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EFFECT OF IRRIGATION WATER QUANTITY AND APPLICATION OF NITROGEN AND POTASSIUM AS FERTIGATION METHOD ON SWEET POTATO PLANTS UNDER SANDY SOIL CONDITIONS

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ABSTRACT: This work was carried out during the two summer seasons of 2000 and 2001 under the conditions of sandy soil at El-Khattara Experimental Farm, Faculty of Agriculture, Zagazig University to study the effect of irrigation water quantity and different rates of nitrogen and potassium fertilizers on the growth rate, photosynthetic pigments and plant nutritional status as well as the productivity of sweet potato plants.

The obtained results showed that, in most cases, application of irrigation water at the level of 3000 m^3/ fed. being the most effective and favourable treatment on increasing plant growth rate, plant nutritional status and the productivity of tuber roots per plant and per unit area (feddan)*. That was followed by irrigation water at 4000m^3/feddan. While, application of the lowest level of irrigation water (1000m^3 / fed.) being the superior treatment and recorded the maximum values of photosynthetic pigments, proline amino acid content and water use efficiency of sweet potato plant.

On the other hand, application of nitrogen and potassium fertilizers at the rate of 100 kg N + 140 kg K_2O/ fed. through irrigation water (fertigation method) recorded the maximum values of plant growth rate and photosynthetic pigments. Whereas, application of the balance rate of nitrogen and potassium (60 kg N + 60 kg K_2O/ fed.) being the superior treatment regarding plant nutritional status (N, P, K content and their total uptake), proline amino acid content and the marketable yield of tuber roots per plant and per feddan as well as water use efficiency.

The interaction between the two factors of study, in general, did not reflect any significant effect on most studied parameters except few characters which were fluctuated in the two seasons.

Key words: Sweet potato, irrigation water quantity, N+K_2O fertilizers, fertigation, growth , chemical constituents and yield.

* feddan (fed.) = 4200m^2

INTRODUCTION

Sweet potato (*Ipomoea batatas (L.) Lam.)* is very important crop in tropical and subtropical regions of the world. The chief use of sweet potato is for human consumption and for manufacture of starch. The roots as well as leaves are highly nutritious .

Thus, maximizing the productivity of yield of excellent specific quality under the conditions of sandy soil could be achieved by application of the optimum quantity of irrigation water and fertilizers rate as well as choosing the suitable method of fertilizers application.

Moreover, previous studies reported that increasing soil moisture content and /or irrigation water quantity in sand soil greatly promoted the growth rate and the productivity of various vegetable crops. In this regard, Nair and Nair (1995), on sweet potato, Marutani and Cruz (1989) on potato, who reported that application of irrigation water at a level of 3000 m^3/fed. significantly increased the growth rate; i.e., length of vine, leaf number per plant and leaf area index.

It has been proved, particularly in recent time, that for reaching maximum utilization efficiency of fertilizer and further increase of yields of vegetable crops under sandy soil conditions, it can be achieved by possible means such as fertigation frequency, suitable fertilizers and adequate quantity of irrigation water. Advantage resulting from fertigation technique, by reducing the amount of fertilizer and interval between applications. Through this technique it is possible to maintain uniform level of nutrients and to control the nutrient supply in the soil in accordance with changing plant needs during the growth season (Sterling, 1983). He added that, application of nutrients such as nitrogen and potassium are easily to be applied through drip irrigation system (fertigation) whereas, phosphorus is not usually recommended for application.

Application of fertilizers through irrigation system (fertigation) reduced leaching of added fertilizer (Jannings and Martin, 1990). Generally, the shorter the fertigation frequency, the greater the dry matter of tomato vegetative parts. However, this could not be generalized, data given showed that such behaviour was, to some extent, governed by the application timing as well as by the applied quantity (Nader, 1991).

Increasing irrigation water quantity or soil moisture contents increased elements nutrient in plant organs (El-Mansi *et al.* 2004a on garlic), total yield of sweet potato (Said *et al.*, 1984 ;

Resendle and Resendle, 1999) and decreased chlorophyll a, b and total (a +b) as well as carotenoids and prolein in leaf tissues (Khalil, 1977 on carrot; Khalil, 1982 on tomato ; El-Mansi *et al.*, 2004a on garlic).

In addition, Abdel-Rheem, (2003) reported that the irrigation regime significantly affected number of both branches and stems and total yield in both seasons. He added that, values of total yield / fed. were decreased as water stress increased.

Furthermore, application of N+ K_2O fertilizers through irrigation water and increasing such rates under the conditions of sandy soils caused a significant and marked effect as well as improved plant growth rate (Yeh *et al.*,1981; Li and Yen, 1988; El-Denary, 1998; Abdel-Razik and Gaber, 1999; Feleafle 2001), sweet potato leaf contents of chlorophylls and carotenoids (Ayoub, 1998; El-Denary, 1998), plant nutritional status of sweet potato (El-Denary, 1998; Alphonse *et al.*, 2001; Mansour *et al.*, 2002) as well as yield and its components (Sarong *et al.*,1986; Nwingi, 1988; Marcano and Diaz (1994); Ayoub 1998; El-Denary,1998; Al-Easily, 2002).

Therefore, the aim of this work was to study the influence of irrigation water quantity and application of different levels of nitrogen and potassium fertilizers on the growth rate, photosynthetic pigments, plant nutritional status and yield of sweet potato tuber roots under the conditions of sandy soil.

MATERIALS AND METHODS

This work was conducted during the two successive summer seasons of 2000 and 2001 under the conditions of sandy soils at El-Khattara Experimental Farm, Faculty of Agriculture, Zagazig University, to study the effect of irrigation water quantity, different rates of nitrogen and potassium fertilizers on the growth rate, photosynthetic pigments, plant nutritional status and yield and its components as well as water use efficiency of sweet potato plants.

The physical and chemical properties of the experimental soil field and irrigation water are presented in Tables 1 and 2, respectively.

The monthly mean temperature and relative humidity during the period from March till December in 2000 and 2001 seasons were recorded according to Abou-Kabeer Meteorological Station, Sharkia Governorate, Egypt (Table 3).

This experiment included 16 treatments which were the combinations between four irrigation water quantities; i.e., 1000, 2000, 3000 and 4000 m^3/ fed., and four different combined rates of nitrogen + potassium fertilizers; i.e., 80 kg N +100 kg K_2O/fed. as soil application (the

Table 1: The physical and chemical properties of the experimental soil field.

Soil Properties					
Physical properties (%)			Chemical properties		
	2000 season	2001 season		2000 season	2001 season
Sand	95.7	94.3	Organic matter (%)	0.06	0.08
Silt	2.5	3.6	Available K (ugg^{-1})	67.00	64.00
Clay	2.4	2.1	Available P (ugg^{-1})	2.90	2.30
Water holding capacity	14.3	14.7	Available N (ppm)	4.98	3.13
Field capacity	7.7	7.4	Total N (%)	0.05	0.03
Wilting point	2.9	2.6	$CaCo_3$ (%)	0.24	0.28
Available water	4.8	4.8	P^H	8.16	8.24
Texture	Sand	Sand	E.C. (dsm^{-1})	1.99	2.07

Samples of the soil was obtained from 25cm soil surface.

Table 2: Analysis of irrigation water.

Characters		Values
E.C.	(dsm^{-1})	1.53
pH	(mol./L)	8.31
Ca^{+2}	(mol./L)	1.27
Mg^{+2}	(mol./L)	1.09
Na^{+1}	(mol./L)	12.87
K^{+1}	(mol./L)	0.15
SO_4^{-2}	(mol./L)	1.59
CO^{-2}	(mol./L)	0.00
CL^{-1}	(mol./L)	6.07
HCO_3^{-1}	(mol./L)	7.61
Sodium adsorption ratio (SAR)	(mol./L)	11.73

Table 3: The monthly mean temperature and relative humidity during growth period

Month	Temperature (°C) 2000 season			Temperature (°C) 2001 season			Relative humidity (%) 2000 season			Relative humidity (%) 2001 season		
	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean
March	24.9	12.3	18.6	31.2	16.9	24.0	86	40	63	84	36	60
April	30.6	15.4	23.0	34.1	19.8	27.0	83	30	57	82	27	55
May	36.4	20.8	28.6	37.7	23.5	30.6	85	27	56	81	26	53
June	38.3	25.4	31.8	35.7	21.6	28.6	85	32	59	83	30	56
July	38.6	26.6	32.6	30.3	25.1	27.7	84	46	65	83	44	63
August	37.5	27.1	32.3	35.9	25.7	30.8	84	48	66	84	45	64
September	37.3	25.2	31.2	34.8	23.2	29.0	84	42	63	85	39	62
October	34.7	23.8	29.2	31.2	19.7	25.4	87	40	63	82	36	60
November	30.5	18.8	24.6	24.9	15.1	20.0	81	40	60	80	38	59
December	26.2	15.1	20.6	20.4	11.3	15.8	82	45	63	80	38	59

control treatment) , 60kgN + 60kg K_2O, 80 kg N + 100 kg K_2O and 100 kg N + 140 kg K_2O/ feddan. These later three treatments were added as fertigation.

