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EFFECT OF WATER QUALITY AND IRRIGATION PRACTICIES ON SOME SOIL PROPERTIES AND PRODUCTIVITY

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ABSTRACT

Lysimeter experiments were carried out at Sakha Agric. Res. Station during the two growing seasons of 1999/2000 and 2000/2001 in three successive crops to study the effect of different water sources and water regime on the productivity of maize, sugar beet and cotton crops, some soil chemical properties and water relations under surface and sub surface irrigation. The main results can be summarized as follows:

1- There were significant affects of water sources, methods of irrigation and water applied levels on yield and yield components of the three crops. Irrigation with secondary treated sewage water produced the highest yield and its components under surface irrigation method. The irrigation at 50% depletion of available soil moisture (I_3) gave the highest yield and yield components of the three crops. While the lowest yield was obtained with irrigation at 80% depletion of available soil moisture by well water.

2- The contents of macro and micro nutrients and heavy metals in maize grains, sugar beet roots and cotton seeds were increased with secondary treated sewage water followed by drainage water. While the lowest content was achieved by fresh water. The concentration of elements in maize grains was higher than sugar beet roots and cotton seeds by about 16 and 25%, respectively. The surface irrigation increased the elemental contents of maize, sugar beet and cotton by about 20, 10 and 5%, respectively over that with sub surface irrigation.

3- Soil salinity (ECe) and alkalinity (SARe) were increased as a result of irrigation by well water under subsurface irrigation and irrigation at 80% depletion of available soil moisture. While the lowest values of ECe and SARe were obtained with irrigation at 35% depletion of available soil moisture by fresh water under surface irrigation.

4- Soil elemental content was increased with low quality water, this increase was pronounced with irrigation at 35% depletion of available soil moisture by sewage water and drainage water under surface irrigation.

5- The highest amount of irrigation water applied and water consumptive use (WCU) were obtained with irrigation at 35% depletion of available soil moisture under sub surface irrigation method. While the irrigation at 80% depletion of available soil moisture and surface irrigation method recorded the highest values of crop water use efficiency (CWUE).

Keywords: water quality, water regime, surface and subsurface irrigation systems, soil productivity, soil properties and water relations

INTRODUCTION

Under the condition of arid and semi-arid regions, the irrigation water is the limiting factor for agricultural expansion. The use of low quality water, such as drainage water, treated and untreated sewage water, well water and even sea-water for irrigation without proper management could produce negative effects on crop-production and soil properties (Shainberg and Shalhevet, 1984).

Increasing levels of heavy metal in soil irrigated with sewage water is considered to pose potentially serious hazards in the soil-plant-animal system (Aboulrous *et al.,* 1991).

Fatma El-Shafie and El-Koumey (1994) and Selem *et al* (2000) showed that using sewage effluent in irrigation of clay soil increased soil salinity, total and available N, P and K, soil available Fe, Mn, Zn, Cu and heavy metals (Pb, Co, Ni, Cd and Cr). Increasing salinity of drainage water seems to increase salinity of the investigated soil (*Amira, 1997*).

Hegazi(1991), Abo-Soliman *et al.*(2001), Gazia(2001)and Omar *et al (2001*) observed that soil salinity and alkalinity and soil available N, P and K, micro nutrients and heavy metals were increased as a result of irrigation by treated sewage water either directly or blending with well water.

Ragaa Zein and Zein (2000), Gazia (2001) and Omar *et al* (2001) found that, the contents of total and available macro and micro- nutrients and heavy metals in sugar beet, canola, sunflower, soybean, cotton, wheat and maize plants were increased with increasing the period of irrigation by drainage and sewage water or blended sewage water with drainage water. Moreover, using sewage effluent or blended effluent water for irrigation increase the yield of different crops (Fatma el-Shafei and El-Koumey, 1994; Ragaa Zein and Zein, 2000; Gazia, 2001 and Omar *et al*, 2001).

Irrigation management practices (method, amount and interval) are among the main important factors that should be considered with using brackish water for keeping the root zone salinity below the permissible levels (*Ayers and Wostcot, 1985*). Sub irrigation is a common method with the high water table condition. The efficiency of sub irrigation depends heavily on soil characteristics and the depth of the natural water table. About 162000 ha. of Florida's irrigated agricultural crops use sub irrigation method (Smajstrla *et al.*, 1992).

This work aims to study the effect of different water sources and water regime on the productivity of maize, sugar beet and cotton crops, some soil chemical properties and water relations under surface and subsurface irrigation.

MATERIALS AND METHODS

Lysimeter experiments were conducted at Sakha Agric. Res. Station during two growing seasons to study the effect of different water sources, and water regime on the productivity of three successive crops (maize, sugar beet and cotton), some soil chemical properties and water relations under surface and sub surface irrigation. The lysimeter units (82 cm diameter and 110 cm depth) were planted by maize (triple hybrid 324V.) in the summer season of 1999, sugar beet (Raspoly V.) in the winter season of 1999/2000 and cotton (Giza 86 V.) in the summer season of 2000. A split- split plot design with three replicates was used as follows:

- **Water sources treatments were located in the main plots:**
  - *F*: Fresh water (Nile water).
  - *S*: Secondary treated sewage water.
  - *D*: Drainage water
  - **W**: Well water
  - ***S1***: ***W1***- sewage water blended with well water at ratio 1:1
  - ***S2***: ***W1***-sewage water blended with well water at ratio 2:1

- **Irrigation methods Occupied the sub plots:**
  - M_1: Surface irrigation
  - M_2: Subsurface Irrigation

- **Irrigation water applied levels were laid in the sub-sub plots**:
  - I_1: irrigation at 80% depletion of available soil moisture .
  - I_2: irrigation at 65% depletion of available soil moisture.
  - I_3: irrigation at 50% depletion of available soil moisture.
  - I_4: irrigation at 35% depletion of available soil moisture.

