its components of sweet potato plants as affected by micronutrients, P_2O_5 rates and biofertilizers, during 2002 and 2003 seasons.

Parameters	Yield/plant				Yield (ton/fed).					
	Weight (gm)		Number of tuber roots		Marketable yield		Non-marketable yield		Total yield	
Treatments	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
a- Effect of micronutrients										
Without	445.8	549.6	5.23	4.05	9.83	12.09	0.631	0.491	10.19	12.56
With	582.7	615.1	5.28	4.31	12.96	13.61	0.356	0.451	13.32	14.06
LSD (5%)	53.04	15.18	N.S	N.S	1.22	0.45	N.S	0.003	1.20	0.35
b- Effect of P-rates										
Control	443.7	486.1	4.87	3.57	9.77	10.66	0.373	0.501	10.14	11.11
30 kg P_2O_5/fed	483.9	558.1	5.20	3.88	10.70	12.29	0.362	0.477	11.06	12.76
45 kg P_2O_5/fed	552.8	636.1	5.38	4.46	12.29	14.08	0.339	0.463	12.64	14.54
60 kg P_2O_5/fed	567.7	648.9	5.60	4.78	12.82	14.39	0.360	0.444	13.18	14.83
LSD (5%)	59.28	12.50	N.S	0.22	1.35	0.29	0.008	0.007	1.35	0.27
c- Effect of biofertilizers										
Control	484.4	529.5	5.08	3.50	10.69	11.62	0.383	0.491	11.07	12.10
VAM[1]	554.4	625.9	5.51	4.77	12.33	13.05	0.337	0.454	12.67	14.31
Phosphorein	504.1	591.6	5.18	4.25	11.16	13.89	0.355	0469	11.52	13.52
LSD (5%)	42.52	9.41	N.S	0.18	0.95	0.22	0.007	0.01	0.97	0.21

1- VAM = vascular arbuscular mycorrhiza.

Regarding the effect of biofertilizers on yield and its components, data presented in Table (6) reveal that all studied characters of sweet potato yield and its components, except the non-marketable yield, were generally greater with biofertilizer treatments than without. Soil inoculation with VAM-fungi, in both seasons, or phosphorein, in the second season only, exerted significant increases in the total yield, marketable yield and tuber yield/plant. Meanwhile, number of tuber roots/plant significantly increased, in the second season only. Non-marketable yield was significantly reduced by bioifetilizer treatments, in both seasons. The highest total yield was obtained from plants inoculated with VAM-fungi. Plants inoculated with VAM-fungi increased total yield by 14.45 and 18.26% compared with the untreated ones, in the first and second seasons, respectively. In additions, non-marketable yields were reduced by VAM-fungi treatment than without biofertilizers by 13.46 and 8.15%, in both seasons. The favorable effect of VAM fungi on yield and its components of sweet potato may be due to the fact that there is symbiotic association between VAM fungi and plant roots, where the fungus benefits from the flow of photosynthetic products from the shoots to roots, and uses these products as a source of food. On the other hand, VAM fungi have the ability to supply the plant with N, certain micronutrients and some hormone substances, i.e., gibberellins, auxins and cytokinins. Moreover, VAM fungi play a great role in correcting the solubility problem and releasing the fixed phosphate form to available one, suitable for plant nutrition (Abou El-Khair, 2004).

Concerning the interaction effect of micronutrients x P-rates on sweet potato yield and its components, data in Table (7) show that there were significant effects, in both seasons, on total and marketable yields, as well as mycorrhizatuber root weight/plant. However, no significant effects were found in non-marketable yield or number of tuber roots/plant, in both seasons, as a result of interaction of micronutrients with P-rates. Generally, most studied characters of yield and its components had the highest values as a result of the interaction of 45 or 60 kg P_2O_5/fed. with micronutrients. The obtained results are in harmony with those of Badillo and Lopez (1976) on sweet potato, and Abdel-Fattah *et al.* (2002) on garlic, who indicated that the application of micronutrients in combination with different p-rates increased total yield and its components as compared with control plants.

