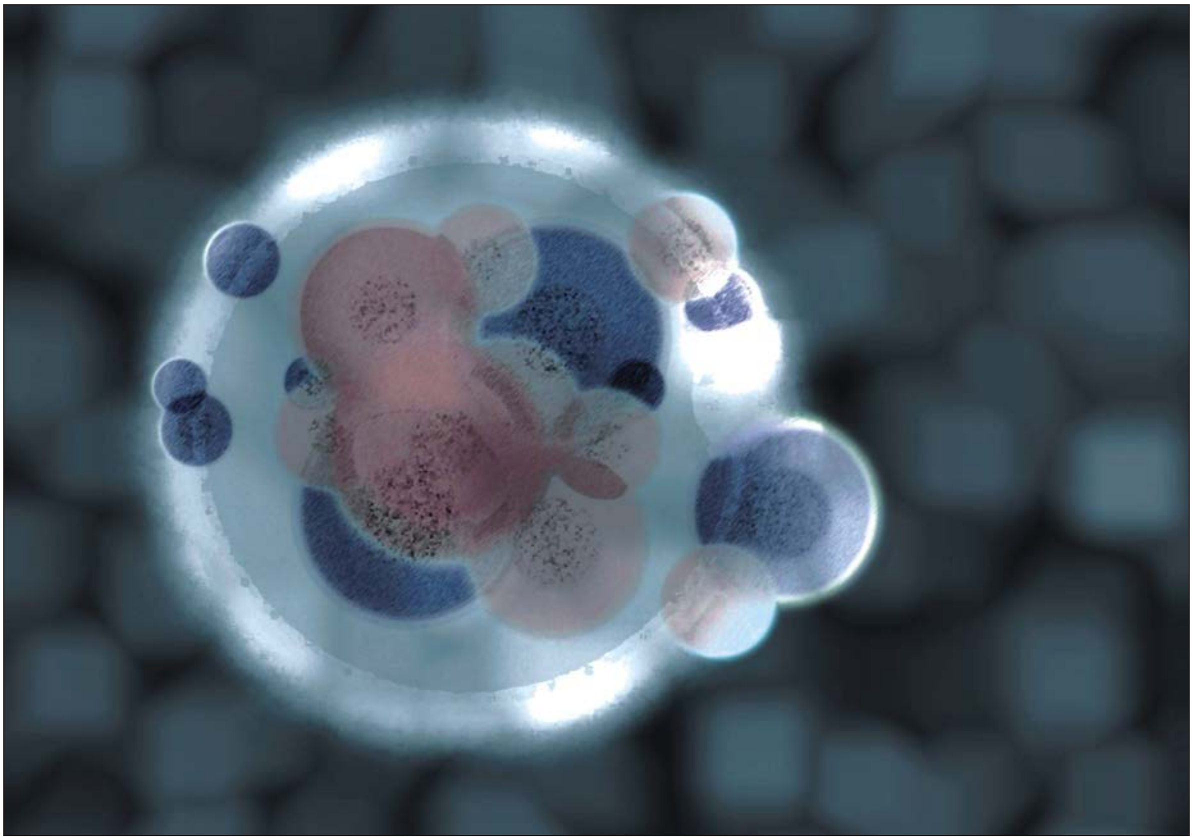

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Response of Sweet Potato to Integrated Effect of Chemical and Natural Phosphorus Fertilizer and Their Levels in Combination with Mycorrhizal Inoculation

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Abstract: Agricultural practices based on combinations of biofertilizer and inorganic or natural sources of fertilizer would produce vigor growth and more sustainable yield than either using biofertilizer or inorganic fertilizer alone. In this respect, two field trials were performed in 2007 and 2008 summer seasons to determine the growth, root quantity and quality response of sweet potato to chemical and natural Phosphorus (P) fertilizer (superphosphate and rock phosphate) under four levels of P in combination with Vesicular Arbuscular Mycorrhiza (VAM) fungi inoculation treatment and their integrated effects. The obtained results showed superior growth, increased total and marketable yield, in addition improved root quality (total sugars, total carotene, total soluble solids and carbohydrates) with superphosphate comparing with natural rock phosphate. Application of the highest level of P (100% P_2O_5) enhanced vine length, leaves number and vine fresh weight. Also, increased root quantity and quality traits. Inoculation plants with VAM-fungi significantly increased productivity and improved root organic composition. Integrated effects between either superphosphate under the recommended level (100% P_2O_5) or between VAM-fungi inoculation under the same level exhibited improving in plant growth and yield production. Sweet potato plants tended to reveal their best quality performance when superphosphate is applied combined with VAM-fungi inoculation treatment. In general, the obtained results indicated that for increasing sweet potato root production and quality, a combination between superphosphate at the recommended P level and VAM-fungi inoculation treatment was the best. The integrated effect between superphosphate and VAM-fungi was better than either using inorganic or bio-phosphate fertilizer alone.

Key words: Sweet potato, superphosphate, rock phosphate, VAM-fungi inoculums, root productivity, organic composition

INTRODUCTION

Sweet potato (*Ipomoea batatas* L.) is a tuber root-bearing vegetable species grown in tropic areas for either domestic or industrial uses. Tuber roots have great food quality, since they qualified as an excellent source of anti-oxidants and carotenes (precursors of vitamin A), chiefly in the orange flesh color varieties, thus providing cheap and rich source of vitamin A for poor people (Woolfe, 1992). Sweet potato have a high production yield of biomass, accordingly it could have superior impact as industrial material for application in medicinal purposes (Berberich *et al*., 2005) or for processing other profit products like starch, alcohol as well as for table use (Yasmin *et al*., 2007). Sweet potato production represents about 95% of the world output and it is considered as a food crop that can be used to reduce the food shortage and defeat hunger (Kassali, 2011). The cultivated area of sweet potato in Egypt was about 10.000 ha in 2009, producing 265.000 tons. Egypt ranks the ninth of the 10 top leading countries in the world before Brazil for exported sweet potato (FAOSTAT, 2011). In the last decade, Egyptian farmers paid great attention for improving sweet potato production and quality with the aim of increasing local consumption and exported yield (Hassan *et al*., 2005a). To maximize crop yield per unit area, largely chemical fertilizers are used. Phosphorus (P) is one of the vital minerals added for most vegetable species including sweet potato (El-Sayed *et al*., 2011). Under Egyptian soil conditions, P availability is considered one of the major growth-limiting factors for growing plants. The P of the applied fertilizers converts fast to unavailable form for plant absorption by its reaction with the soil constituents (Dawa *et al*., 2007). This could be explained why the cultivated soils require a high amount of mineral P fertilizers to complete supplies of plants. Yet, the use of large amounts of such fertilizers is responsible for rising production cost, as well as leads

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to the crisis of environmental pollution, particularly water and soil (Zarei *et al*., 2012). The use of bio-fertilizer and/or natural fertilizer is low-cost resources for providing the plants with P during their growth schedule, which could fairly alternates the expensive applied chemical P fertilizers. Thus, leading to significant reduction in the production cost and pollution level in the soil and water could be decreased (Shaheen *et al*., 2012). The use of bio-phosphate fertilizer; Arbuscular Mycorrhizal Fungi (AMF) is proposed as a low-cost and low-energy mechanism to amplify agronomic efficiency of rock phosphate fertilizer (Antunes *et al*., 2007). The AMF symbiosis is recognized for its ability to increase uptake some insoluble sources of inorganic minerals, particularly P in the soil (Demir, 2004). Hence, employing of vesicular arbuscular mycorrhiza (VAM-fungi) to supplement mineral fertilizer use, as an integrated management system, is of supreme magnitude to reduce the cost of applied mineral fertilizer, maximizing yield and sustaining sweet potato. The objective of this investigation was to determine the growth, root yield and quality response of sweet potato 'Abees' cultivar to an integrated scheme of supplementing chemical and natural P fertilizer; superphosphate and rock phosphate under different levels combined with VAM-fungi inoculation.

