Effect of Humic Acid and Foliar Application of Different Potassium Sources on Yield, Quality and Water Use Efficiency of Sweet Potato Grown under Drip Irrigation in Sandy Soil

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ABSTRACT

Two field experiments were conducted at El-Bostan area at Aly Mubark experimental farm south Tahrir region, El Behira Governorate (30^0 54 N, 29^0 52 E, and 25 m above sea level), during 2012/2013 and 2013/2014 to study the effect of humic application with/without foliar application of different potassium source (potassium nitrate, potassium silicates, potassium humate, potassium sulphate) on sweet potato yield and quality characteristics under drip irrigation system. The results indicated that humic acid applications significantly increased the total tuber yield and all measured growth parameters of sweet potato. The relative increases of total tuber yield, marketable tuber yield, average tuber weight, tuber dry weight, foliage dry weight and leaf area were 6.64, 5.24, 7.47, 19.07, 4.35 and 7.92 %, respectively. Humic acid applications significantly increased total nitrogen, potassium and phosphorous content of sweet potato tubers. Also, foliar application of different potassium sources significantly increased total tuber yield of sweet potato and the most of quality characteristics. Potassium nitrate (KN) and potassium silicates treatments have the highest ability to increase the yield and other growth parameter than other potassium sources (potassium humate and potassium sulphate) under sandy soil condition. Interaction effects between humic acid and foliar application of different potassium sources indicated that there was a significant effect between soil application (fertigation) of humic acid and the foliar application of different potassium sources except for tuber potassium and phosphorus content and also, for available nitrogen, potassium and phosphorous in soil at harvest stage. Calculated water use efficiency (WUE) for total tuber yield increased with increasing rates of soil application of humic acid for the two growing season (2012/2013-2013/2014). Relative increases in WUE for total tuber yield were 4.46 and 11.65 % for HA_2 and HA_4, respectively as a mean value of the tow growing seasons. Also, WUE for marketable yield were more affected by soil application of humic acid compared to WUE for total yield, where the relative increases were 6.07 and 14.51 % for HA_2 and HA_4, respectively as a mean value of the tow growing seasons. Potassium silicate have the highest WUE for total tuber root yield values 3.76 ton/m^3 followed by potassium nitrate 3.61 ton/m^3 while potassium sulphate have the lowest WUE for total tuber root yield 3.20 ton/m^3 as a mean values of the two growing season. It can be concluded that humic acid at rate of 4 kg/feddan with potassium silicate as a foliar application was good practice to increase sweet potato production under sandy soil condition.

Keywords: humic acid, foliar application, yield, water use efficiency, sweet potato, drip irrigation, sandy soil.

INTRODUCTION

Humic acids known as plant growth promoters which can enhance plant yield and quality parameters under biotic and abiotic stresses. Humic substances can enhance seed germination, seedling growth, root growth, and overall growth, uptake of macro- and micro-elements, the bioavailability of nutrients through amendment of the soil environment at the rhizosphere (Chen and Aviad 1990, Varanini and Pinton1995, Bryan and Stark, 2003; Mikkelsen, 2005). Humic acid can directly increase the growth of shoots and roots, uptake of nitrogen, potassium, calcium, phosphorus and magnesium by plant through chelating different nutrients to be more available for plants. Humic acid is consistent with nature and is not dangerous for the plant and environment (Haghighi et al., 2011, Abdel Mawgoud et al., 2007).

Several studies showed that application of humic acid increased the growth and enhanced crop quality for various cultivated crops, Bryan and Stark (2003) reported that humic acid application increased total yield, marketable yield and gross return of potato crop. Shankle et al. (2004) found that soil application of humic acid plus nutrients increased total marketable yield of sweet potato than the standard fertility program. Verlinden et al. (2009) indicated that tuber yield of the potato field trial showed a high response to the application of humic substances. Soil application of humic acid had significant increases in sweet potato growth characters, total and marketable yield and tuber root quality and increased chemical composition of tuber roots (Saif El-Deen et al., 2011).

Humic acid had a positive coloration with macronutrients uptake, such as nitrogen, phosphorus and sulfur (Chen and Aviad, 1990, , Mackowiak et al., 2001;

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Sharif et al., 2004), and micronutrients, that is, Fe, Zn, Cu and Mn (Chen et al., 1999). When humic acid applied to the soil, the requirements for nitrogen, phosphorus and potassium fertilization are reduced (Pettit, 2004).