These treatments were arranged in a split plot design with three replicates. The irrigation water quantities were randomly distributed in the main plots, while, the combined rates of nitrogen and potassium fertilizers were assigned at random in the sub plots.

The area of experimental unit was 12.60m^2 contain three dripper irrigation lines with 6 m in length and 70 cm in width. One dripper line was used for measuring vegetative growth characters, while the other two lines were used for measuring the yield and its components. A guard area (1.5 m wide) was left between the experimental units to avoid the overlapping infiltration of irrigation.

Sweet potato *cv* Abies was used in two experimental seasons. The selected transplants (15–20cm length) were transplanted with irrigation water a 25cm apart on April 15th, during 2000 and 2001 seasons, Just beside the dripper lines immediately after dipping in fungicide solution of Benlate at a rate of 1 gm/L.

Drip irrigation system was used as a modified method of irrigation. The dripper lines with discharge of 2.1L/h for each dripper at 1 bar wee used.

All experimental plots received equal amount of water (50m^3 /fed.)during transplanting stage till 20 days from transplanting. The irrigation treatments started on May 5th, in both seasons of study.

The irrigation treatments were stopped 5 days before harvest time.

Irrigation water quantity (m^3/fed.), number of irrigations, time and amount of water at every irrigation (m^3/fed. and/plot) during all growth stages of sweet potato plants are shown in Schedule 1.

Schedule 1. Irrigation water quantity, number of irrigation, time of every irrigation and amount of water at every irrigation during the growth stages of sweet potato plants.

Irrigation water quantity (m^3/fed.)	Number of irrigations	Time of every irrigation (minute)	Amount of water at every irrigation	
			(m^3/plot) 12.6 m^2)	(m^3/fed.)
1000	47	30	0.0638	21.276
2000	47	60	0.1277	42.553
3000	47	90	0.1915	63.830
4000	47	120	0.2553	85.106

The sources of nitrogen and potassium fertilizers were ammonium sulphate (20.6% N) and potassium sulphate (48.52% K_2O), respectively. One third of the different rates of these fertilizers was added with farmyard manure (FYM) as soil application during soil preparation time in the center of the row and covered with sand. The rest amount of both nitrogen and potassium fertilizers (two thirds) were devided into eight equal portions, and then added as soil application or through irrigation water (fertigation method) weekly beginning 20 days after transplanting. In addition, 45 kg P_2O_5/ fed. was added; 75% as calcium superphosphate (15.5% P_2O_5) during soil preparation along farm yard manure, while the rest amount (25%) was added as phosphoric acid (85% P_2O_5). The amount of phosphoric acid was splitted into eight equal portions and added with nitrogen and potassium fertilizers through irrigation water (fertigation method) at the same time of application.

The other normal agricultural treatments for growing sweet potato plants were practiced.

Data Recorded

A random sample of nine plants from every treatment (three plants from every plot) were randomly taken at 120 days after transplanting in the two growing seasons (2000 and 2001) for measuring the following items.

1. Morphological characters

a.Stem length (cm),
b.Number of branches/plant,
c.Number of leaves/plant,
d.Leaves area/plant (cm^2), and
e.Number of tuber roots/plant.

2. Fresh weight

a.Fresh weight of branches / plant (gm)
b.Fresh weight of leaves /plant (gm),
c.Fresh weight of tuber roots/plant (gm) and
d.Total fresh weight / plant (gm),

3. Dry weight

The different parts of sweet potato plant; i.e., branches, leaves and tuber roots were oven dried at 70°C till constant of the weight and the following data were determined:

a.Dry weight of branches / plant (gm)
b.Dry weight of leaves/plant (gm),
c.Dry weight of tuber roots/plant (gm), and
d.Total dry weight of whole plant (gm).

4. Photosynthetic pigments

A random sample from the fourth upper leaf on the main stem was taken to determine both chlorophyll a and b as well as total carotenoids at 120 days after transplanting, during the two investigated seasons, according to the method described by Wettestein (1957).

5. Plant nutritional status: Nitrogen, phosphorus and Potassium contents

The dry matter of branches, leaves and tuber roots at 120 days after transplanting, in the second season (only), were finely ground and wet digested for N, P and K determination according to the procedures described by Bremner and Mulvaney (1982), Olsen and Sommers (1982), and Jackson (1970), respectively.

6. Proline amino acid content

It was determined in the dry matter of leaves at 120 days after transplanting, in the second season, in the first experiment (only) according to the method described by Bates (1973).

7. Yield and its components

At harvest time (135 days) after transplanting in the first and second season) the tuber roots of every plot were harvested and weighed, then separated into three grades; i.e., oversized, marketable and culls according to their sizes, as specification down by the Ministry of Economics for sweet potato exportation (1963) and the following data were recorded:

a. Average number of tuber roots/plant

$$= \frac{\text{Total number of tuber roots/plot}}{\text{Total number of plants /plot}}$$

b. Average weight of tuber roots/plant (gm)

$$= \frac{\text{Total weight of tuber roots/plot}}{\text{Total number of plants /plot}}$$

c. Total weight of oversized tuber roots (ton/fed.) (tubers roots with diameter more than 6 cm).

d. Total weight of marketable tuber roots (ton/fed.) (tuber roots with diameter between 3-6 cm).

e. Total weight of culls tuber roots (ton/fed.) (tuber roots with diameter less than 3 cm).

f. Total tuber roots (ton/fed.) = oversized + marketable + culls tuber roots.

8. Water use efficiency (W.U.E.)

It was calculated according to the equation of Begg and Turner (1976) as follows:

Water use efficiency =

$$\frac{\text{Total yield (kg / fed.)}}{\text{Irrigation water quantity (m}^3\text{ /fed.)}}$$

Statistical analysis

Statistical analysis was conducted for all collected data of both experiments under study. The analysis of variance was calculated according to Snedecor and Cochran (1980), Mean separation was done according to L.S.D. at 0.05 level.

RESULTS AND DISCUSSION

I. Vegetative Growth Characters

a. Effect of irrigation water quantity

Data presented in Tables 4 and 5 show the effect of different irrigation water quantities (1000,

Table 4 : Effect of irrigation water quantity , rates of nitrogen and potassium fertilizers and their interaction on the growth characters of sweet potato plants at 120 days after transplanting during 2000 season

