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Full Length Research Paper

Responses of productivity and quality of sweet potato to phosphorus fertilizer rates and application methods of the humic acid

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Two field experiments were conducted on Sweet potato (*Ipomoea batatas,* L.) cv. Beaure Card at the Horticulture Research Farm of El-Bramoon, El-Dakahlia Governorate, during the two successive summer seasons of 2009 and 2010 to evaluate the effects of different rates of phosphorus (15, 30 and 45 kg P_2O_5/fed) either single and/or in combination with application methods of humic acid (control, foliar spray, transplant treatment and soil application) on plant growth, yield and its components, as well as chemical constituents and storability of tuber roots. In general, results showed that the increasing of applied phosphorus rate from 15 kg P_20_5 up to 45 kg P_20_5/fed significantly increased main stem length, canopy dry weight plant leaf area, total chlorophyll and carotenoids as well as total and marketable yield, dry matter percentage of tuber root and tuber root weight and diameter, Moreover, Application phosphorus at 45 kg P_2O_5/fed significantly increased N, P, K, carbohydrate and total sugars in tuber roots. This P-rate had the most interesting observation was the enhancing of storability and reduced decay percentage. On the other hand, application methods of humic acid had a significant effect on all studied characters in both seasons. Soil application method of humic acid had a significant increases in plant growth characters, photosynthetic pigments, total and marketable yield and tuber root quality. Besides, this application method significantly increased chemical composition of tuber roots and reduced the weight loss and decay percentages. The combined treatments of P-rates and application method of humic acid were generally more effective on the most studied parameters than with single ones. The best results were obtained by application 30 kg P_2O_5/fed with soil application method of humic acid. This treatment achieved increases in vegetative growth characters, total and marketable yield, average of tuber root weight and diameter as well as concentrations of N, P, K, carbohydrate and total sugars in tuber roots. In addition, this combine J treatment enhanced the tuberous roots storability and reduced decay% comparing with the other ones. Therefore, this treatment could be recommended for raising sweet potato yield and improving tuberous roots quality as well as reduced the need for chemical P-fertilizer by about 33.3%, thereby reducing costs and environment pollution under similar conditions to this work.

Keywords: *Ipomoea batatas*, L, sweet potato, humic acid, phosphorus, fertilizer, productivity and quality.

INTRODUCTION

Phosphorus element is one of the main nutrients for most plant species including sweet potato plants (*Ipomoea batatas*, L.). The necessity of phosphorus as a plant nutrient is emphasized by the fact that it is an essential constituent of many organic compounds that are very important for metabolic processes, blooming and root development (Purekar et al., 1992). In most soils, in spite

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Table 1. Some physical properties of experimental soil (average two seasons).

Physical Properties (%)				
Texture	**clay**	**Silt**	**Fine Sand**	**Coarse Sand**
Clay loam	40.5	33.6	18.1	7.71

Table 2. Some chemical properties of experimental soil (average two season).

Chemical Properties							
Texture	**TSS (%)**	**OM (%)**	**EG (ds/m-1at 25°C)**	**Total N (%)**	**Avail P (ppm)**	**Exch. K (ppm)**	**pH (1:2.5 w/v)**
Clay loam	0.49	1.92	1.11	0.22	11.82	298.0	8.12

of the considerable addition of P-fertilizers, the amount available for plants is usually low since it is converted to unavailable form by its reaction with the soil constituents (Marschner, 1995). This could be explained why the cultivated soils in Egypt needs a high amount of mineral P-fertilization to fulfill requirements of plants, However, the increase in the rate of applied P-fertilizer may be at the expense of increasing production costs. Therefore, it has become essential to use some substances to enhancing solubility of phosphorus and other nutrients, consequently, improve its availability to plants.

In this respect, humic acid has a one of potential benefits for plants, increased water anc1 nutrient holding capacity, enhanced solubility of P, Zn, Fe, Mg and Cu (Bryan and Stark, 2003; Mikkelsen, 2005). Besides, Rizk et al. (2010) mentioned that humic substances are recognized as the most chemically active compounds in soils, with cation and anion exchange capacities far exceeding those of clays and help to break up clay and compacted soils. On the other hand, Sarir et al. (2006) mentioned that humic coal applied at 2000 g/ha^{-1} seem to be more conductive for P availability and suppress P fixation either through chelation, acidifying mechanism or microbially induced mineralization process. Several investigators reported that addition of specific amount of humic substances as soil application can enhance the growth of roots, shoots and leaves, and encourage nutrient absorption by plants. In this respect, Bryan and Stark (2003) found that averaged across years and P rates, humic acid application increased total yield, marketable yield and gross return of potato crop. Shankle et al. (2004) indicated that application of humic acid plus nutrients to soil increased total marketable yield of sweet potato than the standard fertility program.

Verlinden et al. (2009) found out that tuber production of the potato field trial showed a high response to the application of humic substances. Total potato yield increased with 13 and 17% for humifirst liquid (liquid solution to the soil) and humifirst incorporated (solid incorporated in mineral fertilizers), respectively. Moreover, some researchers showed that the foliar spray of humic acid enhanced nutrient uptake, plant growth and yield (Delfine et al. 2005 on wheat and Sangeetha et al. 2006 on onion). On the other hand, numerous trials have been carried out to explain the efficiency of P-nutrition on growth and productivity of sweet potato plants. In this respect, Rhodes (1988); Li and Yen (1988); Marcano and Diaz (1994); Abdel-Fattah and Abdel-Hameid (1997); El-Morsy et al. (2002) and Hassen et al. (2005) they reported that P-fertilizer application positively increased sweet potato productivity compared with the untreated control.