Potassium is an important nutrient in many physiological and biochemical processes in plants, or even more than nitrogen (Marschner, 1995). The potassium requirement is higher in crop roots than in others (O'Sullivan et al., 1997). Potassium has an important role on photosynthesis, especially protein and carbohydrate synthesis (Pier and Berkowitz, 1987; Robitaille and Lawrence, 1992), and regulates cell turgor and stomatal movement (Beringer and Nothdurft, 1985; Hsiao and Lauchli, 1986). Potassium influences plant water status and tends to reduce the effect of water stress (Marschner, 1995; Losch et al., 1992). Potassium appears to be the most important nutrient in the production of sweet potato as its application increases root yield by the formation of larger sized tubers. Potassium also affects the size, number, quality and the unit weight of tuberous roots produced, while the minimum levels of potassium suggested for healthy growth and yield are twice those recommended for nitrogen, although three times as much may be applied and occasionally even more (Degras, 2003). In Japan, it was estimated that a tuberous yield of 13 t/ha, removes about 70 kg N/ha, 20 kg P_2O_5/ha and 110 kg K_2O/ha from the soil depending on sweet potato variety, crop duration and agro-climatic region (Degras, 2003). Jain-wei et al., 2001 showed that adequate potassium inputs generally increase sweet potato yield, tuber weight and starch content.

Foliar application of potassium nitrate significantly increase plant height, leaves number, leaf area, leaf relative water content and chlorophyll of sweet potatoes and there are no significant effect of increasing potassium nitrate on tuber yield and tuber number. Potato plants need more potassium than many other vegetable crops (Al-Moshileh and Errebi, 2004, BenDkhil et al., 2011). Under sandy soil condition sweet potato subjected to many biotic and a biotic stress which can reduce its productivity and tuber quality, humic acid and foliar application of potassium could be expected to increase its ability not only in increasing productivity, but its quality. The objective of this study was to investigate the effects of humic acid and foliar applications of different potassium sources on yield , yield characteristics and water use efficiency of sweet potato grown under drip irrigation in sandy soil.

MATERIALS AND METHODS

Field experimental site:

Two field experiments were conducted at El-Bostan area at Aly Mubark experimental farm south Tahrir region (sandy soil) (30^0 54 N, 29^0 52 E, and 25 m above sea level) during 2013 and 2014 to study the effect of humic acid application , foliar application of different potassium source and the interaction effect on sweet potato yield and quality characteristics under drip irrigation system. Soil physical and chemical properties of experimental site were analyzed according to Jackson, (1973) and Page et. al., (1982) (Tables 1and 2).

Experimental treatments:

Spilt plot design with four replicates was used, the main plots were assigned to the humic acid treatments through irrigation system, while the sub plots assigned to foliar application of the different potassium sources. The experimental unit consists of six drip irrigation lines (30 m long). Humic acid treatments were 0 (HA_0), 2 (HA_2) and 4kg/fed (HA_4) and applied through the fertigation. The sub-main treatments were foliar application of different potassium sources at the rate of 1000 mgl^{-1} (potassium silicates (K=8%) (KSi) potassium nitrate (K=18.26%) (KN), potassium sulphate (K=41.5%) (KS), potassium humate (K=10%) (KH) and the control (K_0).

Table 1. Soil physical properties of experimental site

Soil depth, cm	F.C%*	W.P%**	A.W,%***	BD, gm/cm^3	Particle size distribution, %			Texture class
					sand	Silt	Clay	
0-15	12.3	5.2	7.1	1.53	90.5	5.4	4.1	Sandy
15-30	10.3	4.3	6.0	1.73	91.9	3.2	4.9	Sandy

Table 2. Soil chemical properties of experimental site

Soil depth,cm	EC dS/m	pH	Soluble cations and anions (meq/L)							
			Ca^{+2}	Mg^{+2}	Na^+	K^+	CO_3^{--}	HCO_3^-	SO_4^{-2}	Cl^-
0-15	0.43	8.22	1.30	0.75	1.9	0.35	0.16	1.19	0.52	2.4
15-30	0.39	8.30	1.25	0.62	1.83	0.20	013	1.25	0.55	2.10

Values are mean of the growing seasons.

F.C. * = field capacity W.P. **= welting point A.W. *** = total available water

N fertilizer in the form of NH_4NO_3 (33.5 % N) at the rate of 238 kg N/ha were injected into the irrigation water (fertigation technique) in 12 equal doses (2-doses/wk) using the traditional fertilizer tank. Land preparation, mineral fertilizers and other field practices are done as recommended by horticulture Research Institute, Agriculture Research Center.

Sweet potato *(*Ipomoea batatas L*.)* variety Abese was transplanted during the first week of May and harvested on the second week of September. A total 50 mm of irrigation water was daily applied in ten portions to ensure good plant establishment. Times of irrigation (after establishment) were estimated for each irrigation event to calculate the amount of applied irrigation water for calculation water utilization efficiency under each treatment as follows.