Treatments: Irrigation water quantity (m^3/fed.)	Rates of N+K_2O (Kg/fed.)	Stem length (cm)	No. of branches /plant	No. of leaves / plant	Leaves area/ plant (cm^2)	No .of tuber roots/ plant	Fresh weight /plant (gm): Branches	Fresh weight: Leaves	Fresh weight: Tuber roots	Fresh weight: Whole plant	Dry weight /plant (gm): Branches	Dry weight: Leaves	Dry weight: Tuber roots	Dry weight: Whole plant
1000	80 +100 *	46.89	27.67	353.0	7253.7	1.67	159	275	309	743	37.13	33.47	45.67	116.26
	60 + 60 **	60.50	42.67	464.7	8026.8	2.00	277	340	439	1056	42.62	35.53	90.67	168.81
	80 +100 **	75.66	34.00	346.7	11403.8	2.67	325	465	387	1177	50.54	53.74	49.00	153.28
	100 +140 **	74.73	41.00	363.7	9635.3	2.00	422	486	314	1222	57.84	48.17	42.67	148.68
	Mean	64.44	36.33	382.0	9079.9	2.08	296	391	362	1049	47.03	42.73	57.00	146.76
2000	80 +100 *	95.66	33.67	407.7	7849.7	1.67	279	378	124	781	39.21	37.14	19.67	96.02
	60 + 60 **	105.99	45.67	484.0	8616.2	3.00	335	405	743	1483	45.63	41.48	104.00	191.11
	80 +100 **	87.67	55.00	514.0	11199.1	2.67	332	374	191	897	50.50	50.70	29.33	130.53
	100 +140 **	103.83	57.00	532.7	10555.8	1.67	496	460	128	1084	83.98	52.68	17.00	153.66
	Mean	98.29	47.83	484.6	9555.2	2.25	360	404	296	1061	54.83	45.50	42.50	142.83
3000	80 +100 *	86.67	44.00	420.7	8762.6	4.67	294	355	756	1405	44.72	39.87	115.67	200.26
	60 + 60 **	104.16	61.00	544.7	10728.1	6.00	407	486	1693	2586	71.86	56.23	258.00	386.08
	80 +100 **	144.33	43.00	497.7	13697.1	5.33	404	538	1586	2528	62.95	62.88	252.67	378.50
	100 +140 **	194.00	52.33	864.0	21607.1	3.00	843	967	352	2162	126.38	108.13	52.00	286.51
	Mean	132.29	50.08	581.8	13698.7	4.75	487	586	1097	2170	67.48	66.78	169.58	312.84
4000	80 +100 *	81.17	44.00	333.0	7521.0	3.00	337	337	407	1081	55.76	42.94	60.00	158.70
	60 + 60 **	108.67	60.00	428.7	7643.4	4.33	434	382	1367	2183	67.51	44.06	214.00	325.57
	80 +100 **	107.66	57.33	484.7	8065.7	3.00	335	429	695	1458	52.83	45.37	117.67	215.87
	100 +140 **	134.17	69.00	942.7	17802.8	3.33	879	879	361	2118	139.03	106.30	60.67	306.00
	Mean	107.92	57.58	547.3	10258.2	3.42	496	507	708	1710	78.78	59.67	113.09	251.54
Mean values of N+K_2O rates (kg/fed.)														
	80 +100 *	77.60	37.33	378.6	7846.0	2.75	267	336	399	1002	44.20	38.35	60.25	142.80
	60 + 60 **	95.33	52.33	480.5	8753.6	3.83	363	403	1060	1826	56.90	44.32	166.67	267.89
	80 +100 **	103.83	47.33	460.8	11091.4	3.42	349	451	715	1515	54.20	53.17	112.17	219.54
	100 +140 **	126.81	54.83	675.8	14900.3	2.50	660	698	289	1647	101.81	78.82	43.08	223.71
L.S.D. at 0.05 level														
Irrigation water quantity		10.59	5.23	86.5	2110.9	0.67	76	62	153	244	13.67	7.89	24.52	32.23
Rates of N+K_2O (kg/fed.)		13.57	4.60	70.9	1858.7	0.62	55	58	231	204	8.65	6.59	36.74	36.21
Water quantity x Rates of N+K_2O		27.17	9.20	141.8	3717.8	1.24	107	116	461	407	17.27	13.19	73.80	72.03

* : Soil application (the control treatment).

** : Fertigation.

Table 5 : Effect of irrigation water quantity , rates of nitrogen and potassium fertilizers and their interaction on the growth characters of sweet potato plants at 120 days after transplanting during 2001 season

Treatments: Irrigation water quantity (m^3/fed.)	Rates of N+K_2O (Kg/fed.)	Stem length (cm)	No. of branches /plant	No. of leaves / plant	Leaves area/ plant (cm^2)	No .of tuber roots/ plant	Fresh weight /plant (gm): Branches	Leaves	Tuber roots	Whole plant	Dry weight /plant (gm): Branches	Leaves	Tuber roots	Whole plant
1000	80 +100 *	65.33	22.00	511.0	11813.8	2.67	182	458	191	831	28.70	51.27	19.67	99.64
	60 + 60 **	67.16	35.00	418.0	13152.9	3.00	205	505	295	1005	30.52	56.10	46.00	132.62
	80 +100 **	76.17	32.67	501.7	10727.3	3.00	195	439	158	792	27.27	49.05	23.00	99.32
	100 +140 **	64.11	38.00	580.0	10859.7	2.67	299	547	94	940	39.91	54.44	16.67	108.02
	Mean	68.19	31.92	502.7	11638.4	2.83	220	487	185	892	31.60	52.72	26.34	109.90
2000	80 +100 *	78.99	29.33	451.7	10249.0	3.67	261	406	217	884	37.87	44.76	31.33	113.96
	60 + 60 **	86.66	34.00	425.0	10015.8	3.67	267	434	316	1017	38.05	43.69	48.67	130.41
	80 +100 **	95.52	37.67	502.0	11760.2	2.67	272	508	298	1078	40.64	54.27	43.00	137.90
	100 +140 **	110.11	35.67	457.7	11093.6	2.67	350	508	202	1060	40.65	55.51	26.00	122.16
	Mean	92.82	34.17	459.1	10779.6	3.17	287	464	258	1009	39.30	49.56	37.25	126.10
3000	80 +100 *	71.66	36.33	422.0	8283.0	3.67	227	341	206	774	35.88	38.13	32.67	106.68
	60 + 60 **	91.17	32.00	358.7	13853.5	5.67	220	415	628	1263	44.54	64.55	96.00	205.09
	80 +100 **	92.50	39.33	599.0	9543.1	4.00	266	601	549	1416	42.24	45.96	77.67	165.87
	100 +140 **	84.83	40.67	663.7	14156.2	3.67	332	515	155	1038	56.15	73.51	23.67	153.33
	Mean	85.04	37.08	510.8	11458.9	4.25	261	477	385	1122	44.70	55.54	57.50	157.74
4000	80 +100 *	75.11	36.33	510.7	12305.3	3.00	229	520	375	1123	36.76	58.13	48.67	143.56
	60 + 60 **	94.33	36.67	605.7	12949.9	3.33	252	548	499	1299	42.11	61.42	57.00	160.53
	80 +100 **	82.66	39.67	505.0	12767.5	3.33	264	562	404	1230	43.24	63.41	46.67	153.31
	100 +140 **	103.56	52.67	948.0	17361.2	2.33	432	910	140	1482	69.45	94.23	26.67	190.35
	Mean	88.92	41.33	642.3	13845.9	2.99	294	635	355	1284	47.89	69.30	44.75	161.93
Mean values of N+K_2O rates (kg/fed.)														
	80 +100 *	72.77	31.00	473.8	10662.8	3.25	225	431	232	888	34.80	48.07	33.08	115.95
	60 + 60 **	84.83	34.42	451.8	12493.0	3.92	236	475	434	1145	38.80	56.44	61.92	157.16
	80 +100 **	86.71	37.33	526.9	11199.5	3.25	249	527	352	1128	38.35	53.17	47.58	139.10
	100 +140 **	90.65	41.35	662.3	13367.7	2.83	353	628	148	1129	51.54	69.42	22.50	143.46
L.S.D. at 0.05 level														
Irrigation water quantity		13.12	4.46	N.S.	N.S	0.62	52	83	136	120	6.75	9.21	14.67	17.37
Rates of N+K_2O (kg/fed.)		8.91	3.85	92.3	1733.2	0.62	50	81	127	176	7.38	8.36	14.46	20.11
Water quantity x Rates of N+K_2O		N.S	7.75	185.2	3463.5	N.S.	NS	162	N.S.	N.S.	N.S.	16.78	N.S.	N.S.

* : Soil application (the control treatment).

** : Fertigation.

2000, 3000 and 4000 m^3/fed.) on the vegetative growth characters of sweet potato plants expressed as stem length, number of branches, leaves and tuber roots and leaves area per plant as well as the fresh and dry weights of branches, leaves, tuber roots, and whole plant at 120 days after transplanting in 2000 and 2001 seasons.

It is quite clear from the data that, increasing irrigation water supply exerted a marked and significant effect on all studied growth characters as described above. Whereas, the maximum values of stem length per plant were more distinct with application of irrigation water at 3000m^3 and 2000 m^3/fed. in the first and second seasons, respectively.

Moreover, application of the relatively highest level of water supply (4000 m^3/fed. during the growing season recorded maximum increment of number, fresh and dry weight of branches per plant and came in the first rank in this respect.

On the other hand, irrigation water supply at 3000 m^3/fed. being the most effective and favourable treatment on increasing number, fresh and dry weight of roots per plant. These results were true in both seasons of study. In addition, such level of irrigation water recorded the maximum values of number and area of leaves per plant in first season only, while, in second seasons, all used treatments did not reflect any significant effect in this respect.

In spite of that, the maximum values of fresh and dry weight of leaves and whole plant were recorded with application of irrigation water at 3000 m^3/fed. and 4000 m^3/fed. in the first and second seasons, respectively.