This study was planned to determine the effects of some P rates and application methods of humic acid as important goal to Improving availability of phosphorus in soil, and also facilitate other elements, to improve productivity and storability of sweet potato under the conditions of Dakahlia Governorate.

MATERIALS AND METHODS

Two field experiments were carried out at El-Bramoom Agricultural Research Farm, Dakahlia Governorate, during the two successive summer seasons of 2009 and 2010, to investigate the effects of different rates of phosphorus fertilizer, application methods of humic acid and their interactions on plant growth, yield and its components, as well as chemical constituents and storability of tuberous roots of sweet potato (*Ipomoea batatas* L.) cv. Beaure Gard. Randomized samples were collected from the experimental soil at 0.0 to 50.0 cm depth, before planting to determine the physical and chemical properties in accordance to the methods of Page (1982). Data of soil analysis is presented in Tables (1 and 2).

Each experiment included 12 treatments which were 3 rates of phosphate fertilizer and 4 application methods of humic acid as follows:

a Phosphate fertilizer rates

Applied phosphorus rate from 15 kg P_20_5, 30 kg P_2O_5/fed and 45 kg P_2O_5/fed recommended rate (as a control).

b Application methods of humic acid

Humic acid was produced in Soil, Water and Environment Res. Institute and applied humic acid as follow:

1- Control (without treatment).

2- Foliar application: Humic acid solution at the rate of 0.5% sprayed at 30 days from transplanting.

3- Transplant treatment: Soaking transplants in humic acid solution 0.5% for four hr and hence transplanted in the presence of water.

4- Soil application: Humic acid 0.5% was added beside the transplants with first irrigation.

The experiments were designed as split-plot with 3 replicates. Phosphorus fertilizer rates were in the main plots, which subsequently subdivided into 4 sub plots, each contained one of the humic acid application method. Each experimental plot area was 17.5 m^2 and consisted 5 rows, 5m long and 0.7m wid. Transplanting was carried out during the second week of April, in both seasons of the study. Nearly similar top slips (cuttings), 20 cm length were manually planted on the third top of slope ridge at 25 cm apart. The added amount of phosphorus were equally divided and applied before planting and 30 days after transplanting. Agricultural practices other than the aforementioned treatment were conducted according to the recommendations of the Agric. Res. Center in Egypt. Harvesting was done 120 days after transplanting in both seasons.

Growth parameters Determination

At 90 days after transplanting, a random sample (3 plants) was taken from each experimental unit to measure stem length, number of branches/plant, plant leaf area (Koller, 1972), canopy dry weight/plant and Total chlorophyll (a and b) Commar and Zscheile (1941).

Yield production

At harvest time, all tuber roots of plants grown in the rows of each sub-plot were weighted in kg and data were calculated as total yield/fed. Tuber root sample (10 storage roots) was randomly chosen from each treatment to determine tuberous root traits (weight, length and diameter).

Physiological studies on tuber roots

Determined the Total Carbohydrates Content, Total Carotene and Macro elements (N, P, and K) constituent of tuberous roots: Five uniform sized of tuber roots from each treatment were cleaned, cut, dried, ground and analyzed to determine total carbohydrates content, total carotene as well as concentrations of N, P, and K according to the methods described by Michel et al. (1956), Booth (1958), A.O.A.C (1990), John (1970), and Brown and Lilleland (1946), respectively.

Storability

After curing, a random sample (10 kg of marketable tuber roots) was taken from each treatment, cleaned with dry clean towels, poked in plastic boxes and stored at the normal room conditions and weight loss percentage was recorded monthly during storage period and Decay percentage at the end of storage period (4 months).

Statistical analysis

All data recorded were subjected to *Analysis of Variance* and *least significance differences* (*L.S.D*) was used to separate means, as mentioned by Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

Effect of P-rates on vegetative growth

Data in Table (3) and Appendix Table (3) show that, all growth parameters of sweet potato plants were significantly increased with increasing P rate from 15 up to 45 kg P_2O_5/fed. Plants which received 45 kg P_2O_5/fed had significant increases in most vegetative growth traits, compared to the other rates in both studied seasons. Meanwhile, there are no significant differences between 45 and 30 kg P_2O_5/fed in total chlorophyll and carotenoids 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 (Purekar et al., 1992). These results are in agreement with those obtained by Prasad and Rao (1986); El-Gamal and Abdel-Nasser (1996), El-Morsy et al. (2002) and Hassan et al. (2005) they found that increasing applied P-rate to sweet potato plants significantly increased plant

Table 3. Effects of P-Rates and Methods of Humic Acid Application on Vegetative Growth Parameter of Sweet Potato In 2009 and 2010 Season

Growth Parameter / Treatments	Main Stem Length (cm)		Canopy Dry Weight (g)		Leaf Area/Plant (cm)	
	2009	2010	2009	2010	2009	2010
P- Rates						
15kgP_2O_5/fed.	113.5	102.4	227.67	237.10	419.80	414.70
30kgP_2O_5/fed.	122.6	118.2	273.58	251.24	476.62	442.80
45kgP_2O_5/fed.	120.4	122.5	290.26	262.21	498.24	456.44
L.S.D at 5%	0.9	4.2	2.76	2.52	8.23	6.11
Humic Application Method						
Control[1]	106.4	100.6	235.42	225.80	384.06	363.42
Foliar application[2]	117.4	111.1	259.74	245.21	448.06	426.96
Transplant treatment[3]	126.2	118.4	273.08	260.63	494.39	466.10
Soil application[4]	130.6	127.4	287.10	269.09	520.49	495.42
L.S.D at 5%	003.2	003.4	2.48	2.17	8.17	9.63