MATERIALS AND METHODS

Two field trials were carried out at the Agricultural Experimental Station Farm, Fac. of Agriculture, Alexandria Univ., Alexandria, Egypt in 2007 and 2008 summer seasons. The most famous Egyptian sweet potato local cultivar 'Abees', a purple skin with sweet orange-flesh was used. Preliminary to each experiment, soil samples of 0-30 cm layer were taken at random from various locations of the study area before planting for analysis (Page *et al*., 1982). Soil analysis results of the study area are shown in Table 1.

Phosphorus fertilizer sources and levels: Two foremost sources of P fertilizers; chemical calcium superphosphate and natural rock phosphate were used at the equal full dose of 45 kg P_2O_5 feddan^{-1} (one fed. = 4200 m^2 = 2.4 ha) which is considered as a recommended dose for sweet potato production (Hassan *et al*., 2005a). (a) Calcium superphosphate form (15.5% P_2O_5) was applied at 4 levels; 0, 72.5, 145 and 290 kg which represent 00, 25, 50 and 100% of the recommended dose (45 kg P_2O_5 fed.$^{-1}$, 100% dose), (b) Rock phosphate form (22.5% P_2O_5) was added at 4 levels; 00, 50, 100 and 200 kg which represent 00, 25, 50 and 100% of the same recommended dose.

All amounts of different P sources were applied at the time of final land preparation.

Table 1: Pre-planting soil analysis results of the study area

Summer season	Soil texture	EC (dS m^{-1})	pH	OM (%)	Available N, P and K (mg g^{-1}) N	P	K
2007	Clay	3.6	8.1	1.8	211	23	756
2008	Clay	3.2	7.2	2.0	199	25	740

The physical and chemical properties analyses were conducted at the Soil and Water Science Department, Faculty of Agriculture, Alexandria University

Vesicular arbuscular mycorrhiza inoculation source: The symbiotic VAM-fungi species (*Glomus mosseae*) was supplied by the Soil and Water Science Dep., Fac. of Agriculture, Alexandria Univ., Egypt. The VAM-fungi inoculums (50 g) were added to the root absorption zone of sweet potato plants, two weeks from planting (Dawa *et al*., 2007). Percentage of mycorrhizal colonization was estimated by gridline intersect method (Giovannetti and Mosse, 1980).

Experimental design: Experiment was executed in split-split-plots system in a Randomized Complete Blocks Design (RCBD) with three replications. Each replicate included 16 treatments which represent all possible combinations. Two P fertilizer sources; superphosphate and rock phosphate were set as the main plots. The sub-plots were considered four levels of super-and rock-phosphate (0, 25, 50 and 100% P_2O_5). While, the two VAM-fungi inoculation treatments (with and without) were allocated as the sub-sub-plots. Individual plots consisted of three rows of 4 m long and 0.75 m apart. Healthy vine cuttings (20 cm length) of 'Abees' cv. were set up in the field on 5 and 12 June of 2007 and 2008, respectively. They were planted on one side of the row at 25 cm apart. All experimental units received (100 kg fed.$^{-1}$) of each N as ammonium sulphate (20.5% N) and K as potassium sulphate (48.5% K_2O). N fertilizer was equally side-dressed to the soil in three diverse intervals after 3, 7 and 10 weeks from planting. The doses of K fertilizer were equally split and applied after 3 and 7 weeks from planting. Extra agricultural practices often used in sweet potato production; irrigation and pest control were adopted using the Egyptian Ministry of Agriculture recommendations.

Measured parameters

Vegetative growth traits: Five plants randomly picked up from the sub-sub-plots, two weeks before harvesting (within 100 days from transplanting), to measure the following traits: vine length plant^{-1} (cm), number of branches plant^{-1}, number of leaves plant^{-1}; vine fresh weight plant^{-1} (kg) and leaves dry weight plant^{-1} (%).

Tuber roots yield and its components: At harvesting stage 120 days after planting, all tuber roots plots^{-1} were collected and the following measurements were recorded: fresh weight of root (average five uniform roots, g), total root yield plant^{-1} (kg), total root yield (ton fed^{-1}), marketable root yield (ton fed.$^{-1}$) and unmarketable root yield (ton fed.$^{-1}$). Unmarketable yield is represented by thinner (less than 3 cm) or thicker (more than 10 cm) roots in diameter as well as cut and injured roots.

Organic composition of tuber roots: A random sample of five uniform roots from the sub-sub-plots were carefully washed with distilled water, then weight and analyzed for root organic composition analyses. Total carotenoides as β-carotene (mg 100 g^{-1} fresh weight) was measured (Witham *et al*., 1971). Total sugars, starch and carbohydrates were determined following the standard methods of association of official analytical chemists (AOAC, 1995). Total Soluble Solid (TSS) was estimated using a portable refractometer.

Statistical analysis: The reached data were analyzed statistically using a computer program (Co-Stat Software, 2004). The comparisons among means of the treatments were achieved by way of Duncan's multiple range tests at 0.05 probability level (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Vegetative growth traits

Effects of phosphorus sources: Addition of P fertilizer as a superphosphate for sweet potato plants gained the most vigor plant growth traits; tallest vine length, largest number of branches plant^{-1} and largest number of leaves plant^{-1}, if compared with a rock phosphate (Table 2). This might be due to that the superphosphate is more availability and solubility for plant absorption, increasing P near roots zone and hence better uptake by the roots (Shaheen *et al*., 2012). These results agree with Shaheen *et al.* (2007, 2012), who reported that onion plants which received its P requirements as chemical superphosphate were detected the vigor plant growth if compared with that plants supplied by the natural rock phosphate. On the contrary, vine fresh weight plant^{-1}, in both seasons and leaves dry weight, in the second season were increased by the application of rock phosphate source. This result is in conformity with El-Banna and Abd El-Salam (2000), who reported in potato plants that using rock phosphate fertilizer increased significantly both foliage fresh and dry weights plant^{-1}. They explained this increase in potato foliage fresh and dry weights was derived from the contents of rock phosphate source from CaO, F_2O_3, SiO4, SO_4, AlO_3 and MgO, which help in increase metabolites such as plant growth-promoting substances.

