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EFFECT OF IRRIGATION BY WASTEWATER ON SOIL PROPERTIES, PLANT GROWTH AND DRAINAGE WATER QUALITY

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ABSTRACT

This study were carried out to evaluate the effect of irrigation by treated wastewater (TWW) on some chemical properties of cultivated lacustrine and calcareous soils, the growth and macronutrients contents of soybean (*Glycine max* L.), corn (*Zea mays* L.) faba bean (*Vicia faba*) and wheat (*Triticum aestivum* L.) plants and the chemical composition of drainage water. Pot experiments were carried out in the greenhouse at the Agriculture Research Farm, Faculty of Agriculture, Alexandria University. Fifty kgs soil were placed in a plastic pot and the seeds of each plant species were sown and irrigated by freshwater (FW) for two weeks then by the tested water treatments: FW, TWW or 1:1 FW/TWW. Soil and plant samples were collected two weeks before plant harvest for analysis and samples of drainage water were collected for the determination of pH, TDS, NO_3^- and total P.

The results showed significant increases in the ECe, OM and available N, P and K in soils as a result of TWW and 1:1 FW/TWW irrigation. Also, the concentrations of N, P and K in leaves of plants irrigated by TWW and 1:1 FW/TWW were significantly higher than in those irrigated by FW. In addition, the dry weights of plants were significantly higher as a result of irrigation by TWW and 1:1 FW/TWW than of those irrigated by FW.

The drainage waters of the cultivated soils irrigated by TWW and 1:1 FW/TWW had higher concentrations of TDS, NO_3^- and total P than of those irrigated by FW. The concentrations of TDS in drainage waters from cultivated calcareous soils were almost higher than of those from cultivated lacustrine soils. The results obtained proved that the beneficial effects of irrigation by treated wastewater were relatively more found with calcareous soil than with lacustrine soil.

Keywords: Treated Wastewater, Freshwater, lacustrine soil, calcareous soil, plant growth, drainage water quality.

INTRODUCTION

The water of Nile River is the main source of surface freshwater in Egypt. According to the Nile Agreement with the Sudan in 1959, Egypt's water budget is fixed at 55.5 Billion m^3/y (Abu Zeid, 1992). However, because of increasing population growth and needs for food production, additional new lands of the eastern and western deserts had been planned to be used for agricultural horizontal extensions. As a result of the limited quantity of freshwater available for agricultural irrigation and other vital sectors in the country, the Egyptian government policy plan was oriented to the reuse of unconventional water resources, as supplements, for irrigating the new reclaimed lands (Abu Zeid, 1992 and Elsokkary and Abukila, 2012).

Many countries have included wastewater reuse as an important dimension of water resource planning, releasing high quality water supplies for potable use (Mara and Cairncross, 1989 and Pescod, 1992). It is generally accepted that reuse of wastewater in agricultural irrigation is justified on agronomic and economic grounds; i.e., not only as a water resource but also as a supplement of macronutrients (N, P and K) in addition to traces of micronutrients and organic matter (Pescod, 1992). It was reported also that the reuse of wastewater has been found to be successful for irrigation of a wide array of crops and for increase in crop yield from 10 to 30% (Chen et al., 1998). Study carried out by Tamoutsidis et al. (2009) showed that irrigation by treated wastewater effectively increased the yield of corn and wheat plants. They reported that this increase was probably due to the nutritional value of wastewater. Also, Singh et al. (2012) found that treated municipal wastewater irrigation significantly increased the crop yields of maize and wheat as compared with those of plants irrigated by canal water. They attributed this positive effect to contribution of macro- and micro-nutrients in wastewater for increasing crop yield.

The objectives of this study, therefore, were to investigate the effect of irrigation by treated wastewater on both; the chemical characteristics of cultivated lacustrine and calcareous soils, the growth and macronutrients contents of four plant species grown on these soils and the chemical composition and quality of drainage waters from these soils.

MATERIALS AND METHODS

Experimental Layout:

Pots experiments were carried out in the greenhouse of Agric. Res. Farm at Faculty of Agriculture, Alexandria University, Egypt to evaluate the effect of irrigation water quality on the chemical characteristics of soils, plants growth and quality of drainage waters.