Appendix Table 3. Effects of P-Rates and Methods of Humic Acid Application on Vegetative Growth Parameter of Sweet Potato In 2009 and 2010 Seasons

Growth Parameter / Treatments		Main Stem Length (cm)		Canopy Dry Weight (g)		Leaf Area/Plant (cm)	
		2009	2010	2009	2010	2009	2010
Interaction							
P-Rates	**Humic Application Method**						
15kgP_2O_5/fed.	1	96	85.5	202.48	214.31	338.57	328.77
	2	108.9	99.9	219.93	228.78	415.30	409.90
	3	120.7	107.1	237.51	248.95	450.40	433.03
	4	128.3	117.1	250.74	256.37	474.93	487.10
30kgP_2O_5/fed.	1	107.8	103.6	240. 54	223.21	380.30	370.10
	2	119.4	112.9	264.74	242.67	434.26	421.50
	3	130	123.1	282.40	262.27	505.77	479.60
	4	133.3	133.2	306.63	276.82	550.13	500
45kgP_2O_5/fed.	1	115.4	112.8	263.25	239.89	433.30	391.40
	2	123.8	120.3	294.55	264.17	496.27	449.50
	3	127.9	125.1	299.33	270.67	527.0	485.67
	4	130.4	131.9	303.92	274.09	536.40	499.20
L.S.D at 5%		5.6	5.8	4.3	3.75	14.15	16.68

length, plant leaf area, canopy dry weight, total chlorophyll and carotenoids.

Effect of methods of humic acid application

Data recorded in Table (4) and Appendix Table (4) demonstrate that all growth parameters of sweet potato plants expressed as main stem length, canopy dry weight, leaf area/plant, total chlorophyll (a+b), and carotenoids were significantly influenced by application methods of humic acid compared to the control treatment in both seasons. The highest values of these traits were obtained with the soil application method. These results

Table 4. Effects of P-Rates and Methods of Humic Acid Application on Photosynthetic Pigments Chlorophyll a and b and Carotenoids of Sweet Potato in 2009 and 2010 Seasons

Treatments \ Growth Parameter	Total Chlorophyll (a+b) (mg/g F.Wt.)		Carotenoids (mg/g F. Wt.)	
	2009	2010	2009	2010
P- Rates				
15kgP_2O_5/fed.	1.55	1.39	0.86	0.88
30kgP_2O_5/fed.	1.63	1.46	0.91	0.95
45kgP_2O_5/fed.	1.66	1.49	0.49	0.98
L.S.D at 5%	0.03	0.06	0.07	0.03
Humic Application Method				
Control[1]	1.46	1.36	0.78	0.81
Foliar application[2]	1.59	1.41	0.89	0.89
Transplant treatment[3]	1.68	1.47	0.95	1.00
Soil application[4]	1.72	1.54	1.00	1.05
L.S.D at 5%	0.03	0.04	0.07	0.05

Appendix Table 4. Effects of P-Rates and Application Methods of Humic Acid on Photosynthetic Pigments Chlorophyll a and b and Carotenoids of Sweet Potato in 2009 and 2010 seasons

Treatments \ Growth Parameter		Total Chlorophyll (a+b) (mg/g F.Wt.)		Carotenoids (mg/g F. Wt.)	
		2009	2010	2009	2010
Interaction					
P-Rates	**Humic Application Method**				
15kgP_2O_5/fed.	1	1.39	1.30	0.73	0.77
	2	1.51	1.36	0.83	0.84
	3	1.63	1.43	0.92	0.93
	4	1.67	1.47	0.96	0.96
30kgP_2O_5/fed.	1	1.46	1.37	0.79	0.80
	2	1.61	1.41	0.89	0.89
	3	1.69	1.47	0.92	1.02
	4	1.77	1,58	1.03	1.10
45kgP_2O_5/fed.	1	1.53	1.41	0.82	0.85
	2	1.65	1.46	0.94	0.94
	3	1.72	1.51	1.00	1.05
	4	1.73	1.57	1.01	1.07
L.S.D at 5%		0.06	0.67	0.11	0.08

may be due to the important role and beneficial effects of humic substances on the growth of plants as they can produce various morphological, physiological and biochemical effects on plants (Nardi et al., 2002). In this respect, several investigators shown that the addition of a specific amount of humic substances to plant can enhance vegetative growth parameters, i.e., plant length, number of main stems/plant, foliage fresh and dry weight/plant (Awad and EL-Ghamry, 2007; Verlinden et al., 2009).

Effect of the interaction between P-rates and methods of humic acid application

The interaction between P-rates and methods of humic acid application on growth of sweet potato plants are shown in Tables (3 and 4) and Appendix Tables (3 and 4). It is clear from the data that, the combined treatments were much superior effect than single ones. The data declared that, plant main stem length, canopy dry weight/plant, leaf area, total chlorophyll and carotenoids were significantly influenced by the combination treatments in both seasons, moreover, the highest value of these traits were recorded with 30 kg P_2O_5/fed combined with the method of humic acid application in soil comparison with the other treatments. These pronounced positive effects on vegetative growth parameters of sweet potato plants, may be attributed to the role of humic acid in increasing water and nutrient holding capacity particularly at the higher P-rates, increasing reserve of slow release of P nutrient, enhanced solubility of phosphorus, and potassium, improved soil aggregation, reduce the interaction phosphorus with calcium, ferric, magnesium, and aluminum and make these elements in available form for plants; enlarged root system and increased stimulation of plant growth due to hormones (Bryan and Stark, 2003; Mikkelsen, 2005). Sarir et al. (2006) mentioned that humic coal applied at 2000 g/ha (soil application) seem to be more conductive for P availability and suppress P fixation either through chelation, acidifying mechanism or microbially induced mineralization process.