Some physical and chemical properties of the used soil were determined according to Black (1965), Garcia (1978) and Lindsay and Norvell (1978) as shown in Table 1.

Some chemical and biological properties of different water sources were determined according to *Cottenie et al. (1982)* (Table 2).

The studied parameters:

1- Yield and yield components: At maturity time, grain yield and 100-grain weight for maize, root and sugar yield and sucrose % for sugar beet were determined. Seed cotton yield, total bolls/ plant, bolls % (open bolls × 100/total bolls), lint % (lint × 100/seed cotton yield) and 100-seed weight for cotton were determined.

2- Elemental contents (NPK, Zn, Mn, Fe, Cu, B, Pb, Cd, Ni, Co and Cr of plant tissues (Maize grain, sugarbeet root and cotton seeds) were determined according to *Cottenie et al. (1982).*

3- Water relations:

3.1. Amount of irrigation water applied was calculated for each treatment according to *Booher (1974).*

3.2. Water consumptive use (WCU) was calculated according to *Israelsen and Hansen (1962).*

3.3. Crop water use efficiency (CWUE) was calculated in kg/m3 as **follows:**

$$\textbf{CWUE} = \frac{\textbf{yield (kg/fed.)}}{\textbf{Water consumptive use (m}^3\textbf{/fed.)}}$$

4- Soil salinity (ECe) and alkalinity (SARe) were determined in soil past extract before and after harvesting.

Statistical analysis was done according to Cochran and Cox(1960).

RESULTS AND DISCUSSIONS

1- Yield and yield components:

Data in Table (3) show significant effects of water sources on yield and yield components of the three crops. Irrigation with secondary treated sewage water (S) produced the highest grain yield and 100-grain weight of maize (3273.5kg/fed. and 41.33 gm, respectively), root and sugar yields of sugar beet (33.73 and 6.56 ton/fed., respectively) and seed cotton yield, number of total

Table 1: Some physical and chemical properties of soil lysimeter before cultivation

Moisture characters(%)			Bulk density gm/cm^3	SARe	ECe dSm^{-1}	Soil pH 1:2.5	O.M. %	Total Carbonate, %	Particle size distribution, %		
A.S.M.	W.P.	F.C.							Clay	Silt	Sand
21.1	20.4	41.5	1.28	5.92	3.65	8.05	1.20	2.40	42.5	33.7	23.8

Available micro-elements and heavy metals (ppm)										Available macro elements(ppm)		
Cr	Co	Ni	Cd	Pb	B	Cu	Fe	Mn	Zn	K	P	N
0.25	0.28	0.60	0.17	1.78	2.20	2.10	14.6	15.6	2.20	252	6.4	22.2

Table 2:Some chemical and biological properties of different water source

Water sources	EC dSm^{-1}	SAR	COD mg/L	BOD mg/L	NO_4(N) mg/L	NO_3(N) mg/L	Suspended solids mg/L	Dissolved solids, mg/L
Fresh W.	0.48	1.42	25	8	1.20	5.1	236	480
Sewage W.	1.32	4.50	120	70	18.0	34	910	1300
Drainage W.	1.58	5.20	42	22	11.0	27	406	1550
Well W.	2.95	9.20	0.0	0.0	2.0	3.7	28	3005
S1:W1	2.55	8.40	100	55	12.0	20	560	2000
S2:W1	2.20	7.65	110	65	14.0	23	700	2500

Element content of different water sources

Water sources	Macro-lements (ppm)			Micro-elements and heavy metals (ppm)									
	N	P	K	Zn	Mn	Fe	Cu	B	Pb	Cd	Ni	Co	Cr
Fresh W.	2.40	0.36	3.60	0.05	0.12	0.15	0.02	0.05	0.04	0.005	0.003	0.02	0.04
Sewage W.	25.10	4.20	8.60	0.20	0.85	1.05	0.10	0.22	0.14	0.02	0.02	0.06	0.07
Drainage W.	18.30	0.48	6.30	0.11	0.25	0.50	0.05	0.04	0.08	0.008	0.003	0.003	0.03
Well W.	1.80	0.28	2.10	0.09	0.10	0.22	0.04	0.03	0.07	0.006	0.008	0.002	0.02
S1:W1	15.20	2.30	5.8	0.07	0.62	0.55	0.06	0.10	0.08	0.01	0.009	0.03	0.03
S2:W1	18.10	2.85	7.00	0.09	0.75	0.75	0.07	0.12	0.10	0.01	0.01	0.04	0.05

bolls, bolls %, lint % and 100-seed weight of cotton (1221.04 kg/fed., 24.42 bolls /plant, 81.52% boll, 44.42% lint and 10.05 gm, respectively).

The lowest yield of three crops were realized with well water, except the sucrose percentage of sugar beet.