Applied Irrigation Water and Irrigation Time:

The amount of applied water was calculated according to the following equation (Vermeiren and Jopling, 1984):

$$AIW = \frac{ET0 * Kr * I}{Ea} + LR$$

Where:

AIW= depth of applied irrigation water (mm)

ET0 = reference evapotranspiration ($mm.d^{-1}$) obtained based on class A pan data

Kr= reduction factor that depends on ground cover . A value of 1.0 was used since spacing between drip lines was less than 1.8 m (James, 1988)

Ea= Irrigation efficiency of the drip system. Average value of 0.8 was used as determined at the beginning of each season (Ismail , 2002)

I= irrigation intervals (days) . An irrigation intervals of 2 days was used in this experiment

LR= leaching requirements, (10% of calculated irrigation water ,AIW, was additionally applied per irrigation during the growing seasons for leaching purposes)

Irrigation time was determined before each irrigation event by measuring the actual emitter discharge according to the equation given by Ismail, (2002):

$$t = \frac{AIW * A}{q}$$

Where:

AIW= depth of applied irrigation water (mm)

t = irrigation time (h)

A= wetted area (m)

q = emitter discharge (L/h)

Water Use Efficiency (WUE):

Water use efficiency was calculated according to Jensen (1983):

$WUE_{\text{total tuber yield}}$= total tuber yield (kg/fed)/ Applied irrigation water (m^3/fed)

$WUE_{\text{marketable tuber yield}}$= marketable tuber yield (kg/fed)/ Applied irrigation water (m^3/fed)

Plant sampling:

After 90 days from transplanting, a random five plants sample were taken from each experimental unit to measure, and foliage dry weight/plant, Leaf area/plant (cm^2) according to Koller, 1972. At harvest time, all tuber roots of plants grown in each plot were weighted in kg and data were calculated as tuber yield (ton/fed). Marketable tuber yield (ton/fed), average tuber root weight (g) and dry matter of tuber roots (%) were determined.

Chemical analysis of tuberous roots:

Five symmetric sized of tuber roots from each treatment were cleaned, cut, dried and ground. Half gram of the oven-dried plant material was subjected to wet digested with H_2SO_4 and H_2O_2 (Chapman and Pratt, 1961). The concentration of nitrogen was measured by macro- Kjeldahl (Jackson, 1973) and the concentration of phosphorus was determined colormetercally by Spectrophotometer (McCarty et al., 2003). The concentration of potassium was determined by flame photometer (Chapman and Pratt, 1961).

Soil Analyses:-

Soil samples from each plot were taken for chemical and physical Analyses according to Page et. al., (1982)

Statistical analysis:-

The obtained data were statistically analyzed using statistical package (CoHort, 1986). The mean values for the four replicates of each treatment were interpreted using the analysis of variance (ANOVA). The Duncan's Multiple Range Test was used for comparisons between different sources of variance according to Steel and Torrie (1984).

RESULTS AND DISCUSSION

Data in Table (3) revealed that humic acid applications significantly increased the total tuber yield of sweet potatoes with increasing humic acid application rates. The mean values of total tuber yield increased from 10.82 to 11.89 ton/fed for the first growing season and from 10.63 to 12.16 ton/fed for the second growing season at $HA_0$and HA_4respectively. The same trend was found for the marketable sweet potato yield where it increased from 9.78 to 10.85 ton/fed for the first growing season and from 9.74 to 11.52 ton/fed for the second growing season at HA_0 and HA_4 respectively (Table3). Average tuber root weight was increased significantly with increasing humic application rate; the relative increases in average tuber root weight for the first growing season were 5.85 and 13.76 % and were 2.71 and 14.46 % for the second growing season, at HA_2 and HA_4 , respectively.

Foliar application of potassium nitrate and potassium silicate significantly increased the total tuber yield, marketable tuber yield and average tuber root weight compared to potassium humate and potassium sulphate. As general foliar application of different potassium sources increased total tuber yield, marketable tuber yield and average tuber root weight. The relative increases in tuber root weight were 13.88, 13.25, 10.70 and 5.65 % for KN, Ksi, KH and KS, respectively, for the first growing season, and the same trend was found for the second growing season, where the relative increases in average tuber weight were 13.71, 15.79, 6.30 and 5.30 % for KN, KSi, KH and KS, respectively. It is clear that the relative increases in average tuber root were high for HA_4 than HA_2 and for KN and KSi for the two growing season compared to other treatments. The revealed data are agree with those reported with Selim et al., (2010) who indicated that humic application significantly increased the tuber yields, tuber quality indicators, NPK nutrient concentrations in potato tissues and also with Shankle et al. 2004, Verlinden et al. 2009 and Saif El-Deen et al., 2011. Table (3) also indicated that there were significant interaction effect between soil application of humic acid and foliar fertilization of different potassium sources, where the total tuber yield increased from 10.10 at HA_0K0 to 12.85 ton/fed at HA_4KN for the first growing season and from 9.81 to at HA_0K0 to 12.95 ton/fed at HA_4KSi for the second growing season. Also,

Table 3. Effect of humic acid and foliar application of different potassium sources on total tuber yield (ton/fed), marketable tuber yield (ton/fed) and average tuber yield (g) for sweet potato plant