Effect of P-rates on yield components

Data in Table (5) and Appendix Table (5) show that P-rates reflected a significant effect on total and marketable tuber yield, tuber dry matter, average tuber root weight and tuber root diameter in both seasons. Yield and its components were increased with increasing P-rate from 15 kg P_2O_5/fed up to 45 kg P_2O_5/fed in both seasons. Also, data show no significant differences between 30 or 45 kg P_2O_5/fed data on tuber root diameter in the first season only. The increases in total tuber yield were about 8.32 and 19.74 % for P_2O_5 at 45 kg/fed over the P_2O_5 at 15 kg/fed in the first and second seasons, respectively. These increments may be due to the important role of phosphorus as an essential component of many organic compounds in plant, such as phosphor-proteins, phospholipids, nucleic acids and nucleotides, which indirectly may reflect positively on yield (Marschner, 1995). Similar results reported by El-Gamal and Abdel-Nasser (1996), Abdel-Fattah and Abdel-Hamed (1997), El- Morsy et al. (2002) and Hassan et al. (2005) they found that fertilization of sweet potato plants with P-fertilizer caused significant increases in total and marketable yield.

Effect of methods of humic acid application on yield components

It is evident from data in Table (5) and Appendix Table (5) that the methods of humic acid application had a significant effect of total and marketable yield, dry matter of tuber roots, and tuber root weight and diameter compared to untreated once in both seasons. The highest values were obtained from soil method of humic acid application in both seasons. These increases in total tuber yield may be due to hormonal effect of humic acid that improve the nutrient status of plants. These results were agreement with those reported by Verlinden *et al.,* (2009), Selim *et. al.,* (2009) and Ezzat *et. al.,* (2010) they found that application of humic substances to potato enhanced tuberous yield quantity and quality.

Effect of the interaction between P-rates and methods of humic acid application

Data in Table (5) and Appendix Table (5) indicate that the combined treatments seemed to be more effective than the single ones. It is obvious from such data that total yield, marketable yield and average tuber root weight and diameter were significantly influenced in both seasons. In general, plants fertilized with 30 kg P_2O_5/fed with the soil application method of humic acid achieved great yield which was not significantly different from that produced by using 45 kg P_2O_5/fed alone. It is notable that, there were no differences between 30 or 45 kg P_2O_5/fed with soil application method in the tuber root weight and diameter in both seasons. These increases were accordance with those of Bryan and Stark (2003) who found that averaged across years and P rates, humic acid application increased total yield, marketable yield and gross return of potato crop. Similar resuks reported by Ayuso et al. (1996) on maize and El-Shabrawy et al. (2010) on cucumber.

Effect of P-rates on chemical constituents of tuber roots

Data presented in Table (6) and Appendix Table (6) shows that P-rates markedly affected most studied chemical contents in tuber roots of sweet potato. Irrespective of the control treatment, increasing the applied P-rates from 15 to

Table 5. Effects of P-Rates and Application Methods of Humic Acid on Yield and Its Components of Sweet Potato in 2009 and 2010 Seasons

Treatments \ Growth Parameter	Total Tuber Yield (ton/fed.)		Marketable yield (ton/fed.)		Dry matter of tuber roots (%)		Average tuber root weight (g)		Tuber root diameter (cm)	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
P- Rates										
15kgP_2O_5/fed.	12.97	13.48	12.12	12.35	26.84	26.37	150.30	155.80	4.80	4.20
30kgP_2O_5/fed.	13.39	15.42	12.64	14.37	29.09	28.09	157.79	164.73	5.05	4.78
45kgP_2O_5/fed.	14.05	16.14	13.56	15.36	30.47	29.64	161.46	169.27	5.17	5.03
L.S.D at 5%	0.12	00.31	00.07	00.18	00.14	0.20	1.973	0.88	0.28	0.24
Humic Application Method										
Control[1]	10.54	13.08	9. 46	11.77	24.97	24.53	141.60	141.57	4.42	3.94
Foliar application[2]	13.02	14.54	12.30	13.59	28.17	27.10	153.04	159.80	4.74	4.44
Transplant treatment[3]	14.62	15.59	14.04	14.70	30.28	29.30	162.50	172.61	5.21	4.92
Soil application[4]	15.68	16.85	15.28	16.07	31.78	31.20	168.92	179.09	5.64	5.37
L.S.D at 5%	0.27	0.16	00.23	0.19	0.11	0.20	3.189	3.61	0.43	0.33

Appendix Table 5. Effects of P-Rates and Application Methods of Humic Acid on Yield and its Components of Sweet Potato in 2009 and 2010 Seasons