In this connection, the promoting effect with increasing irrigation water supply up to 3000 m^3 and /or 4000 m^3/fed. on the growth rate of sweet potato plants is due to the greatest role of water on all internal physiological metabolic processes in the plant.

On the contrary, decreasing soil moisture content and / or application of the lowest level of irrigation water (1000 m^3/fed. being the inferior one on all the studied growth characters of sweet potato plants in the two investigated seasons. This may be due to that water stress causes losses in tissues water which led to reduce the turger pressure in the cells, thereby inhibition enlargement and division of the cells. In this regard, Bagrov (1964) Jain and Misra (1970), and Hsiao and Acevedo (1974) came to similar conclusion.

The obtained results are in agreement with those reported by Li and Yen (1988), and Nair and

Nair (1995) on sweet potato; Marutani and Cruz (1989) on potato.

Finally, from the above mentioned results and discussion, it could be concluded that the growth rate of sweet potato plants varied according to the irrigation water quantity, whereas, such effect was more achieved via increasing soil moisture content, in other words application of 3000 m^3/fed., respectively during the growing season.

b. Effect of N + K_2O fertilizer rates

With regard to the effect of N+ K_2O fertilizer rates on the growth characters of sweet potato plants, the obtained results in Table 4 and 5 indicated that there was a constant and progressive increase in stem length, number of leaves area per plant as well as, the fresh and dry weight of both branches, leaves and whole plant by increasing the application of N + K_2O fertilizers up to the highest rate, i.e. 100 kg N +140 kg K_2O per feddan through irrigation water (fertigation method). In addition, such treatment being the superior one in this respect. Adverse effect, however, was highly obvious with the application of 80 kg N +100 kg K_2O per feddan by using the traditional method (soil application). These results were true in the two investigations.

On the other hand, the maximum values of number fresh and dry weight of tuber roots per plant were more achieved by application of 60 kg N + 60 kg K_2O per feddan, fertigation method whereas, the lowest values in this respect were recorded by application of the highest rate of NK/100 kg N + 140 kg / K_2O/ fed.) through irrigation water (fertigation method). These results were true in both seasons of study.

These results are in harmony with those reported by Yeh *et al.* (1981), Li and Yen (1988), El-Denary (1998), Abdel–Razik and Gaber (1999), Feleafle *et al.* (2001) and Abdel-Rheem (2003).

From the forgoing results, it could be concluded that the promoting effect of using N + K_2O fertilizers through irrigation water (fertigation method) on the growth rate of sweet potato plants might due to the following reasons. Fertilizers availability is fitted to nutritional needs of the plant during its growth cycle, fertilizer elements already in selection become available to the plant roots faster than when placed in the soil and to high uniformity of fertilizers distribution.

Moreover, as for positive effect of both nitrogen and potassium elements in the plant, Mengel and Kirkby (1978), and Gardner *et al.* (1995) concluded that nitrogen is an indispensable elementary constituent of numerous organic compounds of general in portance (amino acids, protein and nuelic acids) and it is needed in formation of protoplasm and new cells, as well as encouragement cell elengation.

On the other hand, they also added that potassium is the prevalent cation in the plant and may be involved in maintenance of ionic balance in the cells and it bounds ironically to the enzyme pururote kinase, which is essential in respiration and carbohydrates metabolism. So the potassium element in very important in the overall metabolism of plant. Moreover, Evans and Wildes (1971) reported that potassium involved in a number of steps in protein synthesis.

c.Effect of interaction of irrigation water quality X N + K_2O rates

Concerning the combination between the two factors of study (irrigation water quantity) X N + K_2O rates), the obtained results in Tables 4 and 5 showed that in the first season, the interaction between irrigation water at 3000 m^3 / fed combination with 100 kg N + 140 K_2O/fed. (fertigation) had a marked and significant effect as well as the stem length, leaves area, fresh and dry weight of leaves per plant, while the combination between such N + K_2O rate with 4000 m^3/fed of irrigation water significantly increased number of branches, fresh and dry weight of branches per plant. On the other hand, the interaction between 3000 m^3/fed. of irrigation water and application of 60 kg + 60 kg K_2O / fed being the superior one for increasing number , fresh and dry weight of tuber roots per plant, as well as total fresh and dry weight of whole plant.

Whereas in the second season, all interaction treatments, in most cases did not reflect any significant effect on the growth characters, except number of branches/plant, number of leaves/plant, leaves area/plant, fresh and dry weight of leaves, as well as number of branches per individual plant .

Consequently, it could be suggested that the growth behaviour of sweet potato plants varied significantly according to the irrigation water quantity and the used rates of N + K_2O fertilizers.

II. Photosynthetic Pigments

a.Effect of irrigation water quantity

Data presented in Table 6 showed the irrigation water quantity exerted a marked effect on the photosynthetic pigments, i.e., chlorophylls a,b, total chlorophyll and total carotenoids

Table 6: Effect of irrigation water quantity, rates of nitrogen and potassium fertilizers and their interaction on the photosynthetic pigments of sweet potato plants at 120 days after transplanting during 2000 and 2001 seasons

Treatments / Characters		Photosynthetic pigments (mg/gm. dry weight of leaves)							
		Chlorophyll			Total carotenoids	Chlorophyll			Total carotenoids
Irrigation water quantity (m^3/fed.)	Rates of $N+K_2O$ (Kg/fed.)	a	b	Total (a+b)		a	b	Total (a+b)	
		2000 season				2001 season			
1000	80+100 *	2.54	2.32	4.86	2.99	2.28	2.17	4.45	2.16
	60+ 60 **	2.64	2.38	5.02	2.77	2.22	1.98	4.20	2.45
	80+100 **	2.79	2.86	5.65	3.37	2.96	2.21	5.17	2.96
	100+140 **	3.25	3.51	6.76	4.12	3.27	2.79	6.06	3.48
	Mean	2.81	2.77	5.57	3.31	2.68	2.29	4.97	2.76
2000	80+100 *	2.11	2.16	4.27	2.53	2.19	1.81	4.00	2.21
	60+ 60 **	2.41	2.33	4.74	2.61	2.26	1.78	4.04	2.23
	80+100 **	2.55	2.65	5.20	2.81	2.57	2.05	4.62	2.64
	100+140 **	3.55	2.90	6.45	3.10	3.34	2.31	5.65	2.91
	Mean	2.66	2.51	5.17	2.76	2.59	1.99	4.58	2.50
3000	80+100 *	2.08	1.98	4.06	2.18	2.23	1.69	3.92	2.01
	60+ 60 **	2.20	2.11	4.31	2.21	1.91	1.55	3.46	2.10
	80+100 **	2.55	2.18	4.73	2.63	2.13	1.81	3.94	2.36
	1 00+140 **	2.79	2.68	5.44	3.47	2.99	2.14	5.13	2.79
	Mean	2.41	2.24	4.64	2.62	2.32	1.80	4.11	2.32
4000	80+100 *	2.02	2.05	4.07	1.91	1.91	1.53	3.74	1.99
	60+ 60 **	2.08	1.89	3.97	2.08	2.02	1.58	3.60	2.02
	80+100 **	2.16	2.21	4.37	2.18	2.13	1.70	3.83	2.29
	100+140 **	2.33	2.51	4.84	2.48	2.73	2.15	4.88	2.39
	Mean	2.15	2.17	4.31	2.16	2.20	1.74	4.01	2.17
<u>Mean values of $N+K_2O$ rates (kg/fed.)</u>									
	80 +100 *	2.19	2.13	4.32	2.40	2.15	1.80	4.03	2.09
	60 + 60 **	2.33	2.18	4.51	2.42	2.10	1.72	3.83	2.20
	80 +100 **	2.51	2.47	4.98	2.75	2.44	1.94	4.39	2.56
	100 +140 **	2.98	2.89	5.87	3.29	3.08	2.35	5.43	2.89
<u>L.S.D. at 0.05 level</u>									
Irrigation water quantity		0..36	0.05	0.38	0.10	0.14	0.14	0.27	0.41
Rates of $N+K_2O$ (kg/fed.)		0.19	0.08	0.17	0.13	0.20	0.15	0.27	0.16
Water quantity x Rates of $N+K_2O$		0.38	0.15	0.34	0.25	N.S.	N.S.	N.S.	0.31

* : Soil application (the control treatment).
** : Fertigation.

in sweet potato leaves in the two investigated seasons.