Treat	1st growing season 2012/2013					2nd growing season 2013/2014				
	Total tuber yield ton/fed									
	HA_0	HA_2	HA_4	Mean	LSD 0.05	HA_0	HA_2	HA_4	Mean	LSD 0.05
KN	11.20	11.58	12.85	11.20		10.58	11.80	13.40	11.93	
KSi	11.90	12.40	12.72	11.90		11.74	12.68	12.95	12.46	
KH	10.79	11.50	11.90	10.79	1.80	10.89	11.75	12.05	11.56	1.55
KS	10.13	10.17	11.10	10.13		10.12	10.32	11.25	10.56	
K0	10.10	10.55	10.89	10.10		9.81	10.25	11.15	10.40	
Mean	10.82	11.24	11.89			10.63	11.36	12.16		
LSD 0.05		0.88					0.73			
LSD0.5 HA*Foliar application were 1.83 and 1.86 for the 1st and 2nd growing seasons, respectively										
	Marketable tuber yield ton/fed									
KN	10.14	10.55	11.84	10.84		9.82	10.44	12.57	10.94	
KSi	10.58	11.34	11.67	11.20		10.86	11.61	11.97	11.48	
KH	9.70	10.45	10.88	10.34	1.71	9.73	10.38	11.78	10.63	1.75
KS	9.28	9.52	9.91	9.57		9.51	9.78	10.71	10.00	
K0	9.18	9.68	9.93	9.60		8.80	9.88	10.58	9.75	
Mean	9.78	10.31	10.85			9.74	10.42	11.52		
LSD0.05		0.52					1.01			
LSD0.5 HA*Foliar application were 1.72 and 1.77for the 1st and 2nd growing seasons, respectively										
	Average tuber root weight g									
KN	142.1	145.1	165.24	150.8		142.1	148.3	169.4	153.3	
KSi	141.2	146.7	162.14	150.0		147.2	152.6	168.6	156.1	
KH	139.1	147.6	153.14	146.6	14.35	135.1	139.5	155.2	143.3	16.1
KS	132.2	140.1	147.52	139.9		137.3	137.4	151.3	141.9	
K0	121.2	135.6	140.60	132.5		129.1	131.3	144.1	134.8	
Mean	135.1	143.0	153.73			138.2	141.8	157.7		
LSD0.05		7.5					6.75			
LSD0.5 HA*Foliar application were 14.68 and 16.6 for the 1st and 2nd growing seasons, respectively										

the interaction effect between soil application of humic acid and foliar application of different potassium sources were significant which increased from 9.18 at HA_0K0 to 11.67 ton/fed at HA_4KSi for the first growing season and from 8.80 at HA0K0 to 12.57 at HA_4KN for the second growing season. The same trend was found for average tuber weight where HA_0KN and HA_4KSi have the highest significant values than other treatments for the first and second growing season, respectively. These results of the interaction effect indicate that humic acid at rate of 4 kg/fed with potassium nitrate (KN) and potassium silicates (KSi) was more efficient for increasing total tuber yield, marketable yield and average tuber weight, this may be due to the associated nitrogen and silicon with the foliar application in enhancing sweet potato growth (Table 3). The other hand, BenDkhil et al., 2011 reported that there is no significant effect of increasing potassium nitrate on tuber yield and tuber number.

Data in Table (4) showed that there are significant increases in dry weight of tuber roots by application of humic acids at rate of 4kg/fed. The dry weight of tuber roots increased from 22.14 to 28.10 gm. at HA_0 and HA_4, respectively for the first growing season and from 23.14 to 29.18 gm for the same treatments at the second growing season. Data also, showed that foliar application of potassium significantly increased dry weight of tuber root and the relative increase as mean values of the two growing season were 25.76, 23.53, 12.41 and 8.04% for KN, KSi, KH and KS as compared to K0, it is clear that KN has the highest relative increases 25.76% then followed by KSi 23.53% . This indicates that potassium nitrate and potassium silicate have the highest ability to enhance growth under sandy soil condition than potassium humate or potassium sulfate (Table 4).

Table 4. Effect of humic acid and foliar application of different potassium sources on dry weight of tuber roots (%), foliage dry weight (g/plant) and leaf area (cm^2/plant) for sweet potato plant