Treatments \ Growth Parameter		Total Tuber Yield (ton/fed.)		Marketable yield (ton/fed.)		Dry matter of tuber roots (%)		Average tuber root weight (g)		Tuber root diameter (cm)	
		2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Interaction											
P-Rates	**Humic Application Method**										
15kgP_2O_5/fed.	1	9.99	11.99	8.61	10.40	23.15	22.80	136.60	132.03	4.30	3.63
	2	12.33	13.01	11.40	11.93	26.19	25.65	147.97	133.23	4.53	4.13
	3	14.29	14.05	13.69	12.99	28.37	27.53	153.70	164.30	4.97	4.37
	4	15.26	14.87	14.77	14.10	29.65	29.49	162.93	172.73	5.40	4.67
30kgP_2O_5/fed.	1	10.03	13.31	8.81	11.92	24.79	24.55	140.60	143.13	4.37	3.93
	2	12.76	14.10	11.90	13.11	28.31	26.65	153.20	152.93	4,70	4.43
	3	14.77	16.10	14.15	15.19	30.20	22.95	165.40	173.40	5.33	5.03
	4	15.98	18.00	15.71	17.88	33.05	32.20	171.97	183.46	5.80	5.73
45kgP_2O_5/fed.	1	11.61	13.95	10.95	12.98	26.96	26.23	147.60	142.63	4.60	4.27
	2	13.99	16.32	13.61	15.72	30.00	28.99	157.90	167.23	5.00	4.77
	3	14.80	16.62	14.29	15.91	32.29	31.41	168.40	180.13	5.33	5.37
	4	15.79	17,67	15.37	16.82	32.65	31.91	171.87	181.07	5.73	5.70
L.S.D at 5%		0.47	0.28	0.398	0.33	0.24	0.35	5.52	6.25	0.74	0.57

45 kg P2O5/fed significantly increased concentrations of N, P and K as well as total carbohydrate content, total sugars. Application of P_2O_5 at 45 kg/fed, increased significantly K contents, in both seasons, whereas, no significant differences were evidence between 30 or 45kg P_2O_5/fed in N and P content as well as total carbohydrates and total

Table 6. Effects of P-Rates and Application Methods of Humic Acid on Organic and Inorganic Components of Sweet Potato in 2009 and 2010 Seasons

Growth Parameter / Treatments	N (%)		P (%)		K (%)		Carbohydrates (%)		Total Sugars (%)	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
P- Rates										
15kgP_2O_5/fed.	1.69	1.63	0.302	0.295	2.48	2.33	60.12	58.83	7.85	8.05
30kgP_2O_5/fed.	1.75	1.62	0.318	0.313	2.61	2.45	62.68	60.22	8.03	8.23
45kgP_2O_5/fed.	1.77	1.72	0.323	0.322	2.66	2.45	63.28	61.83	8.12	8.34
L.S.D at 5%	0.06	0.03	0.005	0.003	0.05	0.05	0.67	0.22	0.13	0.02
Humic Application Method										
Control[1]	1.64	1.55	0.293	0.286	2.42	2.29	57.83	56.77	7.79	7.99
Foliar application[2]	1.69	1.66	0.311	0.303	2.54	2.40	61.23	59.89	7.93	8.13
Transplant treatment[3]	1.77	1.72	0.320	0.318	2.62	2.48	63.50	61.35	8.09	8.26
Soil application[4]	1.35	1.79	0.332	0.332	2.76	2.57	65.24	63.16	8.19	8.43
L.S.D at 5%	0.05	0.04	0.006	0.005	0.04	0.04	0.92	0.18	0.08	0.07

Appendix Table 6. Effects of P-Rates and Application Methods of Humic Acid on Organic and Inorganic Components of sweet potato in 2009 and 2010 seasons

Growth Parameter / Treatments		N (%)		P (%)		K (%)		Carbohydrates (%)		Total Sugars (%)	
		2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Interaction											
P-Rates	**Humic Application Method**										
15kgP_2O_5/fed.	1	1.61	1.46	0.283	0.268	2.34	2.19	56.56	54.61	7.65	7.89
	2	1.65	1.61	0.299	0.288	2.44	2.30	59.65	57.93	7.79	7.99
	3	1.71	1.68	0.307	0.302	2.53	2.39	61.48	60.41	7.93	8.09
	4	1.78	1.76	0.319	0.323	2.61	2.43	62.79	62.37	8.03	8.22
30kgP_2O_5/fed.	1	1.65	1.56	0.296	0.284	2.43	2.29	58.92	56.73	7.76	7.96
	2	1.70	1.65	0.313	0.305	2.55	2.36	61.31	59.75	7.95	8.14
	3	1.76	1.72	0.323	0.324	2.63	2.47	63.52	60.79	8.09	8.27
	4	1.90	1.83	0.341	0.340	2.84	2.66	66.96	63.61	8.29	8.55
45kgP_2O_5/fed.	1	1.66	1.62	0.299	0.306	2.50	2.40	58.01	58.96	7.96	8.13
	2	1.71	1.70	0.322	0.319	2.62	2.52	62.73	61.99	8.05	8.27
	3	1.85	1.77	0.331	0.329	2.71	2.59	65.49	62.86	8.23	8.41
	4	1.87	1.79	0.338	0.333	2.22	2.64	66.87	63.50	8.25	8.53
L.S.D at 5%		0.02	0.07	0.010	0.008	0.07	0.07	1.60	0.31	0.14	0.12

sugars in the first season. This could be due to higher availability of the nutrients with increase in the fertilizer application (P) which ultimately resulted in better root growth and increased physiological activity of roots to absorb the nutrients (Marschner, 1995). The obtained results coincide with those of Prasad and Rao (1986), Li and Yen (1988), and Rhodes (1988) and El-Morsy et al. (2002) they demonstrated that an increase in the rate of applied-P from 15 to 60 kg P_2O_5/fed to sweet potato plants caused an increase in N, P and K contents as well as total carbohydrate and total sugars in tuber roots of sweet potato.