Moreover, there was a consistent and significant increase in chlorophyll a,b, total chlorophyll and total carotenoids in the tissues of sweet potato leaves by increasing soil moisture stress and / or decreasing water supply. Whereas, the maximum values in this respect were obtained by application of the lowest level of irrigation water; i.e., 1000 m^3/fed. during the growing season of sweet potato plant. On the contrary, the lowest values of all photosynthetic pigments were achieved via application of the relatively highest level of water supply (4000m^3/ fed.). These results were hold true in the two investigated seasons.

The obtained results are in agreement with those reported by Khalil (1977) on carrot, Khalil (1982) on totamto and El-Mansi *et al.* (2004) on garlic.

From the above mentioned results it could be suggeste that increasing soil moisture stress gave sweet potato leaves with intense chlorophyll and carotenoids content.

b.Effect of N + K_2O fertilizers rates

It is obvious from data recorded in Table 6 that, the contents of photosynthetic pigments, i.e., chlorophyll a,b, total chlorophyll and carotenoids in the tissues of sweet potato plants were gradually increased with increasing the application of nitrogen and potassium fertilizers rates. Whereas, the maximum values in this respect, were obtained with the application of the relatively highest rate (100 kg N + 140 kg K_2O / fed.). Adverse effect, however, was recorded by application of the lowest rate of N + K_2O (60 kg N + 60 kg K_2O / fed.), which was the inferior one. These results were hold true in both seasons of study .

In this connection, the promoting effect of NK fertilizers on increasing the photosynthetic pigments is probably due to that nitrogen is a constituent of chlorophyll molecule. It also due to the increase in the constancy of chlorophyll by nitrogen application leading to the decrease in its reduction and finally to the increase in total carotenoids content which protect chlorophyll against oxidation. In addition, nitrogen deficiency resulted in the collapes of chloroplastes and also in disturbance of chloroplasts development, Thompson and Weier, 1962). Hence leaves deficient in nitrogen show chlorosis which is generally rather eventy distributed over the whole leaf.

Moreover, the favorable effect potassium on photosynthetic pigments is due to that potassium promote assimilation rate of CO_2 and photosynthetic capacity (Haeder and Mengel 1974).These results are in harmony with those reported by Ayoub (1998) and El-Denary (1998) on sweet potato plant.

c.Effect of interaction between irrigation water quantity and N + K_2O fertilizers rates

With regard to the combined effect, the obtained results in Table 6, generally showed that the lowest level of irrigation water (1000m^3/fed.) and application of the highest rate of NK fertilizers (100 kg N + 140 kg K_2O / fed.) being the superior treatment on the content of chlorophyll b and total chlorophyll (in the first season only) , as well as total carotenoids (in the two seasons). On the other hand, the interaction between irrigation water supply at 2000 m^3/fed. and such rate of NK fertilizers recorded the maximum values of chlorophyll a in the first season only. On the contrary, all used treatments did not reflect any significant effect on chlorophyll a, b and total chlorophyll in the second season.

From the previously mentioned results, it could be conclud that both factors of study (irrigation water and rate of nitrogen + potassium fertilizers) influenced the photosynthetic pigments of sweet potato leaves dependently.

III. Plant Nutritional Status

a.Effect of irrigation water quantity

It is quite clear from data in Tables 7 and 8 that the concentration of N, P and K as well as their total uptake in different plant organs; i.e., branches, leaves and tuber roots were significantly affected by different levels of water supply. Whereas, application of irrigation water at 3000 m^3/fed. being the most effective and favourable treatment which recorded the maximum increment of N, P and K concentrations in the branches, leaves and tuber roots as well as their total uptake in both branches and tuber roots; and total mineral uptake per plant. On the other hand, application of the high level of irrigation water (4000m^3/fed.) being the superior one regarding total uptake of N, P and K in leaves only.

On the contrary, increasing soil moisture stress and / or application of the lowest water quantity (1000 m^3/fed.) being the inferior one on the content of N, P and K as well as their total uptake in different organs of sweet potato plants.

Furthermore, obtained results indicated, in general, that the trend of minerals uptake in the tissues of

Table 7: Effect of irrigation water quantity, rates of nitrogen and potassium fertilizers and their interaction on the chemical constituents of sweet potato plants at 120 days after transplanting during 2001 season

Treatments / Characters		Minerals content (%)									Proline amino acid in leaves (mg/100gm dry weight)
		Branches			Leaves			Tuber roots			
Irrigation water quantity (m^3/fed.)	Rates of N+K_2O (Kg/fed.)	N	P	K	N	P	K	N	P	K	
1000	80+100 *	1.61	0.454	1.66	2.19	0.399	2.23	1.02	0.477	1.90	117.50
	60+ 60 **	1.95	0.449	1.92	3.17	0.404	3.46	1.10	0.548	2.35	200.62
	80+100 **	1.65	0.444	1.75	3.01	0.375	3.30	1.01	0.500	2.11	149.65
	100+140 **	1.64	0.422	1.40	2.81	0.365	3.16	0.59	0.469	1.76	111.95
	Mean	1.71	0.442	1.68	2.80	0.386	3.29	0.93	0.498	2.03	144.93
2000	80+100 *	1.68	0.450	1.70	3.01	0.404	3.43	1.12	0.511	2.13	114.20
	60+ 60 **	2.18	0.479	2.07	3.70	0.404	3.78	1.15	0.558	2.45	116.63
	80+100 **	2.18	0.457	2.02	3.60	0.394	3.64	1.12	0.507	2.37	136.57
	100+140 **	1.85	0.427	1.64	2.52	0.399	3.27	1.11	0.490	2.06	119.15
	Mean	1.97	0.453	1.86	3.21	0.401	3.53	1.12	0.517	2.25	134.14
3000	80+100 *	2.10	0.477	2.33	3.60	0.439	3.62	1.18	0.516	2.54	98.93
	60+ 60 **	2.32	0.548	2.63	4.80	0.464	3.85	1.27	0.572	2.63	125.88
	80+100 **	2.23	0.494	2.42	3.69	0.454	3.68	1.20	0.533	2.58	105.22
	100+140 **	1.83	0.469	2.18	3.36	0.429	3.51	1.06	0.503	2.15	83.67
	Mean	2.12	0.497	2.39	3.86	0.446	3.67	1.18	0.531	2.47	103.45
4000	80+100 *	1.11	0.433	2.22	3.84	0.406	3.51	0.97	0.450	2.01	92.48
	60+ 60 **	2.10	0.440	2.42	4.20	0.426	3.64	1.15	0.548	2.40	115.28
	80+100 **	1.50	0.441	2.38	3.90	0.416	3.64	0.99	0.516	2.16	102.48
	100+140 **	1.10	0.421	1.96	2.84	0.392	3.13	0.91	0.443	1.99	86.62
	Mean	1.45	0.434	2.25	3.70	0.411	3.48	1.00	0.489	2.14	99.22
Mean values of N+K_2O rates (kg/fed.)											
	80 + 100 *	1.62	0.453	1.98	3.16	0.412	3.45	1.07	0.489	2.14	105.78
	60 + 60 **	2.14	0.479	2.26	3.97	0.425	3.68	1.17	0.556	2.46	152.10
	80 +100 **	1.89	0.459	2.14	3.55	0.410	3.56	1.08	0.514	2.31	123.48
	100 +140 **	1.61	0.435	1.80	2.88	0.396	3.27	0.92	0.476	1.99	100. 37
L.S.D L.S.D. at 0.05 level											
Irrigation water quantity		0.19	0.03	0.09	0.15	0.02	0.16	0.10	0.02	0.08	13.74
Rates of N+K_2O (kg/fed.)		0.19	0.02	0.09	0.34	NS.	0.11	0.08	0.01	0.10	8.96
Water quantity x Rates of N+K_2O		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	0.19	N.S.	N.S.	17.94

* : Soil application (the control treatment).