Effects of phosphorus levels: Data in Table 2 show that sweet potato plants which received three P fertilizer levels (25, 50 and 100% P_2O_5) were improved compared with the control treatment. Increasing P level from 50 to 100% P_2O_5 was associated with marked increase in most vegetative growth traits. These increases may be due to the beneficial effect of P on the activation of photosynthesis and metabolic processes of organic compounds in plants, thus, encourage plant growth (Gardner *et al*., 1985). These results are in accordance with those of Hassan *et al*., (2005a) and El-Sayed *et al.* (2011), who found that application of 45 kg P_2O_5 fed.$^{-1}$ (100% P_2O_5) to sweet potato plants was significantly superior in

Table 2: Vegetative growth traits of sweet potato plants 'Abees' cv. as affected by P sources, P levels and VAM-fungi inoculation treatments during 2007 and 2008 summer seasons

Growth traits	Vine length plant^{-1} (cm)		No. of branches plant^{-1}		No. of leaves plant^{-1}		Vine fresh weight plant^{-1} (kg)		Leaves dry weight (%)	
Treatments	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
P sources										
Superphosphate (SP)	195.9a	167.1a	5.16a	5.37a	220.9a	223.7a	1.131b	0.682b	33.51a	32.41b
Rock phosphate (RP)	187.3b	161.5b	4.59b	4.80b	209.9b	173.6b	1.243a	1.093a	30.13b	33.87a
P levels (P_2O_5 kg fed.$^{-1}$)										
0% P_2O_5 (L_0)	189.5b	158.8d	4.57c	4.70c	206.4d	181.2c	0.804c	0.833c	29.29c	29.34d
25% P_2O_5 (L_1)	191.4a	162.9c	4.70bc	5.05b	208.9c	195.7b	1.191b	0.683d	30.57c	35.21b
50% P_2O_5 (L_2)	192.7a	167.8b	4.83b	5.60a	223.4b	198.4b	1.113b	0.878b	32.65b	36.49a
100% P_2O_5 (L_3)	192.9a	171.6a	5.41a	5.00b	227.8a	219.3a	1.650a	1.156a	34.75a	31.51c
VAM-fungi inoculation										
Without mycorrhiza (M_0)	184.9b	158.0b	4.43b	4.73b	195.3b	168.4b	1.012b	0.682b	28.65b	31.17b
With mycorrhiza (M_1)	198.3a	172.2a	5.31a	5.48a	238.1a	228.7a	1.441a	1.092a	34.98a	35.10a

Values with the same letter(s) in the same column in each season are not significantly different using Duncan's multiple range test at 0.05 probability level

increasing vine length, number of branches plant^{-1}, leaf area plant^{-1}, canopy fresh and dry weights, compared with control treatment.

Effects of VAM-fungi inoculation treatments: Inoculated sweet potato plants with VAM-fungi produced significantly higher growth traits; number of leaves plant^{-1}, number of branches plant^{-1}, vine length plant^{-1}, vine fresh weight and leaves dry weight plant^{-1} when compared with un-inoculated plants (Table 2). Similar results were proved by El-Morsy *et al*. (2002) and Hassan *et al*. (2005a), who reported that inoculated sweet potato plants with VAM-fungi markedly, increased vine growth plant^{-1}, fresh and dry weights compared with un-inoculated plants. Mycorrhizal inoculation improves plant growth by facilitating mineral nutrition and progressing water relation which led to larger plant size (Auge, 2001).

Interaction effects between P sources and P levels: Medium or higher levels of superphosphate (50 or 100% P_2O_5) was associated with significant increases in vine length plant^{-1}, number of branches plant^{-1}, number of leaves plant^{-1} and leaves dry weight. However, using rock phosphate at the highest level (100% P_2O_5) gave the highest significant value for vine fresh weight plant^{-1} in the second season (Table 3). This could probably be explained based on the available P content in the study soil area was low (Table 1), which might have led to higher response to increased supply of the nutrient. The obtained results are in harmony with those of Shaheen *et al*. (2007), who indicated that the best plant growth of onion plants was attained with the plants that received the highest P rate (48 units of P_2O_5) as superphosphate form.

Interaction effects between P sources and VAM-fungi inoculation: The integrated effect between superphosphate and VAM-fungi generated the highest significant values for vine length plant^{-1}, number of branches plant^{-1}, number of leaves plant^{-1} and leaves dry weight (Table 3). The enhancement of growth traits resulted in sweet potato plants that inoculated with VAM-fungi may be refer to that the bio-phosphate

Table 3: Vegetative growth traits of sweet potato plants 'Abees' cv. as affected by integrated effects of P sources ×P levels, P sources ×VAM-fungi inoculation and P levels ×VAM-fungi inoculation treatments during 2007 and 2008 summer seasons

Growth traits	Vine length plant^{-1} (cm)		No. of branches plant^{-1}		No. of leaves plant^{-1}		Vine fresh weight plant^{-1} (kg)		Leaves dry weight (%)	
Treatments	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
P sources X P levels (P_2O_5)										
Superphosphate (SP)										
0%	194.3b	155.5d	4.53cd	4.90cd	200.4f	200.4c	0.731a	0.855cd	29.56c	28.43e
25%	194.8b	163.8bc	4.62cd	5.20b	220.8d	220.8b	0.783a	0.485g	32.14b	33.60c
50%	197.4a	172.6a	5.33b	6.31a	236.9a	236.9a	1.114a	0.596f	35.78a	39.23a
100%	197.4a	176.3a	6.17a	5.11b	225.5c	236.9a	1.911a	0.795e	36.54a	28.36e
Rock phosphate (RP)										
0%	184.6d	160.6c	4.62cd	4.52d	196.9g	162.3e	0.870a	0.812de	29.03c	30.25d
25%	188.0c	162.1c	4.78c	4.93cb	212.4e	170.6d	1.604a	0.881c	29.00c	36.83b
50%	188.0c	163.1bc	4.33d	4.91cd	200.4f	159.9e	1.115a	1.160b	29.53c	33.76c
100%	188.5c	167.0b	4.65cd	4.92bc	230.1b	201.7c	1.392a	1.518a	32.97b	34.65c
P sources X VAM-fungi inoculation										
SP										
Without (M_0)	189.4c	161.6c	4.72c	4.82bc	196.5c	194.9c	0.953c	0.487c	30.76c	27.14d
With (M_1)	202.5a	175.8a	5.61a	5.81a	245.2a	252.5a	1.195b	0.878b	36.26a	37.67a
RP										
Without (M_0)	180.5d	154.5d	4.13d	4.63c	193.8c	142.0d	1.350a	0.878b	26.56d	35.07b
With (M_1)	194.1b	168.6b	5.01b	5.14b	230.8b	204.9b	1.347a	1.307a	33.71b	32.48c
P levels (P_2O_5) X VAM-fungi inoculation										
M_0										
0%	172.0f	141.4g	3.52f	3.41d	127.1g	128.3e	0.181d	0.216g	22.11e	27.86e
25%	186.3e	155.3f	4.40e	5.02c	196.9f	170.4c	1.246bc	0.665f	29.52d	33.33c
50%	192.7c	165.7d	4.93cd	5.63ab	216.8e	166.9d	1.280bc	0.793e	30.14cd	35.20b
100%	188.8d	169.7c	4.85cd	4.94c	239.9b	208.4c	1.325b	1.056c	32.86b	28.32e
M_1										
0%	206.9a	182.9a	5.53b	5.71a	285.6a	234.1a	1.590a	1.450a	36.48a	30.82b
25%	196.5b	162.4e	5.00c	5.20bc	220.0d	220.5b	1.221bc	0.702f	31.62bc	37.10a
50%	192.7c	169.9c	4.73d	5.72a	230.0c	230.0a	1.150c	0.963d	35.18a	37.80a
100%	197.1b	173.5b	5.96a	5.31a-c	215.7e	230.3a	1.790a	1.256b	36.65a	34.70c