It can be concluded that the effect of different water sources on yield and yield components of the three crops can be arranged in the following descending order: S > F > S2: W1 > D > S1: W1 > W treatments. These results may be due to that the secondary treated sewage water contains high levels of macro and micro nutrients. While well water contain higher salt content. These results were in good agreement with those recorded by Ragaa Zein and Zein (2000), Gazia (2001) and Omar *et al* (2001).

It is evident that different methods of irrigation significantly affects yield and yield components of different crops as shown in Table 3. The highest values of maize, sugar beet and seed cotton yield (3116.75 kg/fed., 33.48 ton/fed. and 1171.54 kg seed cotton /fed., respectively), as well as their components were obtained with surface irrigation method (M1). These results may be attributed to that the leaching of salts from root zone was more effective with surface irrigation than that with the sub surface irrigation method.

Concerning the effect of water applied levels on the crop yields, data in Table3 show that the yield and yield components of the three crops were significantly increased with increasing the amount of irrigation water.

Table 3: Effect of different treatments on yield and yield components of maize, sugar beet and cotton crops.

Treatments	Maize Crop 1st season 1999		Sugar beet crop 2nd seasons, 1999/2000			Seed cotton crop 3th seasons, 2000				
	Grain yields, kg/fed.	100-Grain weight, gm	Root yields, ton/fed.	Sucrose %	Sugar yields, ton/fed.	Seed cotton yield, kg/fed.	No. of total bolls/ plant	Bolls %	Lint %	100-seed weight(gm)
Water sources (S)										
F	3142.96	40.49	33.57	19.23	6.45	1184.58	23.04	77.67	41.75	9.53
S	3273.50	41.33	33.73	19.74	6.56	1221.04	24.42	81.52	44.42	10.05
D	2947.29	37.30	31.45	20.09	6.29	1116.71	17.54	60.58	36.88	8.42
W	2684.92	36.06	28.11	20.40	5.73	1074.67	15.04	58.33	35.13	5.83
S1:W1	2847.83	36.53	29.20	18.71	5.39	1098.83	21.13	61.96	35.83	7.31
S2:W1	3054.54	38.39	32.33	19.17	6.18	1147.75	23.83	73.13	37.25	9.12
F- Test	**	**	*	**	ns	**	**	**	**	**
L.S.D.0.05	12.718	0.203	3.546	0.288	-	20.999	0.910	0.909	1.094	0.242
L.S.D.0.01	18.089	0.289	-	0.409	-	29.868	1.294	1.294	1.556	0.183
Irrigation methods (M)										
M_1	3116.75	39.99	33.48	19.35	6.42	1171.54	22.28	70.49	39.15	8.61
M_2	2866.93	36.71	29.31	19.77	5.78	1109.65	19.39	67.24	37.93	8.24
F- Test	**	**	**	**	**	**	**	**	**	**
L.S.D.0.05	6.755	0.115	1.676	0.11	0.37	10.907	0.381	0.48	0.622	0.353
L.S.D. 0.01	9.471	0.161	2.349	0.16	0.51	15.292	0.593	0.67	0.873	0.047
Irrigation levels (I)										
I_1	2827.92	35.27	29.91	20.51	6.08	1088.06	18.58	65.92	36.61	8.15
I_2	2984.75	38.18	32.09	19.87	6.24	1146.28	20.86	68.92	38.69	8.40
I_3	3084.86	41.08	32.96	19.19	6.36	1181.58	22.92	71.63	40.81	8.77
I_4	3069.83	38.86	30.63	18.66	5.72	1146.47	20.97	69.00	38.06	8.39
F- Test	**	**	*	**	*	**	**	**	**	**
L.S.D.0.05	22.548	0.522	2.015	0.148	0.40	11.067	0.470	0.664	0.543	0.053
L.S.D. 0.01	29.936	0.393	-	0.198	-	14.693	0.623	0.882	0.744	0.069
Interaction										
S× M	**	ns	ns	Ns	ns	ns	**	ns	**	**
S × I	ns	ns	ns	*	ns	ns	**	**	**	**
M × I	**	**	ns	Ns	ns	*	**	ns	ns	*
S×M×I	ns	ns	ns	Ns	ns	ns	ns	ns	ns	**

Consequently the highest yield and yield components values were obtained with I_3 treatment (irrigation at 50% depletion of available soil moisture). While the lowest values were obtained with I_1 treatment. This result may be attributed to good moisture and aeration condition with I_3 treatment (Sadik *et al, 1995*).

With regard to the interaction effects between the treatments, data in Table (3) indicated that the interaction between water sources, irrigation methods and both of (S × M) and irrigation levels (M × I) have high significant effected only on maize and seed cotton yield. On the other hand, the interaction between water sources and irrigation levels (S × I) was highly significant for number of total bolls, boll %, lint % and 100-seed weight for cotton crop. The S × M × I interaction was not significant for the yield and yield components of the three crops, except 100-seed weight for cotton.

2- **Elemental content of plants**:

The obtained results in Table 4-6 reveal that the contents of macro and micro nutrients and heavy metals in maize grains, sugar beet roots and cotton seeds were increased as a result of irrigation by secondary treated sewage water (S), followed by drainage water (D) and sewage water blended with well water at ratio of 2:1. These results may be due to the high elemental contents in sewage and drainage water. The lowest concentration was achieved with fresh water. The effect of irrigation water sources on the elemental content of the three crops could be arranged in the descending order as follows: S > D > S2: W1 > S1: W1 > W > F. These results were in accordance with those obtained by Ragaa Zein and Zein(2000), Gazia(2001) and Omar *et al.* (2001).