Table (7): Yield and its components of sweet potato plants as affected by the interactions of micronutrients × P_2O_5 rates and micronutrient x biofertilizers, during 2002 and 2003 seasons.

Parameters		Yield/plant				Yield (ton/fed)					
		Weight (gm)		Number of tuber roots		Marketable yield		Non-Marketable yield		Total yield	
Treatments		2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Micro.[1]	P-rates	a-Interaction of micronutrients x P-rates									
Without	Control	403.1	438.8	5.08	3.42	8.84	9.62	0.375	0.525	9.21	10.03
	30 kg P_2O_5/fed	403.2	513.6	5.23	3.68	8.85	11.24	0.366	0.495	9.22	11.74
	45 kg P_2O_5/fed	431.0	613.4	5.23	4.32	9.51	13.54	0.342	0.483	9.85	11.40
	60 kg P_2O_5/fed	546.1	632.4	5.39	4.76	12.12	13.99	0.362	0.463	12.48	14.46
With	Control	484.2	533.3	4.66	3.73	10.70	11.71	0.371	0.478	11.07	12.19
	30 kg P_2O_5/fed	464.6	602.6	5.17	4.09	12.54	13.34	0.357	0.458	12.91	13.77
	45 kg P_2O_5/fed	674.6	658.9	5.52	4.61	15.08	14.62	0.336	0.443	15.42	15.06
	60 kg P_2O_5/fed	607.4	665.5	5.79	4.81	13.52	14.78	0.358	0.427	13.88	15.21
LSD (5%)		83.83	17.69	N.S	N.S	1.90	0.39	N.S	N.S	1.92	0.29
Micro.	Biofertilizers	b- Interaction of micronutrients x biofertilizers									
Without	Control	421.0	489.1	4.92	3.25	9.24	10.69	0.386	0.510	9.62	11.19
	VAM[2]	500.2	596.6	5.55	4.68	11.09	13.25	0.338	0.494	11.43	13.64
	Phosphorein	416.3	562.2	5.23	4.20	9.16	12.35	0.359	0.469	9.51	12.85
With	Control	547.7	569.1	5.25	3.75	12.14	12.55	0.380	0.472	12.52	13.08
	VAM	608.6	655.1	5.47	4.87	13.57	14.54	0.336	0.438	13.91	14.97
	Phosphorein	591.8	620.9	5.12	4.30	13.18	13.75	0.351	0.444	13.53	14.97
LSD (5%)		71.35	16.3	N.S	N.S	1.39	0.31	N.S	N.S	1.85	0.30

1- Micro. = micronutrients 2- VAM = vascular arbuscular

Data illustrated in Table (7) show that total yield of sweet potato roots, marketable yield and plant tuber yield significantly increased, in both seasons, as a result of the interaction of micronutrients and biofertilizers, while no significant effect was detected for the effect of this interaction on marketable yield and number of tuber roots/plant, in both seasons. The highest total yield, marketable yield and root yield/plant were obtained as a result of the interaction between VAM-fungi and micronutrients, followed by the interaction of phosphorein and micronutrients. These results are in agreement with those obtained by Sabik *et al.* (2001), where they showed that inoculation of faba bean plants with phosphate solubilizing bacteria and treating them with micronutrients, at the same time, increased total yield and seed yield/plant compared with the untreated plants.

Data presented in Table (8) show the interaction effect of P-rates with biofertilizers on sweet potato yield and its components. The interaction caused significant increase, in both seasons, in total yield, marketable yield/ fed and plant tuber yield. On the other hand, non-marketable yield was significantly reduced as a result of the interaction, in both seasons. However, no significant effect for the interaction was detected on number of tuber roots/plant, in both seasons. It is notable that plants fertilized with 45 kg P_2O_5/fed in the presence of VAM-fungi, in both seasons, or phosphorein, in the second season only, achieved higher yield/fed, marketable yield and plant tuber yield than those produced by using 60 kg P_2O_5/fed alone. Such results were previously explained by Negeve and Roncadori (1985), who indicated that phosphate fertilization was more effective in stimulating growth and yield of sweet potato in the presence of VAM-fungi. The obtained results are also in harmony with those of El-Shimi (2003) who reported that total yield and marketable yield of sweet potato increased by utilization of 75% of the recommended P + phosphorein, compared with control.