Used Soils: Two soil types; lacustrine (typic torripsamments) and calcareous (typic calciorthids) were used. These two soils were collected from Abis Region, Alexandria Governorate, and Banger El-Sokkar Region, 65 Km west Alexandria at the Northern Coastal Zone, respectively. Each soil was air-dried, passed through 2 mm sieve and kept for pot experimental studies and for analysis.

Water of Irrigation: Two sources of water were used for irrigation. The first is freshwater (FW) from El-Mahmoudiya Canal at West Nile Delta of Egypt, and the second is treated wastewater (TWW) from Alexandria Western Wastewater Treatment Plant. The TWW were taken monthly and kept in an open reservoir of 4 × 5 × 4 m (width, length, height) for irrigation.

Tested plants: Four plant species; soybean (*Glycine max* L.) variety Crawford and corn (*Zea mays* L.) variety Giza 323 as summer field crops, and faba Bean (*Vicia faba*) variety Rena-Blanka and wheat (*Triticum* *aestivum* L.) variety Giza 69 as winter field crops were used in the pot experiments.

Chemical Fertilizers: The three main chemical fertilizers; ammonium nitrate (33.5% N), superphosphate (15.5% P_2O_5) and potassium sulphate (52 % K_2O) were used.

Pot Experiments: Plastic pots of 40 cm inside diameter and 50 cm depth with 5 holes (1 cm diameter) in the bottom were used. Two kgs water-washed gravels (1-2 cm diameter) were placed in each pot followed by 50 kg lacustrine soil or 45 Kg calcareous soil. The experimental design was randomized complete block, and each treatment was repeated in four replicated.

Ten seeds of each plant species were sown in each pot, irrigated every two days in winter and every day in summer, by freshwater for two weeks. The seedlings were thinned to four plants per pot and then irrigated by the tested water. Irrigation was carried out weekly during summer and winter growing seasons. Surface irrigation was applied and the irrigation treatments were freshwater (FW), treated wastewater (TWW) and 1:1 ratio freshwater/treated wastewater (1:1 FW/TWW).

The chemical fertilizers were applied as follow: superphosphate fertilizer was applied to the soil in a single dose before cultivation of the four plant species at an equal rate of 200 kg Fed^{-1}. Ammonium nitrate fertilizer was applied to the soil in two equal doses, just after tillering and one month after, at rates of 50, 100, 50 and 100 kg Fed^{-1} for soybean, corn, faba bean and wheat, respectively. Potassium sulfate fertilizer was applied to the soil just after tillering in a signal dose (50 kg Fed^{-1}) to the four plant species.

Sampling:

Soils: Composite soil sample was taken from each original soil, air-dried, ground and passed through 2 mm sieve and kept for analysis and pot experiments. In addition, at two weeks before plants harvest, samples of soils were collected from each pot at two depths (0-20 and 20-40 cm) air-dried, ground and passed through 2 mm sieve and kept for analysis.

Plants: At two weeks before plants harvest, the shoots of plants were collected, washed with tap water then by distilled water, even-dried at 70 °C for 48 hrs, ground using stainless steel mill and kept for analysis (Chapman and Pratt, 1961). In addition, after 85 days from plant sowing, the above ground parts of plants (shoots) were harvested and the plant weight was measured and the results obtained were expressed as shoot dry weight (g $plant^{-1}$).

Drainage Water: Samples of drainage water were collected weekly from each pot after one day from irrigation and stored for analysis (APHA, 2000). Eight water samples were collected from each pot, during the growth period, and chemically analyzed separately. The results presented in this text are the mean of eight analyses for each pot.

Analysis:

Soil: The chemical characteristics of the soil were determined as follow: EC_e was measured in water extract of saturated soil paste by electrical conductivity meter and the pH was measured in 1:2.5 soil-water suspensions by pH-meter (Black, 1965). The amount of organic carbon (OC) was determined using dichromate oxidation method of Walkly and Black and the amount of organic matter (OM) was obtained by multiplying OC with 1.72 (Page et al., 1982). The amount of total carbonate (CO_3^{-2}) was measured by Calcimeter (Black, 1965). The amount of available N was extracted by 2M KCl and N was measured by micro-Kjeldahl, that of available P was extracted by 0.5 M Na HCO_3 of pH 8.5 and P was measured colorimetrically, and that of available K by extracting with normal NH_4OAc of pH 7.0 and the concentration of K was measured by flamephotometer (Page et al., 1982). The particle size distribution (sand, silt and clay) was measured by hydrometer method (Black, 1965).