The concentration of elements in maize grains was higher than sugar beet roots and cotton seeds by about 16 and 25%, respectively. This finding may be due to that the shallow fiber roots of maize plants have high ability to uptake the elements from the surface layer.

The surface irrigation method increased the elemental contents of maize, sugar beet and cotton by about 20, 10 and 5 %, respectively over than that with the subsurface irrigation. These results may be ascribed to that the high concentration of elements in the upper layers of soil led to increase the amount of elements taken by the plants from the soil .

Table 4:Maize grain elemental contents as affected by different water sources and methods of irrigation.

Water sources	N	P	K	Zn	Mn	Fe	Cu	B	Pb	Cd	Ni	Co	Cr
	%			mg/kg									
SURFACE IRRIGATION													
F	1.0	0.25	0.9	22	26	340	3.8	2.1	1.6	0.03	0.8	1.05	0.6
S	2.4	0.48	1.6	62	48	760	10.6	4.6	3.2	0.20	4.2	2.80	2.20
D	2.2	0.45	1.3	60	45	710	10.0	3.8	2.7	0.16	3.3	2.30	1.80
W	1.1	0.28	1.0	38	30	520	6.2	2.6	1.9	0.09	2.0	1.30	0.90
S1:W1	1.4	0.32	1.1	42	38	560	8.0	2.9	2.2	0.10	2.6	1.60	1.00
S2:W1	2.1	0.40	1.2	55	41	700	9.0	3.4	2.6	0.14	3.0	2.00	1.30
SUBSURFACE IRRIGATION													
F	0.80	0.19	0.70	17	20	270	3.0	1.70	1.2	0.02	0.62	0.85	0.50
S	1.92	0.38	1.28	48	38	610	8.45	3.80	2.60	0.16	3.35	2.25	1.75
D	1.75	0.34	1.04	46	35	562	7.9	3.05	2.20	0.12	2.62	1.81	1.42
W	0.88	0.22	0.81	30	24	415	4.9	2.10	1.53	0.06	1.60	1.05	0.71
S1:W1	1.12	0.25	0.86	33	30	445	6.2	2.32	1.75	0.08	2.10	1.30	0.8
S2:W1	1.68	0.32	0.95	44	33	555	7.2	2.73	2.10	0.10	2.40	1.72	1.05

Table 5: sugar beet root elemental contents (mg/kg)as affected by different water sources and methods of irrigation.

Water sources	N	P	K	Zn	Mn	Fe	Cu	B	Pb	Cd	Ni	Co	Cr
	%			mg/kg									
SURFACE IRRIGATION													
F	0.90	0.24	0.82	20.0	24	332	3.40	1.92	1.40	0.025	0.70	0.98	0.52
S	2.06	0.42	1.38	54.0	41	654	9.12	3.9	2.76	0.17	3.61	2.41	1.89
D	1.89	0.37	1.11	51.0	38	622	8.70	3.27	1.98	0.13	2.84	1.98	1.60
W	0.95	0.24	0.85	33.0	25	448	5.40	1.94	1.62	0.07	1.73	1.11	0.78
S1:W1	1.20	0.27	0.94	36.0	32	482	2.50	2.0	1.90	0.08	2.23	1.38	0.87
S2:W1	1.80	0.34	1.03	47.0	35	612	2.92	2.92	2.25	0.12	2.60	1.74	1.11
SUBSURFACE IRRIGATION													
F	0.86	0.20	0.76	18.0	22	310	3.20	1.73	1.30	0.022	0.63	0.88	0.48
S	1.85	0.37	1.24	38.0	37	590	8.20	3.50	2.48	0.15	3.25	2.17	1.70
D	1.70	0.33	1.00	45.0	34	560	7.80	2.95	1.78	0.12	2.56	1.78	1.45
W	0.86	0.22	0.78	30.0	22	420	4.80	1.75	1.45	0.06	1.56	1.00	0.71
S1:W1	1.09	0.24	0.85	32.0	28	÷35	2.30	1.82	1.71	0.072	2.13	1.25	0.78
S2:W1	1.63	0.31	0.93	42.0	32	560	2.65	2.64	2.05	0.10	2.35	1.56	1.00

Table 6: Cotton seeds elemental contents as affected by different water sources and methods of irrigation.

Water sources	N	P	K	Zn	Mn	Fe	Cu	B	Pb	Cd	Ni	Co	Cr
	%			mg/kg									
SURFACE IRRIGATION													
F	0.88	0.23	0.81	18.2	22.0	302	3.10	1.90	1.40	0.02	0.72	0.95	0.56
S	2.00	0.40	1.36	50.0	37.0	595	8.30	4.18	2.91	0.18	3.8	2.55	2.00
D	1.85	0.36	1.09	46.4	34.0	566	7.90	2.96	2.45	0.14	3.00	2.10	1.62
W	0.94	0.24	0.83	30.0	23.0	410	4.90	1.76	1.72	0.08	1.81	1.18	0.83
S1:W1	1.15	0.26	0.93	32.0	29.0	438	2.27	1.82	2.00	0.09	2.35	1.45	0.92
S2:W1	1.75	0.33	1.00	42.0	32.0	556	2.65	2.67	2.35	0.12	2.71	1.82	1.18
SUBSURFACE IRRIGATION													
F	0.83	0.21	0.71	17.3	20.0	287	2.95	1.8	1.33	0.01	0.67	0.90	0.52
S	1.90	0.39	1.29	47.4	35.0	565	7.88	3.9	2.76	0.17	3.6	2.40	1.90
D	1.75	0.34	1.04	44.1	32.0	537	7.51	2.8	2.33	0.13	2.8	2.00	1.52
W	0.89	0.22	0.78	28.5	21.0	390	4.66	1.67	1.63	0.06	1.7	1.10	0.78
S1:W1	1.10	0.25	0.88	30.4	27.0	416	2.15	1.71	1.91	0.07	2.20	1.35	0.85
S2:W1	1.65	0.31	0.96	40.0	30.0	528	2.51	2.54	2.23	0.10	2.6	1.70	1.15