Table (8): Yield and its components of sweet potato plants as affected by the interaction of P_2O_5 rates × biofertilizers, during 2002 and 2003 seasons.

Treatments (Parameters)		Yield/plant: Weight (gm)		Yield/plant: Number of tuber roots		Yield (ton/fed): Marketable		Yield (ton/fed): Non-marketable		Yield (ton/fed): Total yield	
P-rates	Biofertilizers	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Control	Control	400.6	434.9	4.50	2.97	8.75	9.41	0.404	0.525	9.16	9.94
	VAM[1]	486.7	536.3	5.25	4.03	10.78	11.94	0.342	0.483	11.12	12.26
	Phosphorein	443.6	487.0	4.85	3.73	9.77	10.63	0.374	0.496	10.14	11.13
30 kg P_2O_5/fed	Control	462.6	496.9	4.68	3.18	10.18	10.90	0.385	0.501	10.57	11.36
	VAM	510.4	600.9	5.80	4.60	11.33	13.28	0.340	0.456	11.67	13.73
	Phosphorein	478.7	576.5	5.12	3.88	10.58	12.70	0.359	0.473	10.94	13.18
45 kg P_2O_5/fed	Control	451.6	565.7	5.08	3.73	9.95	12.45	0.369	0.480	10.32	12.93
	VAM	633.2	699.8	5.82	5.13	14.15	15.55	0.322	0.444	14.47	15.99
	Phosphorein	573.5	642.9	5.23	4.53	12.78	14.33	0.326	0.465	13.11	14.69
60 kg P_2O_5/fed	Control	622.6	620.5	6.07	4.15	13.85	13.72	0.376	0.459	14.23	14.18
	VAM	587.2	666.4	5.18	5.35	13.08	14.80	0.345	0.433	13.42	15.23
	Phosphorein	520.4	660.0	5.52	4.85	11.53	14.64	0.360	0.442	11.89	15.09
LSD (5 %)		85.04	18.8	N.S	N.S	1.93	0.45	0.014	0.021	1.95	0.43

1- **VAM =Vascular Arbuscular Mycorrhiza**

Interaction effect of all studied factors, i.e., micronutrients, P-rates and biofertilizers on sweet potato yield and its components is presented in Table (9). The data indicate that total yield, marketable yield and plant tuber yield were significantly influenced by the interaction, in both seasons, but non-marketable yield, and number of tuber roots/plant were insignificantly affected. Plants sprayed with micronutrients, received P at 45 kg P_2O_5/fed and inoculated with VAM-fungi produced the highest total and marketable yield. Similar results were reported by El-Morsy et al., (2002) and El-Shimi (2003), on sweet potato.

Table (9): Yield and its components of sweet potato plants as affected by the interaction of micronutrients, P_2O_5 rates and biofertilizers, during 2002 and 2003 seasons.