Plant: Half gram oven-dried plant material was subjected to wet- digestion in H_2SO_4/H_2O_2 (Jones, 1989). The concentrations of N, P and K were determined in the digested solution according to the methods outlined by Chapman and Pratt (1961).

Water: Samples of freshwater (FW), treated wastewater (TWW) and drainage water were analyzed for the determination of pH, TDS, NO_3^- and total N, P, and K according standard methods (APHA, 2000). The concentrations of Mg^{+2} and Ca^{+2} were measured volumetrically by Na_2EDTA method and those of K^+ and Na^+ by flamephotometer (Chapman and Pratt 1961), and these data are not recorded in the text and were used for calculating the value of SAR (Richards, 1954).

Statistical Analysis: The obtained results were statistically analyzed for the least significant difference (LSD 0.05) according to Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

Table 1 showed wide variations in the chemical and physical properties of the two soils. The lacustrine soil is characterized by relatively lower levels of EC_e and total CO_3^{-2} and relatively higher levels of OM, available N, P and K than those of the calcareous soil. According to Chapman (1996), the amounts of available macronutrients (N, P and K) in the lacustrine soil are within the low range while those in the calcareous soil are within the deficient range. On the other hand, the calcareous soil is more saline than the lacustrine soil but its salinity is less than the critical limit (less than 4 dSm^{-1}). It is also clear that the two soils had slightly alkaline reaction since the average pH values of the lacustrine and calcareous soils are 8.0 and 8.2, respectively. Table 1 showed also that the lacustrine soil contains relatively higher percentages of clay and lower percentage of sand fractions than those of the calcareous soil. These data point out, in general, that the lacustrine soil is relatively more fertile than the calcareous soil with respect to OM and available macronutrients.

Table 1. The main chemical and physical characteristics of the lacustrine and calcareous soils (average value)

Parameters	lacustrine	Calcareous
pH	8.0	8.2
EC_e (dSm^{-1})	0.70	3.30
Total CO^{--}_3 (%)	3.65	28.40
OM (%)	2.18	0.90
Available N (mg kg^{-1})	65	50
Available P (mg Kg^{-1})	8.50	4.80
Available K (mg Kg^{-1})	460	200
Sand (%)	57	79
Silt (%)	20	9
Clay (%)	23	12
Soil texture	Sandy clay loam	Sandy loam

Table 2. The average value of the chemical composition of FW, TWW and 1:1 FW/TWW

Parameters	FW	TWW	1:1 FW/TWW
pH	8.10	8.00	7.45
TDS (mg l^{-1})	660	2200	1500
SAR	3.65	8.65	7.5
Total N (mg l^{-1})	13.00	38.50	29.8
NO^-_3 (mg l^{-1})	9.00	28.00	15.0
Total P (mg l^{-1})	1.80	11.50	8.5
Total K (mg l^{-1})	160	320	220

Table 2 showed that both the FW and TWW had slightly alkaline reaction and low values of SAR. However, both TWW and 1:1 FW/TWW had higher levels of TDS, total N, NO_3^-, and total P and K than those of FW. According to Ayers and Westcot (1985), restrictions should be undertaken concerning the reuse of this TWW for irrigation because of its high TDS. Thus, this water can be classified, according to Richards (1954) with respect to sodium ion and salinity hazards in the C_3S_1 category which requires special management for salinity control.

Effect of Irrigation Water on Soil Characters

Soil pH: Tables 3 and 4 showed that there were no significant differences in the values of pH of cultivated lacustrine and calcareous soils as a result of irrigation by FW, TWW and 1:1 FW/TWW and these pH values were within the normal range. The pH values of lacustrine soil cultivated with soybean, corn, faba bean and wheat were within the range; 7.12-7.54, 7.00-7.80, 7.11-7.30 and 7.15-7.40, respectively, and those of calcareous soil cultivated with these four plant species were in the range 8.00-8.25, 8.00-8.20, 7.95-8.15 and 7.95-8.30, respectively.