3- Some soil chemical properties:

3.1. soil salinity (ECe) and alkalinity (SARe):

Data in Table7 show that the highest mean values of ECe and SARe (5.91dsm^{-1} and 7.48, respectively) were recorded with irrigation by well water followed by well water blended equally with sewage water. The lowest mean values of ECe and SARe (2.39 dSm^{-1} and 4.42, respectively) were obtained by fresh water. Consequently the effect of irrigation water sources on soil salinity and alkalinity can be arranged in the following order W > S1:W1 > D > S2: W1> S > F treatments. It is obvious from the results that increasing the salinity and alkalinity of irrigation water increased the salinity and alkalinity of the soil after harvesting of three crops. This increase was pronounced with the time under subsurface irrigation. The previous results are in good coincidence with those of Fatma El-Shafie and El-Koumey(1994), Amira (1997), Selem *et al.* (2000), Abo Soliman *et al.* (2001), Gazia (2001) and Omar *et al.* (2001).

The data show that, increasing the amount of irrigation water applied decreased soil salinity (ECe) and soil alkalinity (SARe). It can be seen that the best treatment was the treatment I_4 since it recorded the lowest mean values of ECe and SARe (4.11 dSm^{-1} and 6.56, respectively) followed by I_3 treatment under surface irrigation. On the other hand, I_1 treatment led to an accumulation of salts in soil after the three crops (5.10, 5.50 and 5.88 dSm^{-1}, respectively). These results may be due to that the high amount of irrigation water applied enhanced the leaching of salts from soil profile.

3.2. Soil elemental contents:

Data listed in Tables 8-10 indicat that, irrigation with different water sources, except fresh water increased the soil elemental content. Increasing the content of elements N, P, K, Zn, Fe, Mn, Cu, B, Pb, and Ni were pronounced with sewage water (S), drainage water(D) and with sewage blended with well water (2:1). The effect of water sources on soil elements after the three crops can be arranged as the following order: S > D > S2:W1 >S1:W1> W> F treatments. The data show that the availability of the soil elements was increased by the time. This may be due to the high content of these elements in sewage and drainage water. Also, increased soil organic matter and decreased soil pH and consequently the availability of these elements in soil was increased. These results are in agreement with those obtained by Fatma El-Shafie and El-Koumey(1994), Hegazi (1999), Selem *et al.* (2000), Abo Soliman *et al.* (2001) and Omar *et al.* (2001).

Soil elemental contents with different crops were increased with surface irrigation method comparing to the subsurface irrigation. This result may be due to that surface irrigation added some micro elements to the surface layer especially with sewage and drainage water.

Concerning to the irrigation levels, irrigation treatment (I_4) increased the concentration of elements of the soil followed by I_3, I_2 and W1 treatments, respectively.

This increase was pronounced with the time of the experiment. These results may be due to that increasing the amount of irrigation water led to increase the elements content of the soil. Generally, it could be concluded that the concentration of the elements under study in soil and plants is sufficient for plant and they did not reach toxic limits according to National Academy of Science (1972).

Table 7: Soil salinity (ECe) and alkalinity (SARe) as affected by water sources, methods of irrigation and amount of irrigation water applied.