Values with the same letter(s) in the same column in each season are not significantly different using Duncan's multiple range test at 0.05 probability level

fertilizer which had a microorganism, its mode of action with chemical P is more effective which in sequence resulted in increase the absorption of nutrimental elements from the soil (Shaheen *et al*., 2012). The combination between rock phosphate and VAM-fungi revealed significant value for vine fresh weight trait.

Interaction effects between P levels and VAM-fungi inoculation: Inoculation of sweet potato plants with VAM-fungi alone in the absence of P application level gave the highest values of vine length plant^{-1}, number of leaves plant^{-1} and vine fresh weight plant^{-1} traits (Table 3). These results may be explain on the basis that mycorhizal symbiosis facilitates acquisition of many nutrients, mainly P which plays a decisive role in improving plant development in sensitive stage such as transplanting period (Bolandnazar, 2009). However, the combination between VAM-fungi inoculation and medium or higher P levels (50 or 100% P_2O_5) produced the highest values of branches number plant^{-1} and leaves dry weight (Table 3). The obtained results could be explained based on the results of Negeve and Roncadori (1985), who mentioned that phosphate fertilizer was more effective in stimulating growth of sweet potato plants in the presence of VAM-fungi.

Sweet potato root yield and its components

Effects of phosphorus sources: Application of superphosphate was accompanied by significant increases in average root fresh weight, root yield plant^{-1}, root yield fed.$^{-1}$ and marketable root yield fed.$^{-1}$ in comparison with the rock phosphate (Table 4). Application of superphosphate showed significant increase in total root yield plant^{-1} (10.63 and 7.69%) as well as total root yield fed.$^{-1}$ (34.62 and 25.37%) and marketable root yield fed.$^{-1}$ (24.59 and 26.49%) over than rock phosphate, in the first and second seasons, respectively. It could be concluded that, superphosphate source achieved the heaviest root weight and the best root yield of plants. This might be attributed to the better plant growth resulted from superphosphate than rock phosphate (Table 2). These findings can supported by the results of Shaheen *et al*. (2007, 2012), who found that the lowest onion bulbs weight and bulbs yield was associated with the addition of rock phosphate, while superphosphate form gained the heaviest bulbs weight and tonnage of bulbs yield. On the other hand, unmarketable root yield under natural rock phosphate (1.588 and 1.480 ton fed.$^{-1}$) was lower than unmarketable yield with chemical superphosphate (2.633 and 1.782 ton fed.$^{-1}$) (Table 4). This may happened due to the development of outsized or jumbo roots under mineral superphosphate.

Efects of phosphorus levels: Increasing P level from 25 to 100% P_2O_5 reflected significant increases in average root fresh weight, root weight plant^{-1}, total and marketable root yield, while unmarketable yield was significantly decreased comparing with control treatment. There were insignificant differences among the three P levels used on unmarketable root yield trait (Table 4). In general, application of the highest P level was statistically responsible for giving the highest increases for all roots yield and its component traits. This means that P fertilizer impacts on the productivity of sweet potato crop. These results agree with those obtained by El-Sayed *et al*. (2011). They indicated that root yield and its components of sweet potato were increased by increasing P-rate from 15 to 45 kg P_2O_5 fed^{-1}. The increases in both total and marketable yield of sweet potato resulting from mineral fertilization might be credited to its favorable effects on the vegetative growth traits (Table 2), which in turn

Table 4: Root yield and its components of sweet potato plants 'Abees' cv. as affected by P sources, P levels and VAM-fungi inoculation treatments during 2007 and 2008 summer seasons

Root yield components	Root fresh weigh plant^{-1} (g)		Total root yield plant^{-1} (kg)		Total root yield (ton fed.$^{-1}$)		Marketable root yield (ton fed.$^{-1}$)		Unmarketable root yield (ton fed.$^{-1}$)	
Treatments	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
P sources										
Superphosphate (SP)	161.7a	178.3a	0.525a	0.563a	8.909a	10.081a	6.267a	8.298a	2.633a	1.782a
Rock phosphate (RP)	144.4b	168.3b	0.471b	0.521b	6.618b	8.040b	5.030b	6.560b	1.588b	1.480b
P levels (P_2O_5 kg fed.$^{-1}$)										
0% P_2O_5 (L0)	142.4d	158.5d	0.374d	0.473c	6.773d	7.937d	4.415d	5.752d	2.358a	2.682a
25% P_2O_5 (L1)	147.6c	169.0c	0.462c	0.540b	7.453c	8.434c	5.753c	6.347c	1.700b	1.590b
50% P_2O_5 (L2)	158.2b	179.3b	0.540b	0.562a	7.908b	10.090b	6.183b	8.443b	1.725b	1.647b
100% P_2O_5 (L3)	163.3a	186.2a	0.613a	0.614a	8.916a	10.510a	7.246a	9.210a	1.670b	1.300b
VAM-fungi inoculation										
Without mycorrhiza (M0)	140.8b	165.2b	0.421b	0.471b	6.384b	6.366b	4.621b	4.834b	1.763b	1.532b
With mycorrhiza (M1)	165.5a	181.3a	0.575a	0.565a	9.144a	11.800a	6.676a	10.100a	2.468a	1.700a

Values with the same letter(s) in the same column in each season are not significantly different using Duncan's multiple range test at 0.05 probability level

increased root fresh weight, root weight plant^{-1} and consequently, root yield fed.$^{-1}$. The role of P fertilizer on sweet potato production attracted the attention of many researchers e.g., El-Morsy *et al.* (2002), Hassan *et al.* (2005a) and El-Sayed *et al.* (2011). These authors reported that fertilization of sweet potato plants by P caused significant increases in the total and marketable root yield as well as decreased the unmarketable root yield.