Soil Salinity: As shown in Tables 3 and 4, there were significant increase in the values of EC_e of cultivated lacustrine and calcareous soils as a result of irrigation by TWW and 1:1 FW/TWW as compared with those irrigated by FW. Several studies reported that irrigation by treated wastewater had increased soil salinity as compared to irrigation by normal water (Rusan et al., 2007; Kizilogu et al., 2008; Mojiri, 2011; and Morugan et al., 2011).

The values of EC_e of cultivated lacustrine soil irrigated by TWW were almost less than the upper critical limit of non-saline soil (less than 4.0 dSm^{-1}), while those of cultivated calcareous soil had exceeded this limit especially in soils cultivated with faba bean and wheat (Tables 3 and 4). It is also clear that the EC_e values of cultivated lacustrine soils were generally lower than those of cultivated calcareous soils.

Tables 3 and 4 showed also that the EC_e values of soils of the upper layer (0-20cm) were significantly lower than those of the lower (20-40 cm). This clearly observed in both cultivated lacustrine and calcareous soils irrigated by FW, TWW and 1:1 FW/TWW. This distribution of salinity, in soils of the two layers, indicates high transport and leaching of salts from soil of the upper layer to that of the lower layer.

In general, higher values of relative increase in EC_e were recorded in soils of the lower layer than in those of the upper layer. In the case of cultivated soils irrigated by TWW, the average values of relative increase in EC_e of the upper and lower layers of lacustrine soils were 60.7 and 103.2%, respectively, and in the case of calcareous soils these average values were 55.2 and 64.9%, respectively. It is also clear that the values of relative increase in EC_e were almost higher in soils irrigated by TWW than in those irrigated by 1:1 FW/TWW. Thus, on the average, the values of relative increase in EC_e of cultivated lacustrine soils irrigated by TWW were 60.7 and 103.2% in upper and lower layers, respectively, while in soils irrigated by 1:1 FW/TWW these values were 46.4 and 46.8% in the two soil layers, respectively. With respect to cultivated calcareous soils irrigated by TWW, on the average, these values were 55.2 and 64.9 % in soils of upper and lower layers, respectively while those irrigated by 1:1 FW/TWW these values were 25.1 and 30.3%, respectively.

On the basis of an overall average value, with respect to soil irrigation by TWW and 1:1 FW/TWW, the relative increase in EC_e was generally higher in lacustrine soil (64.3%) than in calcareous soil (43.9%). These data point out that irrigation by TWW and 1:1 FW/TWW would increase salinity of lacustrine soil with higher rate than would be predicted for calcareous soil. In addition, the overall average values of the relative increase in EC_e of lacustrine soil cultivated with soybean, corn, faba bean and wheat due to irrigation by TWW and by 1:1 FW/TWW were 73.1, 17.7, 94.1 and 72.2%, respectively and those of calcareous soil cultivated with these plant species were 9.3, 17.2, 75.1 and 74%, respectively. These data indicate that salinization rate, of these two soils, would be predicted to be higher in winter growth season (faba bean and wheat soils) than in summer growth season (soybean and corn soils).

Soil SAR: Tables 3 and 4 showed no significant differences between the values of SAR of the two soil layers of cultivated lacustrine and calcareous soils and also between layers of soils irrigated by FW, TWW and 1:1 FW/ TWW. This can be clearly observed in soils cultivated with the four plant species. It is also clear that all SAR values, of these soils, are less than 15 which is the critical limit of soil alkalinity.

Soil OM: There were significant increases in the levels of OM in cultivated lacustrine and calcareous as a result of irrigation by TWW and 1:1 FW/ TWW (Tables 3 and 4). For example, in lacustrine soil cultivated with soybean, the levels of OM significantly increased in soils of the upper layer from 2.10 (FW-soil) to 2.70%, as a result of TWW irrigation. This trend can be observed in the two soil types and with the four plant species whether irrigated by TWW or by 1:1FW/ TWW, as compared to those irrigated by FW. Studies carried out by Rusan *et al*. (2007) showed that irrigating soils with wastewater increased OM contents in soils and the highest amounts were found in soils of the upper layer (0-20 cm). On the other hand, Wang *et al*. (2007) found slight increase in soil OM as a result of irrigation by treated wastewater. Singh et al. (2012) found that there was higher significant increase of OM in cultivated soils irrigated by treated wastewater than in those irrigated by canal water.