** : Fertigation

Table 8: Effect of irrigation water quantity , rates of nitrogen and potassium fertilizers and their interaction on the mineral uptake (mg/plant) of sweet potato plants at 120 days after transplanting during 2001 season

Treatments / Characters		Minerals uptake (mg)									Total uptake (mg/plant)		
Irrigation water quantity (m^3/fed.)	Rates of $N+K_2O$ (Kg/fed.)	Branches			Leaves			Tuber roots			N	P	K
		N	P	K	N	P	K	N	P	K			
1000	80 + 100 *	481.7	129.4	478.9	1120.7	205.4	1654.9	197.4	93.6	375.9	1799.8	428.4	2509.8
	60 + 60 **	609.7	137.7	589.5	1673.9	222.5	1948.7	521.9	257.3	1063.6	2805.6	617.5	3601.8
	80 +100 **	435.0	120.8	472.8	1460.4	184.6	1617.1	218.3	111.9	479.7	2113.7	417.4	2569.9
	100 +140 **	656.9	168.4	557.4	1559.8	199.9	1654.9	80.1	63.4	240.9	2296.9	431.7	2589.5
	Mean	545.9	139.1	524.7	1453.7	203.1	1740.5	254.4	131.6	540.1	2245.0	473.7	2805.2
2000	80 + 100 *	628.4	170.3	640.3	1339.9	179.7	1540.4	341.3	163.1	660.9	2309.8	513.1	2841.6
	60 + 60 **	837.4	181.1	787.9	1627.8	174.9	1652.8	558.9	271.1	1195.6	3024.1	627.2	3636.4
	80 +100 **	879.8	181.9	819.2	1947.2	215.1	1972.4	491.0	217.2	1016.4	3317.9	614.3	3807.9
	100 +140 **	750.8	172.5	665.5	1406.6	222.1	1812.2	290.9	129.1	533.9	2448.3	522.7	3011.6
	Mean	774.1	176.5	728.3	1580.4	197.9	1744.4	420.5	194.9	851.7	2775.0	569.3	3324.4
3000	80 + 100 *	753.5	170.9	833.1	1375.4	167.6	1381.8	383.6	168.6	825.8	2512.5	507.1	3040.7
	60 + 60 **	1036.8	243.2	1167.7	3097.8	299.5	2488.5	1224.2	552.4	2524.7	5358.4	1095.1	6180.9
	80 +100 **	939.6	207.3	1022.2	1686.4	208.5	1687.3	936.6	413.5	1968.9	3562.5	829.2	4678.4
	100 +140 **	1029.2	262.8	1220.9	2473.9	315.0	2577.1	247.2	118.8	508.3	3750.7	696.6	4306.4
	Mean	939.9	221.0	1061.0	2158.3	247.7	2033.7	697.9	313.3	1456.9	3796.0	782.0	4551.6
4000	80 + 100 *	405.2	158.7	813.6	2232.8	236.0	2041.0	472.4	218.9	975.7	3110.4	613.5	3830.4
	60 + 60 **	884.3	185.6	1018.2	2567.3	262.5	2231.8	664.3	212.3	1344.2	4115.9	960.3	4594.2
	80 +100 **	638.4	190.3	1030.9	2478.6	263.7	2310.2	467.1	240.6	1043.6	3584.2	694.6	4384.7
	100 +140 **	765.0	292.4	1361.1	2666.1	370.7	2958.7	264.5	119.7	537.8	3695.6	782.7	4857.6
	Mean	673.3	206.7	1055.9	2486.2	283.2	2385.4	467.1	222.8	975.3	3626.5	712.8	4416.7
Mean values of $N+K_2O$ rates (kg/fed.)													
	80 + 100 *	567.2	157.3	691.5	1517.2	197.2	1654.5	348.7	161.0	709.6	2433.1	515.5	3055.6
	60 + 60 **	842.1	186.9	890.8	2241.6	239.8	2080.4	742.3	348.3	1532.0	3825.9	775.0	4503.3
	80 +100 **	723.2	175.1	836.3	1893.1	217.9	1896.8	528.2	245.8	1127.2	3144.6	638.9	3860.3
	100 +140 **	800.6	224.0	951.3	2026.6	276.9	2272.3	220.7	107.5	455.3	3047.9	608.4	3678.8
L.S.D L.S.D. at 0.05 level													
Irrigation water quantity		134.9	34.3	163.7	401.4	32.9	348.8	179.9	82.7	349.5	376.2	93.1	373.7
Rates of $N+K_2O$ (kg/fed.)		153.4	30.1	147.6	274.9	37.3	310.8	185.2	82.5	338.5	419.5	95.5	512.1
Water quantity x Rates of $N+K_2O$		N.S.	N.S.	N.S.	552.1	74.6	N.S.	367.5	N.S.	N.S.	841.7	191.5	1024.3

* :Soil application (the control treatment).

** : Fertigation

sweet potato plant was nearly similar to that reported with the dry matter content (Tables 4 and 5).

Similar findings were also reported by El-Mansi *et al.* (2004a) who found that using suitable amount of irrigation water increase minerals nutrient in plant organs, but excess water decreased it .

The superiority of increasing water supply on the content and total uptake of N, P and K elements in different organs of sweet potato plants, is due to that increasing soil moisture content caused a marked effect on increasing the solubility of such elements in the soil which led to promote the absorbing efficiency of such elements by the plants.

Concerning, proline content of leaves data in Table 7 show that proline was significantly increased with reducing water quantity supply up to 1000 m^3 /fed., compared with the other treatments. These results are confirmed with those reported by El-Mansi *et al.* (2004) who found that water quantity at 600 m^3/fed increased prolein in leaf tissues of garlic.

In this connection, Stewart (1977) reported that conversion of proline to glutamic acid, and hence to other compounds/ proline oxidation proceeds readily in turgid leaves and it is stimulated by higher concentrations of proline. This suggests that proline oxidation could function as a control mechanism for maintaining low cellular levels proline in turgid tissues. Under water stress, on the other hand proline oxidation is reduced to negligible rates. It seems likely that inhibition of proline oxidation is necessary in maintaining high levels of proline found in stressed levels. Moreover, Walton (1980) and Jones (1981) indicated that water stress as well as Abscisic acid (ABA) decreased photosynthesis and its enzyme activities, but increased praline and betanine accumulation. Moreover, Barker *et al.* (1993) found that leaf proline concentrations averaged 20 times greater in the stressed as compared to well water plants.

b.Effect of N + K_2O fertilizer rates

Data presented in Tables 7 and 8 showed clearly that all used rate of nitrogen and potassium fertilizers caused a significant differences on the content of N, P and K elements and their total uptake in different organs of sweet potato plants, as well as total uptake per plant. Whereas, application of the balance rate, i.e. 60 kg N + 60 kg K_2O / fed. being the most superior treatment in this respect, except P and K uptake in branches, as well as P uptake in leaves which recorded their maximum values by addition of the highest rate of N K fertilizer, i.e., 100 kg N + 140 kg K_2O / fed. through irrigation water (fertigation method) . On the other hand, there were no significant differences among all tested treatment on P content in leaves.

Application of nutrients such as nitrogen and potassium are easily to be applied through drip irrigation system (fertigation) (Sterling 1983). Also, application of fertilizers through irrigation system (fertigation) reduced leaching of added fertilizer (Jannings and Martin, 1990).

The obtained results are in accordance with those reported by El-Denary (1998), Alphonse *et al.* (2001) and Mansour *et al.* (2002).

In addition, it can be generally, concluded that high efficiency of observation for more N, P and K of the plant showed be also expected to be reflected on having strong vegetative growth with high accumulation of dry matter content.

Finally, from the previously mention results it could be concluded that, application of the balance rate of nitrogen and potassium (60 kg N+60kg K_2O /fed.) through fertigation method being the most effective and favourable treatment in minerals content and their total uptake in different organs of sweet potato, as well as proline amino acid content in leaves.

Concerning, proline amino acid content in sweet potato leaves, the obtained results in Table 7 indicated that application of 60 kg N + 60 kg K_2O / fed. recorded the highest increments and came in the first rank in this respect. Adverse effect however, was more achieved with the application of 100 kg N + 140 kg K_2O/ fed.

Moreover, it is also evident from the some table that, application of 80 kg N + 100 kg K_2O/fed. through fertigation method was more effective as compared with the addition of such rate as soil application.

c.Effect of interaction between irrigation water quantity X rates of N + K_2O fertilizers

With regard to the interaction effect the obtained results in Tables 7 and 8 showed that application 3000 m^3 /fed. of irrigation water combined with 60 kg N + 60 kg K_2O / fed. recorded the maximum increments in N content and its uptake in tuber roots, and N uptake in leaves, as well as total mineral uptake of N, P and K in whole plant . While , such level of water supply combined with 100 kg N + 140 / fed. recorded the heaviest value of P uptake in leaves.

With regard to praline amino content in sweet potato leaves, the obtained results in Table 6 clearly showed that, the maximum values of praline content were highly obvious by the interaction between the lowest level of irrigation water 1000 m^3/fed. (soil moisture stress) and application of 60 kg N + 60 kg K_2O / fedan.

As a general conclusion, it could be suggest that the minerals content (N, P and K) and their uptake, as well as total mineral uptake per whole sweet potato plant, and proline content in leaves varied greatly according to the different levels of water quantities and the rates of N K fertilizers.