Efects of VAM-fungi inoculation: Inoculation of sweet potato plants with VAM-fungi reflected corresponding and significant increases in all roots yield and its component traits than un-inoculated treatment. It is also reduced unmarketable root yield than un-inoculated one (Table 4). The positive effect of VAM-fungi inoculation on sweet potato root yield and its components may be attributed to that, plants inoculated with VAM-fungi (*Glomus mosseae*) are potentially more effective on nutrient and water acquisition (George *et al.*, 1992). The extra-radical phase of the VAM fungus acts in effect, as an extension of the root system for the uptake of mineral nutrients, especially immobile nutrients like P, Cu and Zn which are transported back to the intra-radical structures where they are released by the fungus for uptake by the plant root cells. Thus, increase root and shoot biomass and improve growth and yield (Douds *et al.*, 2005).

Interaction effects between P sources and P levels: The obtained results exhibited significant differences in total root yield plant^{-1} and both total and marketable root yield fed.$^{-1}$ (Table 5). The interactions signify that good root yield can be obtained when superphosphate is applied at the highest P level (100% P_2O). This was probably because application of superphosphate increased P contents in rooting zone area and hence increased their availability for the growing plants (Sebastiani *et al.*, 2007). The relative increases in root weight plant^{-1}, total root yield and marketable yield fed.$^{-1}$ were: 46.55 and 31.25%, 63.63 and 60.45% and 127.63 and 81.20% in comparison with control treatment in both seasons, respectively. Similar findings were detected by Shaheen *et al.* (2007), who concluded that, the heaviest onion bulbs weight and bulbs yield were correlated with that plants received superphosphate at the highest P rate (48 units of P_2O_5).

Table 5: Root yield and its components of sweet potato plants 'Abees' cv. as affected by integrated effects of P sources ×P levels, P sources ×VAM-fungi inoculation and P levels ×VAM-fungi inoculation treatments, during 2007 and 2008 summer seasons

Root yield components	Root fresh weight plant^{-1} (g)		Total root yield plant^{-1} (kg)		Total root yield (ton fed.$^{-1}$)		Marketable root yield (ton fed.$^{-1}$)		Unmarketable root yield (ton fed.$^{-1}$)	
Treatments	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
P sources X P levels (P_2O_5)										
Superphosphate (SP)										
0%	147.5d	159.5f	0.38e	0.48d	6.891d	8.233g	3.750g	6.076g	3.141a	2.157a
25%	153.6c	174.3cd	0.48cd	0.55c	8.528c	8.406f	5.430d	6.915f	3.098a	1.491d
50%	168.6b	187.5ab	0.56b	0.55c	8.942b	10.471c	7.330b	8.892c	1.612e	1.579cd
100%	177.3a	191.6a	0.65a	0.63a	11.276a	13.210a	8.536a	11.311a	2.740b	1.896b
Rock phosphate (RP)										
0%	137.3e	157.5f	0.37e	0.46d	6.655e	8.635e	5.068e	7.426e	1.587e	1.209e
25%	141.6e	163.6ef	0.45d	0.49d	6.378f	7.466h	4.068f	5.780h	2.310c	1.686c
50%	149.3cd	171.2de	0.52c	0.57bc	6.875d	9.708d	5.080e	7.995d	1.795d	1.713c
100%	149.5cd	180.7bc	0.57b	0.59ab	6.566e	10.601b	5.956c	9.102b	0.615f	1.498d
P sources X VAM-fungi inoculation										
SP										
Without (M_0)	148.6c	166.3b	0.43b	0.54b	7.471c	6.318d	5.112c	4.685d	2.359b	1.633b
With (M_1)	174.9a	190.2a	0.61a	0.59a	10.350a	13.842a	7.422a	11.910a	2.928a	1.932a
RP										
Without (M_0)	132.8d	164.0b	0.41b	0.49c	5.297d	6.414c	4.130d	4.984c	1.167d	1.430c
With (M_1)	156.1b	172.5ab	0.54a	0.55b	7.940b	11.790b	5.930b	10.170b	2.010c	1.620b
P levels (P_2O_5) X VAM-fungi inoculation										
M_0										
0%	117.8f	131.3b	0.23d	0.35b	4.398h	3.602h	2.168g	1.918h	2.230c	1.684b
25%	138.8e	169.5a	0.42c	0.44a	6.660g	6.042g	4.543f	4.408g	2.117c	1.634b
50%	148.5d	181.3a	0.49bc	0.55a	6.976f	7.096f	5.156d	5.698f	1.820d	1.398c
100%	157.8c	188.8a	0.55b	0.55b	7.502e	8.725e	6.616c	7.313e	0.886f	1.412c
M_1										
0%	185.3a	185.6a	0.52bc	0.55a	9.148b	13.267b	6.656c	11.580b	2.492b	1.687b
25%	146.0d	168.5a	0.51bc	0.55a	8.246d	9.832d	4.963e	8.287d	3.283a	1.545bc
50%	161.8c	177.3a	0.58ab	0.58a	8.840c	13.083c	7.210b	11.180c	1.630e	1.903a
100%	168.8b	183.5a	0.68a	0.58a	10.341a	15.083a	7.876a	13.100a	2.465b	1.983a

Values with the same letter(s) in the same column in each season are not significantly different using Duncan's multiple range test at 0.05 probability level

Interaction effects between P sources and VAM-fungi inoculation: Pertaining to root yield and yield related components of sweet potato, 'Abees' cv., adding of superphosphate + VAM-fungi inoculation treatment produced the highest values of root fresh weight, total root yield plant^{-1}, as well as total and marketable root yield (ton fed.$^{-1}$) (Table 5). Such favorable interaction effect results may be expected on the basis that different mycorrhizal fungi explore the soil volume with their hyphae penetration to various extents and this can increase efficiency of P assimilation due to these structures facilitate nutrient transport partly by increasing both the root surface area and the root-soil contact (Westphal *et al*., 2008).

Interaction effects between P levels and VAM-fungi inoculation: The highest P level combined with VAM-fungi inoculation treatment resulted in more improvement in root fresh weight, root yield plant^{-1} and gave higher total and marketable root yield (ton fed.$^{-1}$) comparing with other treatments (Table 5). Such good integrated effect can support the findings of Yano and Takaki (2005), who stated that sweet potato plants were highly reliant on mycorrhizal symbiosis for improving shoot growth and root development. On the other side, the highest P level in the absence of VAM-fungi inoculation decreased unmarketable root yield (ton fed.$^{-1}$) (Table 5). This result is in disagreement with that of Hassan *et al.* (2005a), who found that unmarketable root yield significantly reduced at the same P level used (45 kg P_2O_5 fed.$^{-1}$) but with the presence of VAM-fungi inoculation treatment.

Chemical composition of sweet potato roots

Effects of P sources: There were significant differences regarding to total sugars, carbohydrates, TSS and total carotene contents, in both seasons as a result of applied superphosphate. However, it revealed higher content of starch, in the second season when compared with rock phosphate (Table 6). This could be due to more solubility and higher availability of nutrients resulted from a mineral Ca-superphosphate compared to rock phosphate or due to the limited solubility of rock phosphate (Shafeek *et al*., 2004).