These data also showed higher values of the relative increase in OM of soils of the upper layer than in those of the lower layer as a result of irrigation by TWW and 1:1 FW/ TWW, with reference to irrigating by FW. The average value of relative increase in OM, as a result of irrigation cultivated lacustrine soil by TWW, was 25.5% in soils of the upper layer and 14.8% in soils of the lower layer. These values in 1:1 FW/ TWW irrigated lacustrine soil, on the average, were 7.1 and 5.2%, respectively. In the case of cultivated calcareous soil irrigated by TWW, the average value of relative increase in OM of soil of the upper layer was 57.8% and that of the lower layer was 34.9%. These values in cultivated calcareous soils irrigated by 1:1 FW/ TWW were 16.1 and 13.0% for the upper and lower soil layers, respectively. These data indicate higher possibility for increasing the level of OM in calcareous soil than in lacustrine soil, as a result of irrigation by TWW.

The values of relative increase of OM in soils irrigated by TWW were higher than those irrigated by 1:1 FW/ TWW. On the average, the values of relative increase of OM in cultivated lacustrine soils of the upper and lower layers, due to TWW irrigation, were 25.5 and 14.8%, respectively and of those irrigated by 1:1 FW/ TWW were 7.1 and 5.2%, respectively. These average values, in cultivated calcareous soils were 57.8 and 34.9% for TWW irrigation, respectively, and were 16.1 and 13.0% for 1:1 FW/ TWW irrigation, respectively. These data point out to higher possibility of increasing OM in cultivated calcareous soil than in cultivated lacustrine soil as a result of irrigation by TWW or by 1:1 FW/ TWW.

Available N in Soil: Tables 3 and 4 showed significant increase in the amounts of available N in cultivated lacustrine and calcareous soils as a result of TWW and 1:1 FW/ TWW irrigation as compared to those of FW irrigation. However, there were no significant differences in the amounts of available N in soils irrigated by TWW and 1:1 FW/ TWW. The amounts of available N in lacustrine soil had increased, due to TWW and 1:1 FW/ TWW irrigation, to levels within the sufficient range for most plant species while those in calcareous soil had increased to levels close to the low range for most plant species (Chapman, 1966). It is also clear that there was no special trend in the distribution of the amounts of available N in soils of the upper and lower layers of both lacustrine and calcareous soils. Rusan *et al*. (2007) and

Kiziloglu *et al*. (2008) found high increase in the amounts of available N in soil irrigated by wastewater than in those irrigated by normal water and the highest amount was recorded in soil of the upper layer.

The values of relative increase in the amounts of available N were higher in lacustrine and calcareous soils irrigated by TWW than in those irrigated by 1:1 FW/ TWW. These values showed no special trend in the case of cultivated lacustrine soil irrigated by TWW and 1:1 FW/ TWW. On the other hand, in cultivated calcareous soil irrigated by TWW and 1:1 FW/TWW, these values were almost higher in soils of the upper than in those of the lower layer. The average values of relative increase in the amount of available N in cultivated lacustrine soil irrigated by TWW were 23.4 and 26.2% in soils of the upper and lower layers, respectively and in soil irrigated by 1:1 FW/TWW were 22.1 and 22.8, respectively.

Table 3. The chemical characteristics of soybean, corn, faba bean and wheat cultivated lacustrine soil as influenced by FW, TWW and 1:1 FW/TWW irrigation treatments