IV.Yield and Its Components

a.Effect of irrigation water quantity

Data presented in Tables 9 and 10 showed the effect of different irrigation water quantity on the yield and its components of sweet potato plants expressed as, number and weight of tuber roots per plant, as well as weight of oversized roots, culls and total tuber roots yield per feddan in both seasons of study.

The obtained results in such table indicated that the different quantities of irrigation water exerted a marked and significant effect in sweet potato yield. Whereas, application of irrigation water at a level of 3000 m^3/fed. being the most effective and favourable treatment as well as recorded the maximum values in this respect.

On the other hand quantities of irrigation water did not a significantly affect the number of tuber roots per plant (in the first season), and weight of tuber roots of culls yield (in the first season).

On the contrary, the lowest values of sweet potato yield and its components were highly obvious with the application of the lowest level of irrigation water and / or increasing soil moisture stress. These results were hold true in both seasons of study.

Moreover, application of irrigation water at a level of 3000m^3/fed. increased the total yield by 65.48%, 41.43 and 34.17, as well as the marketable yield by 61.47%, 39.56% and 32.94% average of 1000, 2000 and 4000m^3/fed. of irrigation water, respectively.

These results are going in agreement with those reported by Said *et al.* (1984), Resende and Resende (1999), who reported that increasing soil moisture content by irrigation did increase of total sweet potato yield and marketable yield.

Finally, as a general conclusion, it is worthy to mention that the superiority of applicate irrigation water at a level of 3000 m^3 per feddan during the growing seasons on sweet potato yield is directly owing to the in increase in number and weight of tuber roots per plant. In addition, the development of sweet potato tuber roots and its production may be considered as an expression of

Table 9: Effect of irrigation water quantity , rates of nitrogen and potassium fertilizers and their interaction on the yield and its components of sweet potato plants during 2000 season

Treatments: Irrigation water quantity (m^3/fed.)	Rates of $N+K_2O$ (Kg/fed.)	Yield of tuber roots/plant: No.	Yield of tuber roots/plant: Weight (gm)	Yield of tuber roots (ton/fed.): Oversized	Marketable	Culls	Total	Water use efficiency (W.U.E.) (kg/m^3)
1000	80+100 *	2.49	433.00	0.285	6.844	0.283	7.411	7.411
	60+ 60 **	2.60	489.73	0.422	10.423	0.091	10.936	10.342
	80+100**	2.73	381.00	0.301	8.028	0.164	8.493	8.492
	100+140**	2.74	353.00	0.191	6.528	0.151	6.870	6.870
Mean		2.64	414.18	0.300	7.956	0.172	8.428	8.279
2000	80+100 *	2.37	351.67	0.646	7.309	0.091	8.047	4.023
	60+ 60 **	2.69	510.67	0.570	10.814	0.112	11.496	5.748
	80+100**	1.99	452.00	0.766	9.895	0.150	10.811	5.406
	100+140**	1.97	363.67	0.423	7.913	0.103	8.440	4.220
Mean		2.26	419.50	0.601	8.983	0.114	9.698	4.849
3000	80+100 *	2.97	582.00	0.760	11.656	0.124	12.540	4.180
	60+ 60 **	3.33	673.77	1.090	14.686	0.187	15.962	5.321
	80+100**	3.08	590.77	1.072	12.032	0.220	13.325	4.442
	100+140**	3.27	576.47	0.602	10.323	0.197	11.122	3.707
Mean		3.16	605.75	0.881	12.174	0.182	13.237	4.412
4000	80+100 *	2.76	552.00	0.549	7.900	0.180	8.629	2.157
	60+ 60 **	2.94	619.33	0.524	10.648	0.169	11.341	2.835
	80+100**	3.31	593.70	0.650	9.564	1.182	10.396	2.599
	100+140**	2.37	542.47	0.345	7.228	0.133	7.705	1.926
Mean		2.85	576.88	0.517	8.835	0.166	9.518	2..379
Mean values of $N+K_2O$ rates (kg/fed.)								
	80+100 *	2.65	479.67	0.560	8.427	0.170	9.157	4.443
	60+ 60 **	2.89	573.38	0.651	11.643	0.140	12.434	6.061
	80+100**	2.78	504.37	0.697	9.880	0.179	10.756	5.235
	100+140**	2.59	458.90	0.390	7.998	0.146	8.534	4.181
L.S.D L.S.D. at 0.05 level								
Irrigation water quantity		0.27	96.89	0.100	2.510	N.S.	2.526	1.267
Rates of N+K2O (kg/fed.)		N.S.	N.S.	0.075	1.590	N.S.	1.575	0.910
Water quantity x Rates of $N+K_2O$		N.S.	N.S.	0.156	N.S.	N.S.	N.S.	N.S.

* : Soil application (the control treatment).
** : Fertigation.

Table 10: Effect of irrigation water quantity , rates of nitrogen and potassium fertilizers and their interaction on the yield and its components of sweet potato plants during 2001 season

Treatments: Irrigation water quantity (m^3/fed.)	Characters: Rates of $N+K_2O$ (Kg/fed.)	Yield and its components: Yield of tuber roots/plant No.	Weight (gm)	Yield of tuber roots (ton/fed.) Oversized	Marketable	Culls	Total	Water use efficiency (W.U.E.) (kg/m^3)
1000	80+100 *	2.67	370.67	0.313	6.900	0.159	7.372	7.372
	60+ 60 **	3.38	605.00	0.348	9.885	0.207	10.440	10.440
	80+100**	2.52	324.00	0.378	7.101	0.189	7.668	7.668
	100+140**	2.81	288.33	0.192	5.722	0.169	6.082	6.082
Mean		2.84	397.00	0.308	7.402	0.181	7.891	7.891
2000	80+100 *	2.49	430.00	0.434	8.716	0.151	9.301	4.650
	60+ 60 **	3.47	553.67	0.465	10.889	0.225	11.579	5.790
	80+100**	2.34	412.67	0.501	8.988	0.193	9.682	4.841
	100+140**	2.44	305.33	0.353	6.442	0.144	6.939	3.470
Mean		2.69	425.42	0.438	8.759	0.178	9.375	4.688
3000	80+100 *	3.33	576.67	0.870	11.754	0.155	12.779	4.260
	60+ 60 **	4.42	832.67	1.035	17.131	0.265	18.431	6.144
	80+100**	3.44	599.67	1.114	12.518	0.256	13.918	4.639
	100+140**	2.35	409.00	0.675	8.907	0.181	9.762	3.254
Mean		3.39	604.50	0.931	12.577	0.214	13.722	4.574
4000	80+100 *	3.24	499.33	0.554	9.411	0.229	10.193	2.548
	60+ 60 **	3.94	614.67	0.664	12.514	0.336	13.515	3.379
	80+100**	3.23	535.67	0.646	10.599	0.248	11.493	2.873
	100+140**	2.24	315.33	0.337	6.756	0.168	7.261	1.815
Mean		3.16	491.25	0.550	9.820	0.245	10.615	2.654
Mean values of $N+K_2O$ rates (kg/fed.)								
	80+100 *	2.93	469.17	0.543	9.195	0.173	9.911	4.708
	60+ 60 **	3.80	651.50	0.628	12.605	0.258	13.491	6.438
	80+100**	2.88	468.00	0.667	9.801	0.222	10.690	5.005
	100+140**	2.46	329.50	0.389	6.957	0.165	7.511	3.655
L.S.D L.S.D. at 0.05 level								
Irrigation water quantity		N.S.	109.01	0.116	1.660	0.048	1.737	0.696
Rates of N+K2O (kg/fed.)		0.31	32.73	0.110	0.885	0.058	0.917	0.483
Water quantity x Rates of $N+K_2O$		0.61	65.43	N.S.	N.S.	N.S.	N.S.	0.966

* : Soil application (the control treatment).

** : Fertigation

plant growth rate and its dry matter content, as well as, plant minerals uptake. In fact, yield can be considered as the final resultant of all physiological and metabolic processes in the plant .

Furthermore, water use efficiency, expressed as consumptive use per season in m^3/ feddan for one kilogram of sweet potato tuber roots, is used to evaluate the efficiencies of irrigation practices for maximum utilization of water supply. In this regard , data illustrated in Tables 9 and 10 indicated that decreasing water supply and / or soil moisture content caused a marked and significant effect on water use efficiency, whereas, application of the lowest level of irrigation water (1000m^3/fed.) being the superior treatment and recorded the maximum values in this respect. In addition such treatment, recorded the lowest total tuber roots yield .