Effects of P levels: Increasing the P level up to 50 or 100% P_2O_5 reflected significant increases in root chemical composition traits (total sugars, starch, carbohydrates, TSS and total carotene) of sweet potato compared with the lowest level of P fertilizer (25% P_2O_5) or control treatment (0% P_2O_5), in the two seasons with only one exception for total carotene, in the first season. Whereas, this trait showed linear increase with each increase in P level comparing with control treatment (Table 6). The obtained results are in agreement with those of El-Morsy *et al.* (2002), Hassan *et al.* (2005b), El-Sayed *et al.* (2011). These authors pointed out that an increase in the rate of applied P fertilizer from 15 to 60 kg P_2O_5 fed.$^{-1}$ caused an increase in total sugars, TSS, carbohydrates, starch and carotenoids contents in sweet potato root tissues.

Effects of VAM-fungi inoculation: Sweet potato plants inoculated with VAM-fungi significantly resulted in higher root contents of total sugars, starch, carbohydrates and TSS, in both seasons, as well as total carotene, in the first season in comparison with un-inoculated treatment (Table 6). The favorable effect of VAM-fungi on organic composition of sweet potato may be pass on VAM-fungi increase the uptake of P element, P plays the prime role during the breakdown of carbohydrates and/or synthesis of polysaccharides and

Table 6: Chemical constituents of sweet potato roots 'Abees' cv. as affected by P sources, P levels and VAM-fungi inoculation treatments during 2007 and 2008 summer seasons

Root quality	Total sugars (%)		Starch (%)		Carbohydrates (%)		Total soluble solids (%)		Total carotene (Mg/100 g f.w.)	
Treatments	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
P sources										
Superphosphate (SP)	7.92a	8.40a	15.04a	14.51a	22.56a	22.81a	12.44a	13.16a	5.69a	5.69a
Rock phosphate (RP)	7.63b	7.69b	14.59b	14.44a	21.71b	22.08b	12.34b	12.97b	5.48b	5.35b
P levels (P_2O_5 kg fed.$^{-1}$)										
0 % P_2O_5 (L0)	7.14d	7.91c	13.79c	13.66c	20.38d	20.40d	12.23b	12.47d	5.42b	5.48b
25 % P_2O_5 (L1)	7.69c	7.53d	14.65b	14.26b	22.21c	21.75c	11.86c	12.86c	5.62a	5.48b
50 % P_2O_5 (L2)	7.98b	8.13b	14.96b	14.59b	23.19b	22.62b	12.66a	13.32b	5.63a	5.56ab
100 % P_2O_5 (L3)	8.28a	8.63a	15.85a	15.45a	23.95a	24.02a	12.77a	13.63a	5.67a	5.64a
VAM-fungi inoculation										
Without mycorrhiza (M0)	7.23b	7.51b	14.45b	13.81b	21.07b	21.21b	11.95b	12.27b	5.49b	5.54a
With mycorrhiza (M1)	8.24a	8.58a	15.18a	15.14a	23.20a	23.67a	12.82a	13.87a	5.67a	5.55a

Values with the same letter(s) in the same column in each season are not significantly different using Duncan's multiple range test at 0.05 probability level

it is very effective in the synthesis of starch from glucose (Jakobsen and Rosendahl, 1990). These results agree with those of Hassan *et al.* (2005b), who found that inoculation of sweet potato plants with bio-phosphate fertilizer; VAM-fungi significantly increased total carbohydrates, total sugars and total carotene in root tissues than un-inoculated plants.

Interaction effects between P sources and P levels: The results in Table 7 reflected progressive effect for superphosphate source, particularly at the highest level of P for all chemical composition traits (e.g., total sugars, starch, carbohydrates, TSS and total carotene) in comparison with other treatments. This result may be explained on the basis that the necessity of available P as a plant nutrient is emphasized by the fact that it is an essential constituent of many organic compounds that are vital for metabolic processes (Purekar *et al.*, 1992).

Interaction effects between P sources and VAM-fungi inoculation: Sweet potato plants tended to express their best performance with the highest values of total sugars, starch, carbohydrates and total carotene contents under application of superphosphate + inoculation with VAM-fungi treatment. However, it was noticed that the differences between superphosphate form+VAM-fungi inoculation and rock phosphate source+VAM-fungi inoculation treatments with respect to starch and TSS were not high enough to be significant (Table 7). The symbiotic association between VAM-fungi and plant roots allows the fungus to supply the growing plants with N, certain micronutrients including P and some hormones, which in turn enhances the uptake of nutrients and increases chemical composition (Hassan *et al.*, 2005b).

Interaction effects between P levels and VAM-fungi inoculation: The results in Table 7 observed higher contents of most chemical composition of sweet potato roots at any level of P used with VAM-fungi inoculation. Meanwhile, the highest P level (100% P_2O_5) in conjunction with VAM-fungi inoculation treatment generated the highest values of starch and carbohydrates of root tissues. Similar treatment reflected higher mean value for total sugars in the first season (Table 7). On the other hand, the highest content of either TSS or total carotene was recorded for fertilizing plants treated with the highest P level + un-inoculated VAM-fungi. These results are in line with those of Hassan *et al.* (2005b), who found that

Table 7: Root chemical composition of sweet potato plants 'Abees' cv. as affected by integrated effects of P sources ×P levels, P sources ×VAM-fungi inoculation and P levels ×VAM-fungi inoculation treatments, during 2007 and 2008 summer seasons