Treat	1st growing season 2012/2013					2nd growing season 2013/2014				
	Dry weight of tuber roots (%)									
	HA_0	HA_2	HA_4	Mean	LSD 0.05	HA_0	HA_2	HA_4	Mean	LSD 0.05
KN	25.14	26.19	30.37	27.23		25.14	27.7	32.17	28.35	
KSi	24.15	25.25	31.23	26.88		24.10	26.62	32.40	27.71	
KH	22.14	23.06	27.90	24.37	3.85	23.14	24.32	28.46	25.31	2.31
KS	20.14	22.43	26.40	22.99		23.18	23.76	27.40	24.78	
K0	19.12	21.06	24.59	21.59		20.14	22.21	25.49	22.61	
Mean	22.14	23.60	28.10			23.14	24.93	29.18		
LSD 0.05		4.32					4.15			
LSD0.5 HA*Foliar application were	6.24 and 5.10 for the 1st and 2nd growing seasons, respectively									
	Foliage dry weight/plant									
KN	210.1	214.2	226.7	217.0		214.2	218.2	230.5	221.0	
KSi	215.1	222.6	225.4	221.0		210.3	216.1	227.5	218.0	
KH	210.1	213.5	220.1	214.6	6.2	205.9	217.8	229.4	217.7	7.2
KS	187.1	198.6	210.9	198.9		204.1	205.9	222.3	210.8	
K0	185.1	190.9	202.0	192.7		188.0	195.3	201.4	194.9	
Mean	201.5	207.9	217.0			204.5	210.7	222.2		
LSD 0.05		6.4					6.15			
LSD0.5 HA*Foliar application were	9.14 and 10.30 for the 1st and 2nd growing seasons, respectively									
	Leaf area cm^2/plant									
KN	389.2	395.6	426.7	403.9		387.1	400.4	435.6	407.7	
KSi	370.2	375.4	419.4	388.3		350.5	387.2	419.3	385.6	
KH	361.9	362.6	398.7	374.4	15.4	345.1	375.9	396.5	372.5	16.3
KS	330.9	338.9	352.5	340.8		330.7	342.8	376.3	349.9	
K0	320.6	330.2	348.2	333.0		325.9	340.0	373.8	346.6	
Mean	354.6	360.6	389.1			347.9	369.3	400.3		
LSD 0.05		27.1					22.1			
LSD0.5 HA*Foliar application were	29.24 and 37.20 for the 1st and 2nd growing seasons, respectively									

Humic acid application significantly increased foliage dry weight per plant, as a mean values foliage dry weight per plant increased from 201.52 g/plant at control (HA_0) treatments to 217.02 g/plant at HA_4 for the first growing season and from 204.51g/plant at control (HA_0) treatments to 222.22 g/plant at HA_4 for the second growing season. Foliar application of different potassium source significantly increased foliage dry weight per plant and increased from 192.70 at the control treatment (K0) to 214.58, 217.00 and 221.04 g/plant for KH, KSi and KN, respectively for the first growing season and from 194.89 at the control treatment (K0) to 210.78, 217.69, 217.97 and 220.98 g/plant for KS, KH, KSi and KN respectively, for the second growing season.

Leaf area for sweet potato plant significantly increased with humic acid application only for HA_4 treatment, it increased from 354.55 to 389.12 cm^2/plant for HA_0 and HA_4, respectively for the first growing season and the same trend were found for the second growing season. Foliar application of potassium substances significantly increased leaf area and the relative increases were 21.27, 16.61, 12.42 and 2.33 for the first growing season and were 17.66, 11.28, 7.50 and 0.97 % for the second growing season for KN, KSi, KH and KS, respectively. These results are agreed with Al-Moshileh and Errebi, 2004 and Trehan et al. 2009.

Data in Table (5) indicate that humic acid application significantly increased tuber nitrogen, potassium and phosphorous content (%) for the two growing seasons , but there is no significant differences between HA_2 and HA_4 for the measured parameters (N, K and P). This was due to that humic substances increased the ability of plants to absorb nutrients and water from the sandy soils, where the low capacity to retain water and nutrients, humic acid increased water holding capacity and soil cation exchange capacity (Haghighi et al., 2011, Abdel Mawgoud et al., 2007).

Table 5. Effect of humic acid and foliar application of different potassium sources tuber nitrogen, potassium and phosphorus content (%) for sweet potato plant

Treat.	1st growing season 2012/2013					2nd growing season 2013/2014				
	Tuber Nitrogen content (%)									
	HA_0	HA_2	HA_4	Mean	LSD 0.05	HA_0	HA_2	HA_4	Mean	LSD 0.05
KN	1.60	1.68	1.69	1.66		1.60	1.67	1.71	1.66	
KSi	1.52	1.66	1.71	1.63		1.58	1.69	1.70	1.66	
KH	1.53	1.60	1.68	1.60	0.08	1.55	1.65	1.67	1.62	N.S
KS	1.49	1.63	1.66	1.59		1.53	1.63	1.65	1.60	
K0	1.50	1.59	1.64	1.58		1.50	1.60	1.66	1.59	
Mean	1.53	1.63	1.68			1.55	1.65	1.68		
LSD 0.05		0.11					0.12			
LSD0.5 HA*Foliar application were 0.16 and 0.15 for the 1st and 2nd growing seasons, respectively										
	Tuber potassium content (%)									
KN	2.26	2.49	2.61	2.45		2.31	2.51	2.65	2.49	
KSi	2. 41	2.51	2.59	2.55		2.35	2.53	2.63	2.50	
KH	2.34	2.44	2.55	2.44	0.12	2.42	2.49	2.56	2.49	0.16
KS	2.18	2.40	2.47	2.35		2.22	2.43	2.52	2.39	
K0	2.10	2.25	2.30	2.22		2.13	2.31	2.32	2.25	
Mean	2.22	2.42	2.50			2.29	2.45	2.54		
LSD 0.05		0.19					0.22			
LSD0.5 HA*Foliar application were not significant for the 1st and 2nd growing seasons.										
	Tuber phosphorous content (%)									
KN	0.23	0.33	0.34	0.30		0.28	0.32	0.33	0.31	
KSi	0.28	0.30	0.35	0.31		0.25	0.33	0.31	0.30	
KH	0.22	0.33	0.33	0.29	N.S	0.23	0.30	0.34	0.29	N.S
KS	0.21	0.28	0.33	0.27		0.23	0.28	0.30	0.27	
K0	0.20	0.27	0.30	0.26		0.21	0.29	0.30	0.27	
Mean	0.23	0.30	0.33			0.24	0.30	0.32		
LSD 0.05		0.10					0.11			
LSD0.5 HA*Foliar application were not significant for the 1st and 2nd growing seasons.										