Water sources and irri. Levels	Before planting		After harvesting						Mean	
			Maize		Sugar beet		Cotton			
	EC dSm^{-1}	SAR	EC dSm^{-1}	SAR	EC dSm^{-1}	SAR	EC dSm^{-1}	SAR	EC dSm^{-1}	SAR
SURFACE IRRIGATION										
F	3.65	5.92	2.92	4.05	2.30	4.45	1.95	4.75	2.39	4.42
S	3.65	5.92	4.10	6.10	4.80	6.55	5.20	7.10	4.70	6.58
D	3.65	5.92	4.52	6.45	5.10	6.80	5.60	7.45	5.07	6.90
W	3.65	5.92	5.35	6.75	5.90	7.30	6.50	8.38	5.91	7.48
S1:W1	3.65	5.92	4.72	6.55	5.30	7.05	5.80	7.94	5.27	7.18
S2:W1	3.65	5.92	4.30	6.18	4.90	6.65	5.38	7.28	4.86	6.69
I_1	3.65	5.92	5.10	7.20	5.50	7.90	5.88	8.15	5.49	7.75
I_2	3.65	5.92	4.60	6.64	4.95	7.32	5.20	7.92	4.92	7.29
I_3	3.65	5.92	4.15	6.20	4.35	7.06	4.74	7.36	4.41	6.87
I_4	3.65	5.92	4.05	6.10	4.22	7.00	4.50	7.20	4.11	6.56
MEAN	3.65	5.92	4.38	6.22	4.73	6.81	5.07	7.35	4.72	6.18
SUB SURFACE IRRIGATION										
F	3.65	5.92	3.08	4.26	2.43	4.65	2.03	4.96	2.51	4.62
S	3.65	5.92	4.30	6.42	5.06	6.89	5.44	7.44	4.93	6.92
D	3.65	5.92	4.70	6.75	5.34	7.11	5.86	7.81	5.30	7.24
W	3.65	5.92	5.60	7.19	6.18	7.68	6.82	8.74	6.20	7.87
S1:W1	3.65	5.92	4.95	6.89	5.56	7.40	6.08	8.31	5.53	7.53
S2:W1	3.65	5.92	4.53	6.49	5.13	6.95	5.62	7.62	5.09	7.02
I_1	3.65	5.92	5.37	7.56	5.76	8.30	6.18	8.58	5.77	8.15
I_2	3.65	5.92	4.82	6.80	5.20	7.66	5.44	8.30	5.15	7.59
I_3	3.65	5.92	4.33	6.54	4.58	7.39	4.96	7.71	4.62	7.21
I_4	3.65	5.92	4.23	6.44	4.44	7.21	4.80	7.50	4.49	7.05
MEAN	3.65	5.92	4.59	6.53	4.97	7.13	5.32	7.70	4.96	7.12

Table 8: Soil available elements (ppm) after maize crop as affected by water sources methods of irrigation and amount of irrigation water applied.

Water Sources	N	P	K	Zn	Mn	Fe	Cu	B	Pb	Cd	Ni	Co	Cr
Before Exp.	22.2	6.4	252	2.20	15.6	14.6	2.10	2.20	1.78	0.17	0.60	0.28	0.25
SURFACE IRRIGATION													
F	20.5	7.1	282	2.10	15.0	15.0	2.0	2.30	1.60	0.20	0.50	0.32	0.30
S	26.4	12.0	325	3.65	24.8	20.0	3.35	3.86	3.10	0.32	1.68	0.65	0.36
D	24.9	10.4	322	3.42	23.0	19.1	2.96	3.52	2.92	0.28	1.52	0.55	0.35
W	23.2	8.2	288	2.45	18.7	17.2	2.70	2.98	1.92	0.21	0.75	0.36	0.31
S1:W1	24.0	9.6	292	2.94	20.8	17.9	2.73	3.10	2.42	0.22	1.28	0.42	0.33
S2:W1	24.8	10.2	318	3.20	22.6	18.6	2.90	3.38	2.71	0.24	1.41	0.48	0.34
SUBSURFACE IRRIGATION													
F	17.40	6.0	260	1.75	14.8	13.78	1.92	2.15	1.28	0.16	0.40	0.25	0.23
S	22.30	10.1	300	2.90	21.1	17.40	2.68	3.00	2.49	0.26	1.34	0.53	0.29
D	21.2	8.82	295	2.54	19.6	16.00	2.37	2.81	2.32	0.22	1.21	0.44	0.28
W	19.7	6.9	265	1.95	15.8	14.60	2.15	2.38	2.48	0.16	0.60	0.28	0.25
S1:W1	20.2	8.0	268	2.35	17.6	15.21	2.17	2.47	1.92	0.17	1.02	0.33	0.26
S2:W1	21.1	8.7	292	2.56	19.21	15.82	2.32	2.70	2.18	0.19	1.13	0.38	0.27
IRRIGATION LEVELS													
I_1	21.52	7.45	295	2.21	15.8	16.0	2.15	2.42	1.7	0.21	0.53	0.34	0.31
I_2	25.2	10.1	306	3.09	21.8	18.79	2.86	3.22	2.54	0.23	1.34	0.44	0.35
I_3	26.4	11.0	338	3.59	24.15	20.0	3.10	3.70	3.00	0.29	1.60	0.58	0.37
I_4	27.3	12.6	340	3.82	26.0	21.0	3.5	4.00	3.30	0.33	1.76	0.70	0.40

Table 9: Soil available elements (ppm) after sugar beet crop as affected by water sources, method of irrigation and amount of irrigation water applied.