Root quality	Total sugars (%)		Starch (%)		Carbohydrates (%)		Total soluble solids (%)		Total carotene (Mg/100 g f.w.)	
Treatments	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
P sources X P levels (P_2O_5)										
Superphosphate (SP)										
0%	7.04g	7.92cd	13.67c	13.66c	20.71cd	21.38d	12.10d	12.16d	5.51cd	5.66ab
25%	7.92cd	7.90d	15.52ab	14.34b	21.61c	22.16c	12.01d	12.93c	5.61b-d	5.82a
50%	8.22b	8.70b	14.87b	14.49b	23.48b	23.15b	12.75ab	13.65ab	5.75ab	5.43cd
100%	8.48a	9.10a	16.10a	15.55a	24.46a	24.55a	12.87a	13.92a	5.88a	5.85a
Rock phosphate (RP)										
0%	7.25f	7.90d	13.91c	13.66c	20.45d	21.43d	12.36c	12.78c	5.33e	5.28d
25%	7.45e	7.15f	13.78c	14.18bc	20.00d	22.30c	11.72e	12.80c	5.63bc	5.46cd
50%	7.75d	7.55e	15.05b	14.56b	22.91b	22.07c	12.58b	12.98c	5.52cd	5.53bc
100%	8.08bc	8.16c	15.61ab	15.25a	23.45b	23.48b	12.67ab	13.35b	5.46de	5.28d
P sources X VAM-fungi inoculation										
SP										
Without (M_0)	7.41c	7.89c	14.73b	13.82b	21.46c	21.59c	12.08b	12.38b	5.54b	5.59b
With (M_1)	8.43a	8.87a	15.35a	15.21a	23.66a	24.02a	12.81a	13.97a	5.84a	5.80a
RP										
Without (M_0)	7.23d	7.13d	14.16c	13.79b	20.67d	20.84d	11.83c	12.16b	5.48b	5.50b
With (M_1)	8.04b	8.25b	15.02ab	15.08a	22.74b	23.32b	12.85a	13.79a	4.75b	5.27c
P levels (P_2O_5) X VAM-fungi inoculation										
M_0										
0%	6.06j	6.54g	12.63c	12.45e	17.88f	18.67g	11.09g	10.50e	5.00e	5.52abc
25%	7.20gh	7.25f	14.55b	13.59d	20.29e	20.79f	11.70f	12.43d	5.53d	5.63ab
50%	7.70ef	7.90d	14.95b	14.08c	22.65c	21.94e	12.37d	12.82d	5.61cd	5.31c
100%	7.98cd	8.36c	15.66a	15.10b	23.46b	23.46c	13.37a	14.45a	5.83a	5.70a
M_1										
0%	7.94cd	9.27a	14.95b	14.87b	23.46b	24.14b	12.66c	13.34c	5.81ab	5.43bc
25%	8.17ab	7.81e	14.75b	14.93b	21.32d	22.71d	12.06e	13.30c	5.72a-c	5.65ab
50%	8.26ab	8.35c	14.98b	14.97b	23.75ab	23.28c	12.96b	13.82b	5.65b-d	5.65ab
100%	8.57a	8.90b	16.05a	15.80a	24.46a	24.56a	12.89b	13.93b	5.52d	5.43bc

Values with the same letter(s) in the same column in each season are not significantly different using Duncan's multiple range test at 0.05 probability level

Table 8: Integrated effects among P sources, P levels and VAM-fungi inoculation treatments on root yield and quality traits of sweet potato 'Abees' cv. during 2007 and 2008 summer seasons

Root traits	P levels	VAM-fungi	Total yield (ton fed.$^{-1}$)		Marketable yield (ton fed.$^{-1}$)		Total sugars (%)		Carbohydrates (%)	
Treatment	(P_2O_5 kg fed.$^{-1}$)	inoculation	2007	2008	2007	2008	2007	2008	2007	2008
P sources										
Super- phosphate	0	M_0	4.516l	3.267n	1.736l	1.050n	6.23j	6.58k	18.06h	18.92j
	25	M_0	7.593g	5.047l	5.240g	3.550l	7.28gh	7.70g	20.93f	20.96hi
	50	M_0	8.786e	7.143k	5.866e	5.850i	7.89ef	8.50d	22.94cde	22.56fg
	100	M_0	8.986d	9.817h	7.606c	8.290g	8.22cd	8.80c	23.92bc	23.93bcd
	0	M_1	9.266c	13.200e	5.776e	11.100d	7.86ef	9.25b	23.35bcd	23.85bcd
	25	M_1	9.463b	11.770g	5.636f	10.280f	8.56ab	7.93f	22.29e	23.36de
	50	M_1	9.096d	13.800b	8.810b	11.930bc	8.54ab	8.90c	24.02ab	23.72cd
	100	M_1	13.566a	16.600a	9.466a	14.330a	8.76a	9.40a	24.99a	25.16a
Rock phosphate	0	M_0	4.280m	3.936m	2.600k	2.786m	6.53i	6.50k	17.70h	18.43j
	25	M_0	5.726j	7.037k	3.846j	5.266k	7.13h	6.80j	19.66g	20.62i
	50	M_0	5.166k	7.050k	4.446h	5.547j	7.49g	7.30i	22.34de	20.96hi
	100	M_0	6.017i	7.633j	5.626f	6.336h	7.75f	7.93f	22.99b-e	23.00f
	0	M_1	9.030d	13.330d	7.536c	12.060b	7.97ef	9.30ab	23.20b-e	24.43b
	25	M_1	7.030h	7.896i	4.290i	6.293h	7.77ef	7.52h	20.34f	22.05g
	50	M_1	8.583f	12.360f	5.610f	10.440e	8.00de	7.80g	23.48b	22.83ef
	100	M_1	7.117h	13.570c	6.286d	11.870c	8.43bc	8.40d	23.92bc	23.96bc

Values with the same letter(s) in the same column in each season are not significantly different using Duncan's multiple range test at 0.05 probability level

the highest content of total sugars and carbohydrates in roots were obtained as a result of interaction between VAM-fungi + the highest P rate (60 kg P_2O_5 fed.$^{-1}$).

Integrated effects among P sources, P levels and VAM-fungi inoculation: On the subject of the interaction among various P sources, P levels and VAM-fungi inoculation treatments on root production and quality of sweet potato 'Abees' cv., the obtained results showed that the highest significant values for both total and marketable root yield (13.566-16.600 ton fed.$^{-1}$) and (9.466-14.330 ton fed.$^{-1}$) in the two seasons, respectively as well as root quality traits (total sugars and carbohydrates) were obtained by the application of chemical superphosphate source at the highest P level with the presence of VAM-fungi inoculation treatment in comparison with all other treatments (Table 8). Hence, the obtained results can support the recent concept of Yeng *et al.* (2012), who reported that the use of organic fertilizer to supplement inorganic fertilizer use, as an integrated management strategy, is more importance for detecting several aims such as reducing soil mineral input cost, maximizing yield and sustaining sweet potato crop as well as other vegetable crops.

CONCLUSION

Integrated mineral superphosphate form under the recommended P level with VAM-fungi inoculation treatment improved sweet potato 'Abees' cultivar growth and development which led to increased root productivity and enhanced root quality more than either using inorganic fertilizer or bio-phosphate fertilizer (VAM-fungi) alone.

REFERENCES

AOAC, 1995. Association of Official Agricultural Chemists. 10th Edn., AOAC., Washington, DC., USA.

Antunes, P.M., K. Schneider, D. Hillis and J.N. Klironomos, 2007. Can the arbuscular mycorrhizal fungus *Glomus intraradices* actively mobilize P from rock phosphates? Pedobiologia, 51: 281-286.

Auge, R.M., 2001. Water relations, drought and vesicular-arbuscular mycorrhizal symbiosis. Mycorrhiza, 11: 3-42.

Berberich, T., T. Takagi, A. Miyazaki, M. Otani, T. Shimada and T. Kusano, 2005. Production of mouse adiponectin, an anti-diabetic protein, in transgenic sweet potato plants. J. Plant Physiol., 162: 1169-1176.

Bolandnazar, S., 2009. The effect of mycorrhizal fungi on onion (*Allium cepa* L.) growth and yield under three irrigation intervals at field condition. J. Food Agric. Environ., 7: 360-362.

Co-Stat Software, 2004. User's manual version. Cohort Tusson, Arizona, USA.