It is also clear that foliar application of the different potassium source have no significant effect on tuber nitrogen and phosphorous content except for the tuber nitrogen content for the first growing season where it significantly increased from 1.58 to 1.66 % at K0 and KN respectively. On the other had foliar application of different potassium sources significantly increased the amount of tuber potassium content where it increased from 2.22 at K0 to 2.45, 2.55, 2.44 and 2.35 % for KN, KSi, KH and KS respectively for the first growing season and from 2.25 at K0 to 2.49, 2.50, 2.49 and 2.39 % for KN, KSi, KH and KS respectively for the second growing season and there is no significant differences between the different potassium sources for the two growing season. Also it is clear that the relative increases in tuber N, K and P content resulting from humic application treatments were higher than the relative increases resulting from foliar application of the different potassium source that means humic application are more useful tool to increase tuber nutrient content than foliar application of different potassium source.

Table (6) illustrated that there is no significant effect on the amount of available nitrogen, phosphorous and potassium in soil with foliar application of different potassium source and with soil application of different humic acid rates. Soil application of humic acid slightly increased the amount of available N, P and K with increasing application rates and this increases may be higher if the measurement were carried after the application of mineral fertilizer, but in this study the measurements were carried out at harvest and the effect of humic application on the retention of N,P and K may be explained by the increases in tuber contents of N, P and K (Table 5). These increases were a result of the role of humic acid in retain nutrients overall the growing season.

Table 6. Effect of humic acid and foliar application of different potassium sources on the available nitrogen, phosphorous and potassium in soil cultivated with sweet potato

Treat.	1st growing season 2012/2013					2nd growing season 2013/2014				
	Available nitrogen (%)									
	HA_0	HA_2	HA_4	Mean	LSD 0.05	HA_0	HA_2	HA_4	Mean	LSD 0.05
KN	26.17	25.12	16.01	22.43		18.42	26.47	24.87	23.25	
KSi	14.48	22.14	25.14	20.59		24.14	20.17	32.47	25.59	
KH	22.47	21.18	18.42	20.69	NS	30.14	23.47	19.94	24.52	NS
KS	18.45	18.2	23.17	19.94		20.14	20.98	30.33	23.82	
K0	20.14	17.85	22.4	20.13		25.64	24.28	25.17	25.03	
Mean	20.34	20.90	21.03			23.70	23.07	26.56		
LSD0.05		NS					NS			
	Available phosphorous (%)									
KN	5.5	6.6	6.47	6.19		6.18	8.71	7.24	7.38	
KSi	8.14	6.42	5.48	6.68		8.98	8.47	6.73	8.06	
KH	4.29	5.64	8.87	6.27	NS	7.46	6.21	8.57	7.41	NS
KS	6.14	8.24	4.87	6.42		8.17	5.75	6.13	6.68	
K0	5.69	4.18	7.48	5.78		6.46	7.57	9.47	7.83	
Mean	5.95	6.22	6.63			7.45	7.34	7.63		
LSD0.05		NS					NS			
	Available potassium (%)									
KN	100.8	96.47	97.13	98.13		101.58	102.17	106.24	103.33	
KSi	94.4	97.2	95.42	95.67		98.01	100.78	104.72	101.17	
KH	101.87	99.15	97.24	99.42	NS	101.87	103.48	97.2	100.85	NS
KS	88.47	101.02	100.87	96.79		109.35	98.17	101.47	103.00	
K0	98.21	102.7	90.17	97.03		97.54	107.58	104.24	103.12	
Mean	96.75	99.31	96.17			101.67	102.44	102.77		
LSD0.05		NS					NS			

HA*Foliar application were not significant for available N, P and K at the 1st and 2nd growing seasons.

Figure (1) showed that foliar application of different potassium sources increased WUE of total tuber yield of cultivated sweet potato for the two growing season. Potassium silicate have the highest average values of WUE for total tuber root values 3.765 ton/m^3 followed by potassium nitrate 3.615 ton/m^3 while potassium sulphate have the lowest WUE for total tuber root 3.195 ton/m^3 for the two growing seasons . This may be indicated that potassium silicate have the ability to increase sweet potato under different adverse effect of sandy soil and have the ability to increase water use efficiency under different irrigation regime. The same trend was found with the data calculated for WUE for marketable yield for the two growing season 2012 and 2013 (Fig 2). So, we can recommend use of potassium silicate in sandy soil.