Treatments / Characters			Yield/plant				Yield (ton/fed)					
			Weight (gm)		Number of tuber roots		Marketable yield		Non-marketable yield		Total yield	
Micro.[3]	P-rates	Bio.[1]	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Without	Control	Cont.[2]	332.9	374.9	4.50	2.76	7.20	8.02	0.406	0.545	7.61	8.57
		VAM[4]	474.0	499.7	5.70	3.83	10.49	11.25	0.345	0.506	10.83	11.42
		Phos.[5]	402.4	441.9	5.03	3.66	8.82	9.58	0.376	0.524	9.19	10.10
	30 kg P_2O_5/fed	Cont.	379.3	462.7	4.63	3.03	8.28	10.06	0.387	0.516	8.67	10.58
		VAM	444.6	552.6	5.93	4.33	9.82	12.16	0.341	0.472	10.16	12.63
		Phos.	385.8	525.6	5.13	3.70	8.45	11.52	0.371	0.498	8.82	12.01
	45 kg P_2O_5/fed	Cont.	375.0	540.3	5.03	3.36	8.20	11.85	0.375	0.500	8.57	12.35
		VAM	496.9	673.7	5.40	5.13	11.03	14.94	0.324	0.457	11.36	15.40
		Phos.	421.1	626.1	5.27	4.46	9.29	13.82	0.328	0.492	9.62	14.31
	60 kg P_2O_5/fed	Cont.	597.1	581.6	5.50	3.86	13.27	12.81	0.378	0.481	13.65	13.29
		VAM	585.4	660.4	5.17	5.43	13.03	14.65	0.345	0.443	13.38	15.09
		Phos.	455.7	655.3	5.50	4.96	10.05	14.51	0.363	0.464	10.42	14.98
With	Control	Cont.	468.4	494.8	4.50	3.17	10.30	10.81	0.403	0.504	10.71	11.31
		VAM	499.5	572.9	4.80	4.23	11.08	12.64	0.339	0.460	11.42	13.09
		Phos.	484.8	532.2	4.67	3.17	10.71	11.69	0.371	0.469	11.08	12.16
	30 kg P_2O_5/fed	Cont.	545.9	531.2	4.73	3.33	12.09	11.73	0.384	0.486	12.48	12.14
		VAM	576.2	649.3	5.67	4.86	12.83	14.40	0.340	0.440	13.17	14.84
		Phos.	571.7	627.4	5.10	4.06	12.72	13.89	0.349	0.447	13.07	14.34
	45 kg P_2O_5/fed	Cont.	528.2	591.1	5.13	4.10	11.71	13.05	0.363	0.460	12.07	13.51
		VAM	769.6	725.9	6.23	5.13	17.27	16.16	0.321	0.431	17.59	16.59
		Phos.	725.6	659.7	5.20	4.60	16.26	14.64	0.325	0.438	16.59	15.08
	60 kg P_2O_5/fed	Cont.	648.1	659.3	6.63	4.43	14.44	14.63	0.373	0.438	14.81	15.07
		VAM	588.9	672.5	5.20	5.26	13.12	14.95	0.345	0.422	13.46	15.37
		Phos.	585.1	664.7	5.53	4.73	13.01	14.77	0.359	0.420	13.37	15.19
L.S.D at 5%			95.6	26.6	N.S	N.S	2.05	0.63	N.S	N.S	1.98	0.60

1- Bio. = biofertilizers 2- Cont.= control 3- Micro. = micronutrients
4- VAM = vascular arbuscular mycorrhiza 5-Phos.= phosphorein

Tuber root characters:

Data illustrated in Table (10) show the physical properties of sweet potato roots, expressed as weight, length, diameter and shape. Application of micronutrients resulted in significant increases in average weight and diameter of tuber root, in both seasons, and average root length, in the second season only. However, micronutrients did not significantly affect the shape of tuber roots. The improvement effect of micronutrients may be resulted from their effects on increasing vegetative growth of plant, which was subsequently reflected positively on the physical properties of root tubers. These results are in accordance with those of Abdel-Fattah *et al.* (2002) who showed that both bulb weight, and diameter and clove weight of garlic plants were better than the plants sprayed with mixture of micronutrients (Fe + Zn + Cu), compared with the untreated plants.