Dawa, K., E.A. Tartoura, A.M. Abdel-Hamed and A.E. Gouda, 2007. Effect of some nitrogenous and phosphatic fertilizers sources and VA-mycorrhiza inoculums on growth, productivity and storability of garlic (*Allium sativum* L.): 1-Vegetative growth and chemical constituents. J. Agric. Sci. Mansoura Univ., 32: 7665-7684.

Demir, S., 2004. Influence of arbuscular mycorrhiza on some physiological growth parameters of pepper. Turk. J. Biol., 28: 85-90.

Douds Jr., D.D., G. Nagahashi, P.E. Pfeffer, W.M. Kayser and C. Reider, 2005. On-farm production and utilization of arbuscular mycorrhizal fungus inoculum. Can. J. Plant Sci., 85: 15-21.

El-Banna, E.N. and H.Z. Abd El-Salam, 2000. Effect of rock phosphate and superphosphate application with organic manures on growth, yield and quality of potato (*Solanum tubersum* L.). J. Agri. Sci. Mansoura Univ., 25: 4531-4540.

El-Morsy, A.H.A., A.E. Abdel-Fattah and Z.S.A. El-Shal, 2002. Effect of phosphate fertilizer and VA mycorrhizal inoculation on growth, tuber yield and quality of sweet potato. Proceedings of the Minia 1st Conference for Agriculture and Environmental Science, March 25-28, 2002, Minia, Egypt, pp: 1815-1827.

El-Sayed, H.E.A., A.S. El-Dean, S. Ezzat and A.H.A. El-Morsy, 2011. Responses of productivity and quality of sweet potato to phosphorus fertilizer rates and application methods of the humic acid. Int. Res. J. Agric. Sci. Soil Sci., 1: 383-393.

FAOSTAT, 2011. Agricultural data FAOSTAT. Food and Agriculture Organization of the United Nation, (FAOSTAT), Rome, Italy.

Gardner, F.P., R.B. Pearce and R.L. Mitchell, 1985. Physiology of Crop Plants. The Iowa State University Press, Ames, Iowa, pp: 327.

George, E., K. Haussler, G. Vetterlein, E. Gorgus and H. Marschner, 1992. Water and nutrient translocation by hyphae of *Glomus mosseae*. Can. J. Bot., 70: 2130-2137.

Giovannetti, M. and B. Mosse, 1980. An evaluation of techniques for measuring vesicular arbuscular mycorrhizal infection in roots. New Phytol., 84: 489-500.

Hassan, M.A., S.K. El-Seifi, F.A. Omar and U.M. Saif-El-Deen, 2005a. Effect of mineral and foliar application of micronutrients on sweet potato *Ipomoea batatas*, L. 1-Vegetative growth, yield and tuber root characteristics. J. Agric. Sci. Mansoura Univ., 30: 6149-6166.

Hassan, M.A., S.K. El-Seifi, F.A. Omar and U.M. Saif-El-Deen, 2005b. Effect of mineral and foliar application of micronutrients on sweet potato *Ipomoea batatas*, L. 2-Chemical composition of leaves and cured tuber roots. J. Agric. Sci. Mansoura Univ., 30: 6167-6182.

Jakobsen, I. and L. Rosendahl, 1990. Carbon flow into soil and external hyphae from roots of mycorrhizal cucumber plants. New Phytol., 115: 77-83.

Kassali, R., 2011. Economics of sweet potato production. Int. J. Vegetable Sci., 17: 313-321.

Negeve, J.M. and R.W. Roncadori, 1985. The interaction of vesicular-arbuscular mycorrhizae and soil phosphorus fertility on growth of sweet potato (*Impomoea batatas*). Field Crops Res., 12: 181-185.

Page, A, R. Miller and D. Keeny, 1982. Methods of Soil Analysis, Part 2: Chemical and Microbiological Properties. American Society of Agronomy, Madison, WI., USA.

Purekar, P.N., R.R. Singh and R.D. Deshmukh, 1992. Plant Physiology and Ecotogy. 2nd Edn., Chand S. and Co., New Delhi, India.

Sebastiami, S.K., A. Mgonja, F. Urio and T. Ndondi, 2007. Agronomic and economic benefits of sweetpotato (*Ipomoea batatas*) response to application of nitrogen and phosphorus fertilizer in the Northern highlands of Tanzania. proceedings of the 8th African Crop Science Society Conference, October 27-31, 2007, El-Minia, Egypt, pp: 1207-1210.

Shafeek, M.R., F.S. Abdel-Al and A.H. Ali, 2004. The productivity of broad bean plant as affected by chemical and or natural phosphorus with different bio fertilizer. J. Agric. Sci. Mansoura Univ., 29: 2727-2740.

Shaheen, A.M., M.M. Abdel-Mouty, H.A. Aisha and F.A. Rizk, 2007. Natural and chemical phosphorus fertilizers as affected onion plant growth, bulbs yield and its some physical and chemical properties. Aust. J. Basic Applied Sci., 1: 519-524.

Shaheen, A.M., N. Omer, Z.F. Fawzy and S. Faten, 2012. The effect of natural and/or chemical phosphorus fertilizer in combination with or without bio-phosphorus fertilizer on growth, yield and its quality of onion plants. Middle East J., 1: 47-51.

Steel, R.G.D. and F.H. Torrie, 1980. Principles and Procedures of Statistics. 2nd Edn., McGraw Hill Book Co., New York.

Westphal, A., N.L. Snyder, L. Xing and J.J. Camberato, 2008. Effects of inoculations with mycorrhizal fungi of soilless potting mixes during transplant production on watermelon growth and early fruit yield. HortScience, 43: 354-360.

Witham, F.H., D.F. Blaydes and R.M. Devlin, 1971. Experiments in Plant Physiology. Van Nostrand Reinhold Company, New York, pp: 55-56.

Woolfe, J.A., 1992. Sweet Potato an Untapped Food Resources. Cambridge University Press, Cambridge, UK., Pages: 643.

Yano, K. and M. Takaki, 2005. Mycorrhizal alleviation of acid soil stress in the sweet potato (*Ipomoea batatas*). Soil Biol. Biochem., 37: 1569-1572.

Yasmin, F., R. Othman, K. Sijam and M.S. Saad, 2007. Effect of PGPR inoculation on growth and yield of sweetpotato. J. Boil. Sci., 7: 421-424.

Yeng, S.B., K. Agyarko, H.K. Dapaah, W.J. Adomako and E. Asare, 2012. Growth and yield of sweet potato (*Ipomoea batatas* L.) as influenced by integrated application of chicken manure and inorgamic fertilizer. Afr. J. Agric. Res., 7: 5387-5395.

Zarei, I., Y. Sohrabi, G.R. Heidari, A. Jalilian and K. Mohammadi, 2012. Effects of biofertilizers on grain yield and protein content of two soybean (*Glycine max* L.) cultivars. Afr. J. Biotechnol., 11: 7028-7037.