Effect of methods of humic acid application on Potato Tuber

It is obvious from the data in Table (6) and Appendix Table (6)

Table 7. Effects of P-Rates and Application Methods of Humic Acid on Percentage of Loss Weight During the Storage Period and Decay of Sweet Potato in 2009 and 2010 Seasons

Growth Parameter / Treatments	Weight Loss (%)								Decay (%)	
	30 DAS		60 DAS		90 DAS		120 DAS			
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
P- Rates										
15kgP_2O_5/fed.	9.83	10.09	18.74	19.73	28.70	29.96	34.62	36.11	15.96	16.21
30kgP_2O_5/fed.	9.16	9.42	18.07	18.67	27.80	29.29	33.70	35.38	15.53	15.80
45kgP_2O_5/fed.	8.98	9.31	17.79	18.43	27.46	29.06	33.19	34.80	15.43	15.41
L.S.D at 5%	0.11	0.11	00.05	0.13	0.09	0.15	0.02	0.18	0.04	0.10
Humic Application Method										
Control[1]	9.64	10.23	18.61	19.36	28.60	29.75	34.82	37.01	16.25	16.21
Foliar application[2]	9.39	9.83	18.40	18.89	28.18	29.50	33.88	35.86	15.90	15.91
Transplant treatment[3]	9.28	9.37	18.11	18.74	27.85	29.37	33.52	34.81	15.41	15.75
Soil application[4]	8.97	9.00	17.67	18.37	27.33	29.13	33.14	34.04	15.00	15.36
L.S.D at 5%	0.12	0.11	0.12	0.06	0.19	0.14	0.02	0.13	0.17	0.13

that all application methods of humic acid for sweet potato plants exerted significant increases in tuber root contents, i.e. N, P and K concentration as well total carbohydrate and total sugars compared with the untreated ones. However, there were no significant differences between transplant treatment and soil application methods on P and K concentrations in the first season only. Soil application method of humic acid gave the highest values in all chemical constituents in both seasons. These effects are considered as an important action of humic substances on plant nutrient acquisition and in the uptake of nutrients is the root system of plants (Quagiotti et al. 2004). Similar results were obtained by Verlinden et al. (2010) they found that
nitrogen, phosphorus and potassium uptake at the first grass pastures cut was higher after application of humic acid substances at 8.3 kg/ ha.

Effect of interaction between P-rates and application methods of humic acid on yield components

The interaction between P-rates and application methods of humic acid -ad a significant effect of chemical constituents of sweet potato tuber roots, in both seasons Table (6) and Appendix Table (6). The highest value of N, P and K, carbohydrates and total sugars were obtained from soil application of 30 kg P_2O_5/fed combined with the soil application method of humic acid. Data also, shown no significant differences between 30 or 45 kg P_2O_5/fed under the same application method of humic acid in both seasons. These results are in harmony with those reported by Selim et al. (2009) they stated that the application of humic acid combined NPK fertilizers significantly increased N, P and K nutrient concentrations in potato tissues.

Effect of P-rates on storability

The data presented in Table (7) and Appendix Table (7) show that the most interesting observation was reducing weight loss and decay percentages in tuber roots by increasing the applied P-rates up to 45 kg P_2O_5/ fed. The favorable effects of P-fertilizer on weight loss percentage during the storage period and decay at the end of storage period could be explained through the great role of P-element which is extremely important as a structural part of many compounds in plant, such as phosphoproteins, phospholipids, nucleotides and notable nuclic acids (Gardener et al., 1985). The obtained results coincide with those of Kolbe et al. (1995), El-Morsy et al. (2002) and Saif-El-Deen (2005) they found that weight loss and decay were negatively correlated with P-rates application. Also, increasing P-rate up to 60 kg P_2O_5/fed significantly decreased the percentages of the above mentioned parameters during storage. Effect of application methods of humic acid:

It is obvious from data in Table (7) and Appendix Table (7) that application of humic acid significantly reduced

Appendix Table 7. Effects of P-Rates and Application Methods of Humic Acid on Percentage of Loss Weight During the Storage Period and Decay of Sweet Potato in 2009 and 2010 Seasons

Treatments \ Growth Parameter		Weight Loss (%)								Decay (%)	
		30 DAS		60 DAS		90 DAS		120 DAS			
		2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Interaction											
P-Rates	Humic Application Method										
15kgP_2O_5/fed.	1	10.18	10.84	19.01	20.25	29.06	30.45	35.82	36.66	16.35	16.47
	2	9.84	10.15	18.85	19.43	28.86	29.98	34.56	36.59	16.14	16.30
	3	9.74	9.80	18.68	19.13	28.73	29.78	34.20	35.54	15.73	16.13
	4	9.54	9.56	18.45	18.91	28.15	29.63	33.91	34.65	15.62	15.94
30kgP_2O_5/fed.	1	9.48	9.99	18.59	16.00	28.62	29.60	34.98	37.08	16.24	16.40
	2	9.30	9.83	18.38	18.80	28.07	29.42	33.84	36.11	15.87	15.99
	3	9.18	9.17	18.07	18.73	27.62	29.29	33.30	34.65	15.39	15.79
	4	8.66	8.67	17.26	18.08	26.91	28.84	32.68	33.67	14.62	15.02
45kgP_2O_5/fed.	1	9.25	9.84	18.25	18.77	28.13	29.20	33.66	36.29	16.16	15.76
	2	9.04	9.51	17.97	18.44	27.61	29.10	33.24	34.90	15.68	15.43
	3	8.92	9.12	17.61	18.37	27.18	29.04	33.06	34.23	15.12	15.34
	4	8.71	8.76	17.31	18.13	26.94	28.91	32.81	33.80	14.77	15.11
L.S.D at 5%		0.20	0.19	0.21	0.11	0.32	0.24	0.14	0.23	0.30	0.23