Effect of P-rates on tuber root characteristics is presented in Table (10). The obtained results revealed that average weight, diameter and length of tuber roots were increased significantly as the applied P-rate increased from 0 to 60 kg P_2O_5/fed. However, all tested P-rates did not significantly affect shape of tuber roots, in both seasons. The obtained increases in tuber root characteristics may be attributed to the role of P-element as an essential component of many organic compounds in plants and to its major role in protein synthesis and protoplasm formation, factors that may increase the proportion of protoplasm to cell wall, which may result in an increase in cell size (Marschner, 1995). Similar results were reported by Abdel-Fattah and Abdel-Hamed (1997) who revealed that application of sweet potato plants with 68 kg P_2O_5/fed. significantly increased weight, length and diameter of tuber roots, compared with unfertilized plants.

Concerning the effect of biofertilizers on tuber root characteristics of sweet potato, data in Table (10) indicated that inoculation of plants with biofertilizers resulted in significant increases in weight, length and diameter of tuber roots, in both seasons. However, it did not exert any significant effect on tuber root shape, in both seasons. The highest values of weight, length and diameter of tuber root were obtained from VAM fungi followed by phosphorein. Such results may suggest that the used VAM-fungi or phosphorein had the ability to supply grown plants with phosphorus to meet their phosphorus requirements, and they may also alter the plant root morphology, by inducing the growth of an enlarged root system and thus causing a greater surface area for P absorption (Marschner., 1995). Some investigators came to nearly similar results, where Awad (2002), found that inoculation of potato plants with phosphorein or VAM increased significantly weight and length of tuber compared with those of uninoculated plants.

Table (10): Tuber root characteristics of sweet potato as affected by micronutrients, P_2O_5 rates and biofertilizers, during 2002 and 2003 seasons.

Characters	Root weight (gm)		Root length (cm)		Root diameter (cm)		Root shape (length/diameter)	
Treatments	2002	2003	2002	2003	2002	2003	2002	2003
a- Effect of micronutrients								
Without	170.3	142.2	15.90	15.3	5.0	4.8	3.2	3.2
With	180.5	171.5	17.5	16.1	5.4	5.2	3.3	3.1
L.S.D at 5%	5.6	12.7	N.S	0.04	0.25	0.12	N.S	N.S
b- Effect of P-rates								
Control	155.3	116.5	14.5	14.2	4.7	4.4	3.1	3.2
30 kg P_2O_5/fed	179.3	143.4	16.2	15.2	5.1	4.8	3.2	3.2
45 kg P_2O_5/fed	182.2	175.4	18.0	16.1	5.4	5.1	3.3	3.2
60 kg P_2O_5/fed	184.7	191.8	18.4	17.3	5.7	5.7	3.2	3.1
L.S.D at 5%	7.8	11.5	0.7	0.5	0.17	0.08	N.S	N.S
c- Effect of biofertilizers								
Control	169.3	131.9	16.3	14.8	5.0	4.5	3.3	3.3
VAM[1]	187.5	182.7	17.5	16.6	5.6	5.5	3.1	3.1
Phosphorein	169.4	155.8	16.5	15.6	5.1	5.1	3.2	3.1
LSD (5%)	3.9	11.6	0.2	0.4	0.1	0.1	N.S	N.S

1- VAM = vascular arbuscular mycorrhiza.

Data presented in Table (11) show the interaction effect of micronutrients with P-rates on tuber root characteristics. Generally, there were significant effects for the interaction, in both seasons, on weight and diameter of tuber root. However, length and shape of tuber roots were not significantly influenced by the interaction, in the two seasons. It was clear also that plants sprayed with micronutrients at 45 or 60 kg P_2O_5/fed. gave the highest values of tuber root features, in both seasons, while the lowest values were obtained from control plants. The obtained results are in accordance with those of Abdel-Fattah *et al.* (2002).

It is evident from Table (11), that average weight of tuber root, in the second seasons only, and tuber root diameter, in both seasons were significantly increased by biofertilizers application in the presence of micronutrients than in the absence of them. Nevertheless, there was no significant effect for this interaction on tuber root shape, in both seasons. The highest values of tuber root features, in both seasons, were obtained from the

Table (11): Tuber root characteristics of sweet potato as affected by the interactions of micronutrients × P_2O_5-rates and micronutrients x biofertilizers, during 2002 and 2003 seasons.