Water Sources	N	P	K	Zn	Mn	Fe	Cu	B	Pb	Cd	Ni	Co	Cr
SURFACE IRRIGATION													
F	18.4	8.5	296	2.35	17.0	15.9	2.20	2.5	1.54	0.20	0.40	0.30	0.30
S	33.4	15.6	378	4.10	26.3	21.0	3.52	4.18	3.52	0.37	1.82	0.80	0.38
D	28.0	14.0	368	3.72	25.0	20.2	3.04	3.95	3.31	0.30	1.72	0.72	0.36
W	24.1	10.2	310	2.70	19.1	17.5	2.72	3.10	2.10	0.22	1.05	0.38	0.33
S1:W1	25.2	12.0	340	3.15	22.8	18.0	2.78	3.42	2.80	0.24	1.42	0.52	0.34
S2:W1	27.0	13.2	352	3.52	24.2	19.4	2.84	3.72	3.05	0.26	1.62	0.64	0.35
SUBSURFACE IRRIGATION													
F	15.6	7.2	274	1.88	14.5	13.62	1.77	2.05	1.23	0.16	0.31	0.24	0.23
S	28.3	13.2	346	3.28	22.36	17.85	2.81	3.34	2.82	0.30	1.46	0.64	0.30
D	24.0	12.0	336	2.96	21.25	17.16	2.43	3.15	2.65	0.24	1.37	0.58	0.29
W	20.0	8.7	284	2.15	16.22	15.20	2.16	2.45	1.68	0.17	0.84	0.30	0.25
S1:W1	21.4	10.2	311	2.52	19.36	15.80	2.23	2.72	2.24	0.19	1.14	0.41	0.27
S2:W1	23.0	11.3	324	2.82	20.60	16.50	2.30	2.98	2.45	0.21	1.30	0.51	0.28
IRRIGATION LEVELS													
I_1	19.5	9.1	310	2.75	18.10	16.8	2.50	2.85	1.95	0.22	0.85	0.32	0.35
I_2	26.45	12.6	357	3.31	23.9	18.9	2.92	3.60	2.95	0.25	1.50	0.56	0.36
I_3	29.4	14.7	386	3.90	26.2	21.0	3.20	4.12	3.50	0.32	1.80	0.76	0.38
I_4	35.0	16.4	397	4.50	27.3	22.0	3.70	4.40	3.70	0.38	1.91	0.85	0.40

Table 10:Soil available elements (ppm)after sugar beet crop as affected by water sources, method of irrigation and amount of irrigation water applied.

Water sources	N	P	K	Zn	Mn	Fe	Cu	B	Pb	Cd	Ni	Co	Cr
SURFACE IRRIGATION													
F	16.4	10.2	310	2.42	16.4	16.0	2.28	2.35	1.50	0.20	0.40	0.30	0.30
S	38.2	18.0	405	4.65	29.5	23.4	3.85	4.80	3.85	0.40	2.0	0.92	0.40
D	30.0	15.8	385	4.10	17.0	22.0	3.15	4.55	3.70	0.31	1.9	0.81	0.38
W	25.0	11.3	325	2.96	20.8	17.8	2.78	3.30	2.26	0.24	1.20	0.43	0.34
S1:W1	26.8	13.4	332	3.60	24.3	20.2	2.82	3.82	3.20	0.26	1.56	0.56	0.35
S2:W1	29.2	15.0	372	3.82	26.0	21.6	2.90	4.10	3.52	0.29	1.78	0.70	0.36
SUBSURFACE IRRIGATION													
F	13.8	8.6	285	1.94	13.90	13.80	1.82	1.87	1.20	0.16	0.32	0.23	0.24
S	32.4	15.3	372	3.73	25.10	20.00	3.10	3.84	3.10	0.32	1.6	0.74	0.32
D	25.5	13.4	354	3.27	23.00	18.60	2.52	3.62	2.95	0.26	1.53	0.65	0.31
W	21.2	9.6	300	2.35	17.62	15.12	2.21	2.62	1.80	0.19	0.96	0.36	0.27
S1:W1	22.7	11.4	304	2.86	20.60	17.16	2.26	3.05	2.56	0.21	1.25	0.45	0.28
S2:W1	24.8	12.7	342	3.00	22.10	18.37	2.31	3.27	2.81	0.23	1.42	0.55	0.29
IRRIGATION LEVELS													
I_1	16.8	10.71	325	2.54	17.20	16.80	2.40	2.45	1.58	0.21	0.4	0.35	0.36
I_2	28.12	14.0	347	3.76	25.50	21.20	2.96	4.01	3.36	0.27	1.65	0.59	0.39
I_3	31.5	16.6	404	4.30	28.30	23.10	3.35	4.77	3.90	0.33	1.99	0.86	0.41
I_4	40.1	19.0	425	4.86	30.90	24.60	4.05	5.03	4.09	0.40	2.15	0.97	0.42

4- Water relations:

4.1. Amount of irrigation water applied:

The data in Table 11 indicat that the highest amount of irrigation water applied was obtained by I_4 treatment with maize, sugar beet and cotton (3915, 3985 and 4307.5 m^3/fed., respectively). While the lowest values with these crops (3002.5, 3060 and 3092.5 m^3/fed., respectively) were recorded by I_1 treatment. These results may be attributed to that treatment I_4 received high amount and number of irrigation water more than other treatments.

Regarding the method of irrigation, the data revealed that, subsurface irrigation recorded the highest amount of irrigation water applied with different crops.

This may be due to that, the subsurface irrigation technique need higher amount of water than the surface irrigation.

4.2. Water consumptive use (WCU):

The data in Table 11 showed that, I_4 treatment consumed more amount of irrigation water than the other treatments, since it recorded the highest mean values of water consumptive use with maize, sugar beet and cotton (2655, 2725 and 2850 m^3/fed., respectively). While I_1 treatment gave the lowest values of WCU in the three crops. This trend may be due to that, increasing the amount of water applied led to increase water consumptive use. These results could be supported by the data obtained by El-Gibali and Badawi (1978), Sadik *et al.* (1995), EL-Mowelhi *et al* (1996) and Shams El-Din (2000).