weight loss percentage of tuber roots during the storage period at 30, 60, 90 and 120 days than with the untreated control. Soil application method of humic acid gave the best records of weight loss and decay percentages than the other application methods in both seasons. It is well known that hurnic acid enhanced elements in available form for plants, enlarged root system and increased stimulation of plant-growth due to contribute some hormones and supply plants with P-element as well as certain micronutrients which in turn reflects on Storability of sweet potato (Bryan and Stark, 2003; Mikkelsen, 2005).

Effect of interaction between P-rates and methods of humic acid application

Data in Table (7) and Appendix Table (7) show the interaction effect of the applied P-rates with methods of humic acid application on Storability and decay of sweet potato tuber roots. In general, the combined treatments were more useful than single applications. The combinations significantly reduced weight loss percent in tuber roots during storage period at 30, 60, 90 and 120 days and decay at 120 days as compared with single ones. The minimum values of weight loss percent were attained by fertilizing with 30 or 45 kg P_2O_5/fed with the soil application method of humic acid. Similar results were obtained by El-Morsy et al. (2002) and Saif-El-Deen (2005).

From the obtained results, it could be concluded that the sweet potato plants fertilized by 30 kg P_2O_5/fed with soil application method of humic acid is recommended for increasing plant growth and yield as well as improving quality and Storability of tuber roots. This treatment achieved great values were superior for that produced by using 45 kg P_2O_5/fed without application of humic acid. Therefore, the soil application of humic acid reduced the need for chemical P-fertilizer by about 33.3 %, thereby reducing costs and pollution of environment.

REFERENCES

AOAC (1990). *Association of Official Analytical Chemists*. Official Methods of Analysis. 15th Ed., Washington, DC, USA.

Abdel-Fattah AE, AM Abdel-Hamed (1997). Effect of phosphorus and sulphur application on sweet potato *(Ipomoea batatos L.)* plant production. J. Agric. Sci. Mansoura Univ. 22 (3): 883 - 890.

Awad EIMM, AM El-Ghamry (2007). Effect of humic acid effective microorganisms (EM) and magnesium on potato in clayey soil. J. Agric. Sci. Mansoura Univ., 32(9): 7629-7639.

Ayuso M, T Hernandez, C Garcia, J Pascual (1996). Stimulation of barley growth and nutrient absorption by humic substances originating from various organic materials., Bio-source Technology 57: 251-257.

Booth VH (1958). *Extraction and estamination of Carotene*. Univ. Cambridge and medical Res. Council Dunn. National Lab., p. 53 Cambridge, England: W. Heffer and Sons Ltd.

Brown JD, O Lilleland (1946). Rapid determination of potassium and Bryan, H. and J. Stark (2003). Humic acid effects on potato response to phosphorus. IJaho Potato Conference, USA, January 22-23, 5 pp.

Bryan Hopkins , Jeff Stark (2003). Humic Acid Effects On Potato Response To Phosphorus. Presented at the Idaho Potato Conference January 22-23, 2003, College of Agriculture and Life Sciences, University of Idaho, U.

S. Department of Agriculture Cooperating) after reference Brown JD, O Lilleland (1946)

Council Dunn. National Lab., pBryan Hopkins and Jeff Stark (2003): Humic Acid Effects On Potato Response To Phosphorus. Presented at the Idaho Potato Conference January 22-23, 2003, College of Agriculture and Life Sciences, University of Idaho, U. S. Department of Agriculture Cooperatin. 53 Cambridge, England: W. Heffer and Sons Ltd.

Commar A, L Zscheile (1941). Sepectrophotometric method for chlorophyll determination. Plant physoil. 16:651-652.

Delfine S, R Tognetti, E Desiderio, A Alvino (2005). Effect of foliar application of N and humic acids on growth and yield of durum wheat. Agron. Sustainable Dev., 25: 183-191.

El-Gamal AM, G Abdel-Nasser (1996). Response of sweet potato crop to phosphorus and potassium fertilization rates. Fourth Arabic Conf. Minia, Egypt, 1996. Faculty of Agric. Saba Bacha , Alex. Univ., 25-28 (3): 471-488.

El-Morsy AHA, AE Abdel-Fattah, ZSA El-Shal (2002). Effect of phosphate fertilizer and VA mycorrhizal inoculation on growth, tuber yield and quality of sweet potato. Proc. Minia 1st Conf. for Agric. Enuiron. Sci., Minia Egypt, March 25 - 28: 1815-1827.

El-Shabrawy RA, AY Ramadan, Sh M. El-Kady (2010). Use of humic acid and some biofertilizers to reduce nitrogen rates on cucumber *(Cucumis sativus* L.) In relation to vegetative growth, yield and chemical composition. J. Plant Produc. Mansoura Univ., Vol. 1(8): 1041-1051.

Ezzat AS, UM Saif Eldeen, AM Abd El-Hameed (2009). Effect of irrigation water quantity, antitranspirant and humic acid on growth, yield, nutrients content and water use efficiency of potato *(Solatium tuberosum L.).* J. Agric. Sci. Mansoura Univ., 34(12):11585-11603.