Treatments	Parameter	Root weight (gm)		Root length (cm)		Root diameter (cm)		Root shape (length/diameter)	
		2002	2003	2002	2003	2002	2003	2002	2003
Micro.[1]	P-rates	a- Interaction of micronutrients x P-rates							
Without	Control	144.8	111.8	14.5	13.9	4.6	4.3	3.1	3.1
	30 kg P_2O_5/fed.	173.8	128.8	15.5	14.9	4.9	4.6	3.2	3.3
	45 kg P_2O_5/fed.	178.4	152.7	17.0	15.5	5.2	4.9	3.3	3.2
	60 kg P_2O_5/fed.	184.0	175.4	16.9	16.8	5.3	5.6	3.2	3.0
With	Control	165.8	121.3	14.5	14.4	4.8	4.6	3.0	3.1
	30 kg P_2O_5/fed.	184.8	158.0	17.0	15.6	5.4	5.1	3.2	3.1
	45 kg P_2O_5/fed.	186.0	198.2	18.9	16.7	5.6	5.3	3.4	3.2
	60 kg P_2O_5/fed.	185.4	208.3	19.9	17.8	6.0	5.7	3.3	3.1
LSD (5%)		8.2	12.9	N.S	N.S	0.32	0.11	N.S	N.S
Micro.	Biofertilizers	b- Interaction of micronutrients x biofertilizers							
Without	Control	166.2	116.3	15.8	14.2	4.8	4.4	3.3	3.2
	VAM[2]	182.3	174.1	16.6	15.2	5.3	5.3	3.1	3.1
	Phosphorein	162.3	136.1	15.6	16.4	4.9	4.8	3.2	3.2
With	Control	172.5	174.6	16.9	15.4	5.1	4.5	3.3	3.4
	VAM	192.7	191.3	18.5	16.9	5.8	5.6	3.2	3.0
	Phosphorein	176.3	175.5	17.4	16.1	5.3	5.4	3.3	2.9
LSD (5%)		N.S	3.1	N.S	N.S	0.14	0.13	N.S	N.S

1- Micro. = micronutrients 2- VAM = vascular arbuscular mycorrhiza.

interaction of micronutrients with VAM-fungi. Obtained results go well with those of (Mosse, 1973), who found that VAM-fungi enhance the uptake of iron and zinc to the plants.

Data illustrated in Table (12) reveal that average root weight and diameter were significantly affected, in both seasons, by the interaction of P-rates and bioferitilzers. On the contrary, length and shape of tuber roots were not significantly influenced by this interaction, in both seasons. In general, plant fertilized with 45 or 60 kg P_2O_5/fed. in the presence of VAM, almost gave the highest values of tuber root features, except shape, in both seasons. Plants that not supplied with P or treated with VAM gave the lowest values, in both seasons. There were no significant differences between tuber root features of plants treated with the combination of VAM fungi and 45 kg P_2O_5/fed. or treated with 60 kg P_2O_5/fed and VAM fungi. Thus, the application of 45 kg P_2O_5/fed with VAM-fungi inoculum to sweet potato plants, is economically sufficient treatment for good production. These results are in harmony with those of Khasa *et al.* (1992) who stated that sweet potato plants were highly dependent on mycorrhiza for normal growth and tuber root development.

Table (12): Tuber root characteristics of sweet potato as affected by the interaction of P_2O_5 rates × biofertilizers, during 2002 and 2003 seasons.