On the contrary increasing the application of irrigation water up to the highest level (4000 m^3/fed.) recorded the lowest values of water use efficiency in both seasons of study.

These results are in harmony with those reported by El-Mansi *et al.*(2004b) on garlic under sandy soil conditions .

Consequently, it is worth to mention that at application of irrigation water a level of 3000 m^3/ fed. being the most effective treatment on the productivity of sweet potato plants, while the lowest level of water supply ; i.e., 1000 m^3/fed. being the superior one on water use efficiency. These results were hold true in both seasons of study.

b. Effect of N+ K_2O fertilizer rates

With regard to the effect of different used rates of nitrogen and potassium fertilizers on the yield and its components of sweet potato plant, the obtained data in Tables 9 and 10 indicated that the highest increments of number and weight of tuber roots per individual plant as well as weight of marketable, culls, total yield of tuber roots (ton/fed.) and water use efficiency were recorded by application of the balance rate of NK fertilizers; i.e., 60 kg N + 60kg K_2O / fed. through irrigation water (fertigation), as compared with the other treatments .

In spite of that, all used rates of NK fertilizers did not significantly affect both number and weight of tuber roots as well as culls yield (ton/fed.) in the first season only. On the other hand, the highest yield of oversized tuber roots (ton/ fed.) was achieved with the application of 80 kg N + 100kg K_2O/fed. through fertigation methods in the two seasons of study.

On the contrary, increasing the addition of N kg fertilizers up to the highest rate (100 kg N + 140 kg K_2O /fed.) being the inferior one on the yield and its components in both seasons of study.

From the previously mentioned results, it could, concluded that , the promoting effect of addition the blance rate of NK fertilizers on the total yield of sweet potato yield may be directly owing to the increase in both number and fresh weight of tuber roots per individual plant at harvest time (Tables 9 and 10), the dry matter content of tuber roots (Tables 4 and 5). Moreover, such treatment increased the total yield by 35.96% , 20.90% and 62.66% as well as the marketable yield by 37.63%, 23.23% and 63.38% (average of the two seasons) over the treatments of 80 kg N + 100 kg K_2O /fed. and 100 kg N + 140 kg K_2O /fed. (by using fertigation method), respectively.

On the other hand, the depressive effect of increasing the addition of NK fertilizers up to the highest rate (100 kg N + 140 kg K_2O/ fed.) on the yield and its components of sweet potato plants, is due to that plants received the higher level of nitrogen showed more vegetative growth (Tables 4 and 5) on the account of formation and development of tuber roots. Moreover, plants will use nitrogen and carbohydrate building new tissues while, and the rest of carbohydrate will be limit translocation and store in the tuber roots (storage organs). On the contrary, plants under shortage of nitrogen supply well not grow well, and showed poor vegetative growth and consequently of few number of tuber roots (Tables 4 and 5). Therefore, nitrogen supply showed by at the optimum rate , i.e., 60kg N (as fertigation) proved to be enough as well as gave maximum yield of tuber roots . In this connection the results illustrated in (Tables 9 and 10) could be confirmed the light of these discussion.

It is well known that, sweet potato is a xerophytic plant and can grow well with low input. Moreover, reviewing available literature, it could be deduce four points concerning N + K_2O combination, 1. Sweet potato yield had a good response to N fertilization, but heavy applications of N tended to decrease it compared with K applications, as shown by Yeh *et al.*(1981), Marcano and Diaz (1994). 2. Using N + K_2O on equal amount or when the amount of K_2O is slightly higher than N gave maximum root tuber yield and marketable yield, as shown by Nwingi (1988), and Ayoub (1998). 3. The optimum amount satisfy the previously mentioned (in 2) combination depends on soil type (place) and method of application (dressing or fertigation). And 4. Each yield component may need specify combination of N + K_2O, as shown by Sarong *et al.*(1986), Ayoub (1998), El-Denary (1998), Al-Easily (2002). The present results satisfy more than two points of aforementioned the discussion, since the treatment 60 + 60 kg of N + K_2O, respectively when fertigationaly added gave highest yield and its components.

c. Effect of interaction between irrigation water quantity X N + K_2O fertilizer rates

It is seen from Tables 9 and 10 that the interaction between irrigation water quantities and different N + K_2O fertilization rates did not reflect any significant effect on yield and its component as well as the water use efficiency with few exceptions; i.e., the oversized yield / fed., in the first season as well as number and weight of tuber root per plant and water use efficiency in the second season.

Although, the insignificant effect of the interaction treatments was shown in Table 8 the interaction between irrigation water quantity at 3000m^3/fed. and fertigation with 60 kg N + 60 kg K_2O/ fed. being the superior treatment for enhancing the parameters which significantly showed response to these interaction treatments. Under water stress, the lowest water quantity recorded higher values of water use efficiency compared with other interaction treatments. However, the superior interaction treatment in this respect was 1000m^3/fed. irrigation water quantity when combined with 60 kg N+60 kg K_2O/fed. as fertigation.

In general, a few parameters of yield and its components were favoured as a result of the combination between irrigation water quantity at 3000m^3/fed. and fertigation with N + K_2O at the rate of 60 +60 kg/fed., respectively but most parameters were not .

Finally, from the forgoing results and discussion, it could be noticed that the growth rate and yield behaviour of sweet potato plants varied according to the irrigation water quantity and the used rates of nitrogen and potassium fertilizers.

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تأثير كمية ماء الرى وإضافة السماد النيتروجينى والبوتاسى من خلال طريقة التسميد مع ماء الرى على نباتات البطاطا تحت ظروف الأرض الرملية

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أجرى هذا العمل خلال فصل الصيف لموسمى ٢٠٠٠، ٢٠٠١م تحت ظروف الأراضى الرملية بمزرعة الخطارة بكلية الزراعة – جامعة الزقازيق، وذلك لدراسة تأثير كمية ماء الرى، ومستويات مختلفة من الأسمدة النيتروجينية والبوتاسية على معدل النمو، وصبغات التمثيل الضوئى، وحالة العناصر الغذائية فى النبات، وعلاوة على ذلك إنتاجية محصول نباتات البطاطا.

ولقد أوضحت النتائج المتحصل عليها فى أغلب الحالات أن إضافة ماء الرى بمعدل ٣٠٠٠م٣/ فدان كان أكثر المعاملات تأثيراً وفاعلية على زيادة معدل النمو للنبات، وحالة العناصر الغذائية فى النبات، وإنتاجية محصول الجذور الدرنية لكل من النبات ووحدة المساحة (الفدان)، بينما سجل المعدل العالى من ماء الرى (٤٠٠٠ م٣/ فدان) المرتبة الثانية فى هذا الخصوص. وعلى العكس من ذلك فقد كان نقص محتوى رطوبة التربة وإضافة المعدل المنخفض من ماء الرى (١٠٠٠ م٣/فدان) أكثر المعاملات تفوقا وسجل أقصى قيم لكل من صبغات التمثيل الضوئى، ومحتوى الحمض الأمينى البرولين، وكفاءة استخدام ماء الرى فى نباتات البطاطا.

ومن ناحية أخرى، فقد أدت إضافة الأسمدة النيتروجينية والبوتاسية بمعدل ١٠٠كجم/ن + ١٤٠كجم بو٢أ/ فدان خلال ماء الرى (طريقة التسميد مع ماء الرى) إلى تسجيل أقصى قيم لمعدل نمو النبات، وصبغات التمثيل الضوئى، بينما كان المعدل المتوازن من النيتروجين والبوتاسيوم (٦٠كجم ن + ٦٠ كجم بو٢أ/الفدان) أكثر المعاملات تفوقاً بالنسبة لحالة العناصر الغذائية فى النبات، (ومحتوى ن، فو، بو وإمتصاصهم الكلى)، ومحتوى الحمض الأمينى البرولين، علاوة على إنتاجية المحصول الصالح للتسويق بالنسبة للنبات الواحد ووحدة المساحة (الفدان)، وكفاءة استخدام ماء الرى.

وبالنسبة لتأثير التفاعل بين عاملى الدراسة، فقد أوضحت النتائج المتحصل عليها أنه فى أغلب الأحيان لم تعكس معاملات التفاعل أى تأثير معنوى على أغلب القياسات التى تم دراستها، باستثناء بعض القياسات التى سجلت تأثيراً معنوياً ولكنها كانت متباينة من معاملة لأخرى ومن موسم لآخر.