Gardener FD, RB Pearce, RL Mitchell (1985). *Physiology of crop plants*. The Iowa state Univ. Press, USA pp. 327.

Hassan MA, SK El-Seifi, EA Omar, UM Saif El-Deen (2005). Effect of mineral and bio-phosphate fertilization and foliar application of some micronutrients on growth, yield and quality of sweet potato (*Ipomoea batata*, L). 1- Vegetative growth, yield and tuber characteristics. J. Agric. Sci. Mansoura Univ., 30 (10): 6149-6166

John MK (1970). Colorimetric determination of phosphorus in soil and plant material with ascorbic acid. Soil Sci. 109:214-220.

Kolbe H, J Hippe, G Olteanu, K Muller (1995). Relations between nitrogen, phosphorus and potassium concentrations at harvest time and changes in weight loss and chemical composition of potato tubers during long-term storage at 4^0C. Agri. biol. Res. 48 (1): 14 - 25.

Koller HR (1972). Leaf area - Leaf weight relationship, in the soybean canopy. Crop sci. 12: 180-183..

Li L, HF, Yer (1988). The effects of cultural practices on dry matter production and partition of sweet potato (*Ipomoea batatas* L.). J. *Agric. Assoc. of China.,* No. 141 : 46-61 (cf. *Field Crop. Abs*., 41: 6134).

Marcano AJ, LA Diaz (1994). Effect of application of six combinations of N, P and K fertilizers on yield of root and foliage of sweet potato. Agro. Trop. Maracay-Venezuela (C.F *Soils and Fert .,* 58, 12174, 1995).

Marschner H (1995). Mineral Nutrition of Higher Plants. 2 nd Ed. Academic Press, Harcourt Brace and Company, Publishers. London, New York, Tokyo, pp 864.

Michel U, GK Gilles, P Hamilton, F Smith (1956). Colorimetric method for determination of sugars and related substances. Analytic Chemistry, 28 (3): 17-24.

Mikketeen RL (2005). Humic materials for Agriculture. *Better Crops*, 89 (3): 6-10.

Nardi S, D Pizzeghello, A Muscolo, A Vianello (2002). Physiological Effects of humic substances on higher plants. Soil Biol. Bioch., 34: 1527-1536.

Page AL (1982). Methods of Soil Analysis. 2nd Ed., Part 1, Soil Sci. Soc. Amer. Madisci, Wise., USA.

Prasad M, MVL Rao (1986). Effect of N, P and K on sweet potato yield. *J. Root Crops*, 12(2): 111-112.

Purekar PN, RR Singh, RD Deshmukh (1992). Plant Physiology and Ecotogy. 2nd Ed. Chand, S. and Company, New Delhi, India.

Quagiotti S, B Ruperti, D Pizzeghello, O Francioso, V Tugnoli, S (2004). Effect of low molecular size humic substances on nitrate and expression of genes involved in nitrate transport in maize (*Zea mays* L.) J. Experm. Botany, 55: 803-813.

Rhodes ER (1988). Requirements of N, P and K fertilizers for sweet potato plant. Fert.. Res., 17(2): 101-118.

Rizk AH, AMA Mashhour, ESE Abd-Elhadyand, KMA El-Ashri (2010). The rote of some humic acid products in reducing of use mineral Fertilizer and improving soil properties and nutrient uptake. J. Soil Sci. and Agri. Engineering, Mansoura Univ., Vol. 1(8): 765-774.

Saif El Dean, U. M. (2005). Effect of phosphate fertilization and foliar application of some micronutrients on growth, yield and quality of sweet potato *(Ipomoea batatas* L.). *Ph. D. Thesis, Hort. Dept., Fac.* of Agric., Suez Canal Univ., Egypt.

Sangeetha M, P Singaram, U Devi (2006). Effect of lignite humic acid and fertilizers on the yield of onion and nutrient availability. 18th World Congress of f oil Science. July 9-15, Philadelphia, Pennsylvania, USA.

Sarir MS, MI Durrani, IA Mian (2006). Effect of the source and rate of humic acid on phosphorus transformations. J. Agric. Biol. Sci., 1 (1): 29-31.

Selim EM, AA Mosa, AM El-Ghamry (2009). Evaluation of humic substances fertigation through surface and subsurface drip irrigation systems on potato grown under Egyptian sandy soil conditions. Agric. Water Management, 96: 1218-1222.

Shankle MW, TF Garrett, JL Main (2004). Humic acid nutrient trial. Mississippi Agriculture and Forestry Experiment Station Information Bulletin. 405. 218-219.

Sharfuddin AFM, V Voican (1984). Studies on the effect of plant density and NPK dose on the chemical composition of fresh and stored sweet potatoes Bangladesh. J. Agric. Res., 10 (1): 23-27.

Snedecor GW, WG Cochran (1980). Statistical methods. 7th Ed. Iowa State Univ. Press, Iowa, USA.

Verlinden G, B Pycke, J Mertens, F Debersaques, K Verheyen G Baert, J Brif.s, G Haesaert (2009). Application of humic substances results in consistent increases in crop yield and nutrient uptake. J. Plant Nutri. 32: 1407-1426.

Verlinden G, T Coussens, A DeVliegher, G Baert, G Haesaert (2010): Effect of humic substances on nutrient uptake by herbage and on production and nutritive value of herbbage from sown grass pastures. Grass Forage Sci., 65: 133 – 144.