Characters / Treatments		Root weight (gm)		Root length (cm)		Root diameter (cm)		Root shape (length/diameter)	
P-rates	Biofertilizers	2002	2003	2002	2003	2002	2003	2002	2003
Control	Control	138.9	96.5	14.3	13.4	4.4	4.0	3.3	3.3
	VAM[1]	169.5	135.5	14.8	15.1	5.0	4.8	2.9	3.2
	Phosphorein.	157.5	117.5	14.5	14.1	4.7	4.6	3.1	3.1
30 kg P_2O_5/fed	Control	171.9	116.8	15.7	14.3	4.8	4.3	3.3	3.3
	VAM	190.2	172.3	17.1	16.3	5.5	5.3	3.1	3.1
	Phosphorein.	175.8	141.0	16.0	15.2	5.1	4.9	3.1	3.1
45 kg P_2O_5/fed	Control	170.4	144.7	17.4	15.3	5.1	4.5	3.4	3.4
	VAM	197.1	210.1	19.3	16.9	5.9	5.7	3.3	2.9
	Phosphorein.	179.1	171.4	17.3	16.1	5.2	5.1	3.3	3.1
60 kg P_2O_5/fed	Control	196.2	169.7	18.0	16.4	5.7	5.0	3.5	3.2
	VAM	193.2	212.6	19.0	18.2	5.8	6.2	3.3	2.9
	Phosphorein.	164.7	193.0	18.1	17.3	5.5	5.8	3.3	3.0
LSD (5%)		8.53	14.3	N.S	N.S	0.2	0.2	N.S	N.S

1- VAM =Vvascular Arbuscular Mycorrhiza

Results presented in Table (13) show the effect of the interaction of all studied factors viz. micronutrients, P-rates and biofertilizers on tuber root characteristics of sweet potato. The obtained results indicated that all characteristics of tuber roots, with the exception of tuber root weight, were not significantly affected by the three ways interaction, in both seasons. Plants sprayed with micronutrients, supplied with 45 kg P_2O_5/fed and inoculated with VAM-fungi achieved great values, which were nearly similar to those produced by the combination 60 kg P_2O_5/fed. and VAM fungi, in the absence or presence of micronutrients. The obtained results are true in both growing seasons. These results are in agreement with those of Sabik *et al* (2001) on faba bean crop, Alphons *et al.* (2001) and El-Morsy *et al* (2002) on sweet potato.

Table (13): Tuber root characteristics of sweet potato as affected by the interaction of micronutrients, P_2O_5 rates and biofertilizers, during 2002 and 2003 seasons.

Characters / Treatments			Root weight (gm)		Root length (cm)		Root diameter (cm)		Root shape (length/diameter)	
Micro.[3]	P-rates	Bio.[1]	2002	2003	2002	2003	2002	2003	2002	2003
Without	Control	Cont.[2]	128.4	90.1	14.7	12.7	4.3	3.9	3.4	3.2
		VAM[4]	16.2	133.6	14.3	14.9	4.9	4.5	2.9	3.3
		Phos.[5]	145.8	111.8	14.4	13.9	4.7	4.3	3.0	3.2
	30 kg P_2O_5/fed	Cont.	163.2	97.9	15.1	13.7	4.7	4.2	3.2	3.2
		VAM	193.2	167.0	16.1	16.1	5.1	5.0	3.2	3.2
		Phos.	165.0	121.5	15.4	14.8	4.8	4.5	3.2	3.3
	45 kg P_2O_5/fed	Cont.	170.4	123.5	17.3	14.4	4.9	4.4	3.5	3.3
		VAM	191.4	191.7	18.0	16.6	5.6	5.6	3.2	2.9
		Phos.	173.4	142.9	15.8	15.6	5.1	4.8	3.1	3.3
	60 kg P_2O_5/fed	Cont.	202.8	153.9	15.9	16.1	5.5	5.1	2.9	3.2
		VAM	184.2	204.1	17.6	17.9	5.5	6.2	3.2	2.9
		Phos.	165.0	168.1	16.8	16.5	5.1	5.6	3.3	2.9
With	Control	Cont.	149.4	102.9	13.8	13.9	4.5	4.1	3.1	3.4
		VAM	178.8	137.5	15.2	15.3	5.1	4.9	2.9	3.1
		Phos.	169.2	123.3	14.5	14.1	4.8	4.8	3.0	2.9
	30 kg P_2O_5/fed	Cont.	180.6	135.7	16.4	14.9	4.9	4.4	3.3	3.3
		VAM	187.2	177.8	18.1	16.6	5.8	5.5	3.1	3.0
		Phos.	186.6	160.6	16.6	15.5	5.4	5.3	3.1	2.9
	45 kg P_2O_5/fed	Cont.	170.4	165.9	17.5	16.1	5.2	4.6	3.4	3.5
		VAM	202.8	228.6	20.5	17.4	6.2	5.8	3.3	2.9
		Phos.	184.8	199.6	18.9	16.5	5.4	5.5	3.5	3.0
	60 kg P_2O_5/fed	Cont.	189.6	185.6	20.1	16.7	6.0	5.0	3.4	3.3
		VAM	202.2	221.2	20.3	18.5	6.2	6.3	3.3	2.9
		Phos.	164.6	217.9	19.5	18.1	5.9	5.9	3.3	3.1
LSD at (5%)			12.1	16.2	N.S	N.S	N.S	N.S	N.S	N.S