Figure (3) showed that WUE for total tuber yield of cultivated sweet potato increased with increasing rates of soil application of humic acid for the two growing season (2012/2013-2013/2014). Relative increases in WUE for total tuber yield were 4.46 and 11.65 % at HA_2 and HA_4, respectively as a mean value of the tow growing seasons. WUE for marketable yield were more affected by soil application of humic acid compared to WUE for total yield, where the relative increases were 6.07 and 14.51 % for HA_2 and HA_4, respectively as a mean value of the tow growing seasons (Fig 4).

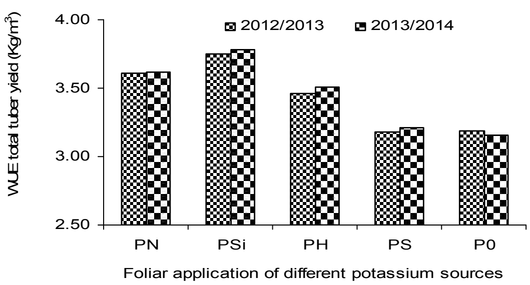

Figure 1. Water use efficiency (WUE) for total tuber yield of sweet potato as affected by different potassium sources

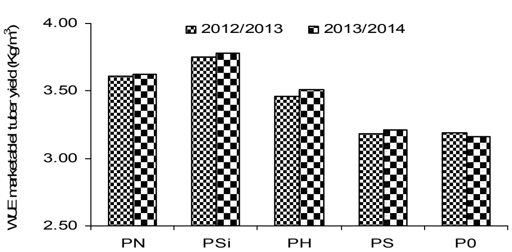

Figure 2. water use efficiency (WUE) for marketable tuber yield of sweet potato as affected by different potassium sources

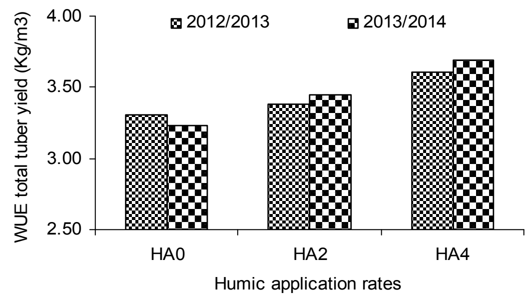

Figure 3. water use efficiency (WUE) for total tuber yield of sweet potato as affected by different humic application rates

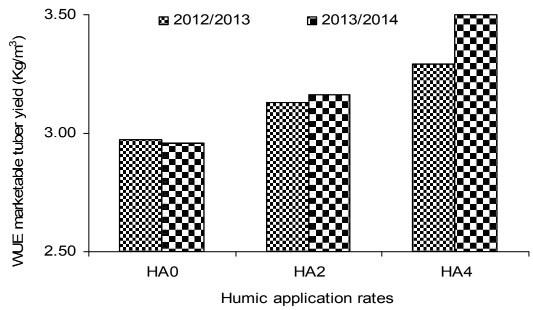

Figure 4. water use efficiency (WUE) for total tuber yield of sweet potato as affected by different humic application rates

CONCLUSION

The study is recommended humic acid at rate of 4 kg/feddan with potassium silicate as a foliar application was good practice to increase sweet potato production under sandy soil condition.

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الملخص العربي

تأثير حامض الهيومك والرش الورقي لمصادر البوتاسيوم المختلفة على المحصول والجودة وكفاءة استخدام المياه للبطاطا الحلوة التي تزرع تحت الري بالتنقيط في التربة الرملية

أحمد إسماعيل، أشرف النماس، عصام النجار

أقيمت تجربتان حقليتان في أرض رملية بمزرعة علي مبارك التجريبية- منطقة البستان - جنوب التحرير- محافظة البحيرة في موسمي ٢٠١٢/٢٠١٣ و ٢٠١٣/٢٠١٤ لدراسة تأثير الإضافة الأرضيه لمعدلات مختلفة من حامض الهيوميك هى ٢ و ٤ كجم/هيوميك بالإضافه الى معاملة المقارنة (الكنترول) مع الرش الورقى لمصادر مختلفة من البوتاسيوم بتركيز ١٠٠٠ جزء فى المليون من البوتاسيوم وكانت المصادر المختلفة هى نترات البوتاسيوم (١٨,٢٦%) وسليكات البوتاسيوم (٨ %) وهيومات البوتاسيوم (١٠%) وسلفات البوتاسيوم (٤١,٥%) بالإضافه الى معاملة المقارنة (الكنترول) وكان الرش ٣ مرات خلال موسم النمو فى تصميم القطع المنشقه مرة واحدة وكانت معاملات الهيوميك موزعة فى القطع الرئيسية ومعاملات الرش الورقى بالبوتاسيوم فى القطع الشقية وذلك لتحديد أفضل معدلات الهيوميك للإضافة الأرضيه وكذلك أفضل صورة من صور البوتاسيوم فى الرش الورقي لزيادة إنتاج وتحسين جودة محصول البطاطا صنف أبيس تحت ظروف الري بالتنقيط فى الأراضى الرمليه بمنطقة البستان وكانت النتائج المتحصل عليها كالأتى:

١- إزدادت كميه المحصول الكلى للدرنات زيادة معنويه بزيادة كميه الهيوميك المضافة حيث إزدادت من ١٠,٨٢ كجم الى١١,٨٩كجم خلال الموسم الأول ومن١٠,٦٣ كجم إلى١٢,١٦ كجم خلال الوسم الثانى وذلك لمعاملات HA_0 و HA_4 على الترتيب وكذلك محصول الدرنات القابل للتسويق حيث بلغت نسبة الزيادة من٦,٢٠ % إلى ١٤,٦١ % لمعاملات HA_2 و HA_4 على الترتيب (متوسط موسمين).

٢- أدت الإضافة الأرضية للهيوميك إلى زيادة معنويه فى كل من متوسط وزن الدرنة ووزن الدرنة الجاف والمساحة الورقية خلال موسمى النمو ٢٠١٣-٢٠١٤ و٢٠١٤-٢٠١٥.

٣- إزداد محصول العروش الجاف للنبات الواحد زيادة معنويه بزيادة إضافة الهيوميك حيث إزداد من ٢٠١,٥جم إلى ٢١٧,٠جم خلال الموسم الأول ومن٢٠٤,٥ جم إلى ٢٢٢,٢جم خلال الموسم الثانى وذلك لمعاملات HA_0 و HA_4 على الترتيب.

٤- إزداد المحتوي الكلى للدرنة من النتروجين والبوتاسيوم والفوسفور والذى قد يرجع إلى قدرة الهيوميك على مسك العناصر الغذائية وزيادة تيسرها للنباتات فى الأراضى الرمليه و تقليل فقدها بالغسيل حيث إزداد تركيز النتروجين زيادة معنوية فى الدرنه من ١,٥٤ إلى١,٦٨ مجم/١٠٠ جم مادة جافة كما وجدت زيادة معنوية لإضافة الهيوميك على تركيز الفوسفور فى الدرنة حيث إزداد تركيز الفوسفور فى الدرنه من ٠,٢٣ إلى٠,٣٣ مجم/١٠٠ جم مادة جافة أما بالنسبه للبوتاسيوم فقد إزداد تركيز البوتاسيوم زيادة معنوية فى الدرنه من ٢,٢٥ إلى٢,٥٢ مجم/١٠٠ جم مادة جافة لمعاملات HA_0 وHA_4 على الترتيب.

٥- أدى الرش الورقى بالبوتاسيوم إلى زيادة معنوية فى المحصول الكلى الدرنات حيث ازداد من١٠,١٠ كجم إلى ١٠,٢٥ و١٠,٣٥ و١١,١٨و١٢,١٨ و١١,٥٧كجم لمعاملات K0 وKs وKH وKsi وKNعلى الترتيب وكانت أفضل صور البوتاسيوم المستخدمة هى نترات

البوتاسيوم وسليكات البوتاسيوم حيث بلغت نسبة الزيادة ١٢,٨٠ % و ١٨,٨١ % على الترتيب (متوسط موسمين).

٦- إزداد المحصول القابل للتسويق وكذلك متوسط وزن الدرنة ووزن العروش الجاف و المساحة الورقية زيادة معنوية مع الرش الورقى بالبوتاسيوم

٧- التاثير التفاعلى بين الإضافة الأرضية للهيوميك و الرش الورقى لصور البوتاسيوم المختلفة كان غير معنويا فقط لكمية النيتروجين والفوسفور والبوتاسيوم المقدر فى الدرنة وكذلك كمية النيتروجين والفوسفور والبوتاسيوم المتاح والمقدر فى التربة عند الحصاد.

٨- ازدادت قيمة WUE مع زيادة كمية الهيوميك المضافة حيث بلغت الزيادة ١١,٦٧%و ١٤,٥١% لكل من محصول الدرنات الكلى والسوقى على الترتيب (متوسط موسمين).

٩- إزدادت قيمة WUE المقدرة للمحصول الكلى للدرنات مع الرش الورقى بالبوتاسيوم وكانت نترات البوتاسيوم وسليكات البوتاسيوم أفضل الصور حيث بلغت نسبة الزيادة١٣,٨٧ %و١٨,٥٩ % على الترتيب.

توصى الدراسة بالإضافه الأرضيه للهيوميك بمعدل ٤ كجم للفدان وأستخدام الرش الورقى إما بسليكات البوتاسيوم أوبنترات البوتاسيوم بتركيز ١٠٠٠ ppm رشا على المجموع الخضري ثلاث مرات خلال موسم النمو لزيادة إنتاج البطاطا وكذلك لرفع كفاءة إستخدام المياه تحت ظروف الأراضى الرملية بمنطقة البستان.