4.3.Crop water use efficiency(CWUE):

The data in Table 11 reveal that, the irrigation at 80% depletion of available soil moisture (I_1) recorded the highest mean values of CWUE with maize, sugar beet and cotton (1.41, 14.61 and 0.52 kg/m^3, respectively) . While the lowest values of CWUE were obtained by irrigation treatment I_4. With regard to the effect of methods of irrigation on CWUE, the results showed that the surface irrigation method increased the CWUE as compared to subsurface irrigation one. These results are in agreement with those obtained by Sadik *et al* (1995), EL-Mowelhi *et al* (1996) and Shams El-Din (2000).

Table (11): Amount of irrigation water applied, water consumptive use and water use efficiency as affected by irrigation levels and methods of irrigation.

Irri. Methods	Amount of irri. water applied (m^3/fed.)					Water Consumptive use (m^3/fed.)					Water use efficiency (kg/m^3)				
	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean	I_1	I_2	I_3	I_4	Mean
MAIZE CROP															
M_1	2875	3200	3560	3845	3370	1932	2150	2390	2580	2263	1.54	1.46	1.36	1.20	1.39
M_2	3130	3440	3785	3985	3585	2100	2310	2540	2730	2420	1.28	1.22	1.15	1.11	1.19
Mean	3002.5	3320	3672.5	3915	3477.5	2016	2230	2465	2655	2341.5	1.41	1.34	1.26	1.16	1.29
SUGAR BEET															
M_1	2940	3312	3690	3920	3465.5	1975	2225	2478	2660	2334.5	16.10	15.45	14.17	12.27	14.50
M_2	3180	3540	3895	4050	3666.3	2135	2380	2615	2790	2480	13.12	12.53	11.77	10.27	11.92
Mean	3060	3426	3792.5	3985	3565.9	2055	2302.5	2546.5	2725	2407.3	14.61	13.99	12.97	11.27	13.21
COTTON CROP															
M_1	3000	3436	3815	4185	3609	2015	2300	2570	2760	2411.3	0.55	0.51	0.47	0.43	0.49
M_2	3185	3650	4030	4430	3823.8	2190	2485	2745	2940	2590	0.49	0.45	0.42	0.38	0.44
Mean	3092.5	3543	3922.5	4307.5	3716.4	2102.5	2392.5	2657.5	2850	2500.6	0.52	0.48	0.45	0.41	0.47

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تأثير نوعية المياه و ممارسات الرى على بعض خواص التربة و إنتاجيتها

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أقيمت هذه التجربة فى أحواض أسمنتية بمحطة البحوث الزراعية بسخا خلال موسمي الزراعة (١٩٩٩/٢٠٠٠، ٢٠٠٠/٢٠٠١) لدراسة تأثير الرى بمصادر مياه مختلفة و ترشيد مياه الري على إنتاجية و مكونات الذرة الشامية و بنجر السكر و القطن و أيضا على العلاقات المائية و بعض الخواص الكيماوية للتربة تحت ظروف الري السطحي و الري تحت السطحي.

يمكن تلخيص أهم النتائج فيما يلي:

١- وجد تأثير معنوي لمصادر مياه الري و طرق الري و أيضا كميات مياه الري المضافة على المحصول و مكوناته فى الثلاث محاصيل المنزرعة. وأن الري بمياه الصرف الصحي المعالج مع طريقة الري السطحي أعطى أعلى إنتاجية للمحصول و مكوناته، و بالمثل كان الرى عند فقد ٥٠% من الماء الأرضي الميسر افضل ما يكون حيث أعطى أعلى محصول و مكوناته. فى حين أن الرى عند فقد ٨٠% من الماء الأرضي الميسر مع ماء البئر أعطى أقل محصول.

٢- ذاد محتوى النباتات من العناصر المغذية و كذا العناصر الملوثة نتيجة الري بمياه الصرف الصحي المعالج يليها الري بمياه الصرف الزراعي فى حين أن الري بالماء العذب أعطى اقل تركيز من هذه العناصر فى النباتات. كان هناك زيادة فى تركيز هذه العناصر في الذرة اكثر من بنجر السكر و القطن بحوالي ١٦، ٢٥% على التوالي. أيرى السطحي أدي لزيادة تركيز هذه العناصر بمقدار ٢٠، ١٠ ، ٥% فى الذرة ، بنجر السكر و القطن على التوالى مقارنة بالرى التحت سطحي.

٣- ارتفعت قيم الملوحة (ECe) و القلوية (SARe) فى التربة كنتيجة للرى بماء البئر تحت ظروف الرى التحت سطحي و الرى عند فقد ٨٠% من الماء الأرضي الميسر. في حين أن اقل قيم للـ E Ece، SARe بالتربة كانت مع الرى بالماء العذب تحت ظروف الري السطحي و الري عند فقد ٣٥% من الماء الأرضي الميسر.

٤- ارتفع محتوى التربة من العناصر المغذية و الملوثة نتيجة للرى بمياه منخفضة الصلاحية و هذه الزيادة كانت أوضح ما تكون مع أيرى بماء الصرف الصحي المعالج و ماء الصرف الزراعي و الرى عند فقد ٣٥% من الماء الأرضي الميسر تحت ظروف أيرى السطحي.

٥- الري عند فقد ٣٥% من الماء الميسر تحت ظروف الري التحت سطحي أدى إلى زيادة كمية مياه الري المضافة و بالتالي كمية المياه المستهلكة(WCU) بواسطة المحاصيل. في حين أن الري عند فقد ٨٠% من الماء الميسر تحت ظروف الري السطحي أعطى أعلى قيم لكفاءة استخدام المحصول للمياه (CWUE).