1- Bio. = biofertilizers 2- Cont.= control 3-Micro. = micronutrients
4- VAM = Vascular arbuscular mycorrhiza 5- Phos.= phosphorein

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تأثير التسميد الفوسفاتى المعدنى والحيوى والرش بالعناصر الدقيقة على البطاطا: ١-النمو الخضرى والمحصول الكلى وصفات الجذور المتدرنة.

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أجريت تجربتان حقليتان فى المزرعة البحثية بالبرامون التابعة لمحطة بحوث البساتين بالمنصورة، خلال صيف موسمى ٢٠٠٢ ، ٢٠٠٣ . وهدفت الدراسة إلى بحث تأثير رش خليط من المغذيات الدقيقة (الحديد والزنك والمنجنيز بمعدل ١٠٠ جزء فى المليون لكل عنصر) والتسميد الحيوى بالفوسفورين أو الميكورهيزا وكذلك التسميد الفوسفورى المعدنى بتركيز صفر ، ٣٠ ، ٤٥ ، ٦٠ كجم فو٢أ٥ / فدان على نمو ومحصول وصفات الجذور المتدرنة للبطاطا صنف أبيس . أوضحت النتائج أن الرش بالعناصر الدقيقة أدى الى زيادة معنوية فى صفات النمو الخضرى ماعدا عدد الأفرع / نبات ، وإلى زيادة معنوية فى محصول النبات وكذلك المحصول الكلى التسويقى / فدان ، كما أدى إلى تخفيض المحصول الغير تسويقى / فدان. وكان هناك زيادة معنوية فى متوسط وزن وقطر الجذور المتدرنة نتيجة الرش بالعناصر الدقيقة .

وجد أن زيادة معدل التسميد الفوسفاتى المعدنى إلى ٤٥ أو ٦٠ كجم فو٢أ٥ / فدان أدت الى زيادة معنوية فى صفات النمو الخضرى ومحصول النبات والمحصول الكلى التسويقى / فدان ، كما أدت إلى خفض معنوى للمحصول الغير تسويقى / فدان وإلى زيادة معنوية فى متوسط وزن وقطر وطول الجذور المتدرنة.

وقد أدى إضافة الأسمدة الفوسفاتية الحيوية ، سواء الفوسفورين أو الميكورهيزا ، إلى زيادة معنوية فى النمو الخضرى والمحصول الكلى التسويقى / فدان ومكوناته. أدى ايضا إستخدام الأسمدة الفوسفاتية الحيوية إلى زيادة فى متوسط وزن وقطر وطول الجذور المتدرنة. ولم يؤثر أى من المعاملات المدروسة فى شكل الجذور المتدرنة معبرا عنه بالطول / القطر. وقد دلت النتائج على وجود تداخل إيجابى مؤثر بين معاملات الرش بالعناصر الدقيقة والتسميد الفوسفاتى المعدنى والحيوى على معظم الصفات التى درست.