Water of irrigation	Soil depth (cm)	pH	EC_e (dSm^{-1})	SAR	OM (%)	Available (mg kg^{-1})		
						N	P	K
Soybean Soil								
FW	0-20	7.22	0.66	1.29	2.10	96	7.85	440
	20-40	7.12	0.70	1.32	2.00	90	8.00	485
TWW	0-20	7.54	1.36	4.70	2.70	114	9.50	780
	20-40	7.35	1.88	4.80	2.40	120	8.80	790
1:1 FW/TWW	0-20	7.20	0.70	1.43	2.32	110	7.83	488
	20-40	7.15	0.78	1.50	2.20	110	7.70	560
LSD 0.05		0.17	0.04	0.60	0.06	13	0.74	85
Corn Soil								
FW	0-20	7.15	0.73	1.33	2.10	85	7.90	550
	20-40	7.40	0.80	1.45	2.00	84	7.70	665
TWW	0-20	7.40	0.93	1.77	2.55	105	9.35	780
	20-40	7.80	0.97	1.95	2.30	104	8.50	880
1:1 FW/TWW	0-20	7.00	0.80	1.74	2.16	100	7.80	730
	20-40	7.20	0.90	2.00	2.04	100	7.80	870
LSD 0.05		0.20	0.03	0.95	0.09	14	0.72	125
Faba bean Soil								
FW	0-20	7.11	0.68	1.06	2.19	88	8.80	475
	20-40	7.25	0.75	1.25	1.95	89	8.25	530
TWW	0-20	7.24	1.35	3.58	2.89	110	11.35	700
	20-40	7.20	1.45	4.10	2.30	112	9.60	890
1:1 FW/TWW	0-20	7.23	1.30	3.27	2.35	110	7.73	560
	20-40	7.30	1.45	4.00	2.08	110	7.90	700
LSD 0.05		0.17	0.13	0.85	0.06	19	0.77	135
Wheat Soil								
FW	0-20	7.25	0.70	1.21	2.00	86	8.15	480
	20-40	7.15	0.85	2.00	1.98	91	8.00	590
TWW	0-20	7.35	1.45	4.57	2.40	108	10.00	790
	20-40	7.15	1.95	5.10	2.10	110	9.15	820
1:1 FW/TWW	0-20	7.30	1.25	4.00	2.15	110	8.230	615
	20-40	7.40	1.45	5.00	2.02	115	8.00	780
LSD 0.05		0.14	0.18	1.40	0.07	13	0.75	140

Similarly, the average values of relative increase in the amounts of available N in cultivated calcareous soil irrigated by TWW were 42.2 and 32.1% in soils of the upper and lower layers, respectively and in soils irrigated by 1:1 FW/ TWW were 18.8 and 13.1%, respectively. These data indicate higher response of cultivated calcareous soil to TWW and 1:1 FW/TWW irrigation, with respect to the amount of available N, than that of cultivated lacustrine soil. Taking into account the overall average values of relative increase in available N in cultivated lacustrine soil (23.6%) and calcareous soil (26.6%) showed that irrigating by TWW had enriched the calcareous soil with relatively higher percentage of available N than that of lacustrine soil.

Table 4. The chemical characteristics of soybean, corn, faba bean and wheat cultivated calcareous soil as influenced by FW, TWW and 1:1 FW/TWW irrigation treatments

Water of irrigation	Soil depth (cm)	pH	EC_e (dSm^{-1})	SAR	OM (%)	Available ($mg\ kg^{-1}$)		
						N	P	K
Soybean Soil								
FW	0-20	8.11	3.15	4.80	0.84	70	3.90	340
	20-40	8.10	3.55	4.95	0.80	74	3.60	480
TWW	0-20	8.25	3.65	5.60	1.45	98	6.25	630
	20-40	8.10	4.00	5.80	1.20	100	5.50	750
1:1 FW/TWW	0-20	8.11	3.20	5.10	1.00	85	4.67	475
	20-40	8.16	3.68	5.50	0.93	84	4.50	650
LSD 0.05		0.22	0.14	0.85	0.07	12	0.77	38
Corn Soil								
FW	0-20	8.10	2.95	5.20	0.92	75	3.75	280
	20-40	8.00	3.10	6.00	0.80	76	3.30	340
TWW	0-20	8.20	3.60	5.54	1.35	95	5.75	500
	20-40	8.10	4.10	6.40	1.10	92	5.25	620
1:1 FW/TWW	0-20	8.00	3.00	5.71	1.15	86	4.45	450
	20-40	8.15	3.50	6.55	0.98	84	3.80	560
LSD 0.05		0.19	0.14	1.00	0.08	13	0.42	44
Faba bean Soil								
FW	0-20	7.95	3.10	4.95	0.95	80	3.56	300
	20-40	8.00	3.30	5.50	0.90	84	3.50	330
TWW	0-20	8.15	5.85	6.75	1.55	125	6.50	620
	20-40	8.00	6.95	7.00	1.25	120	5.00	700
1:1 FW/TWW	0-20	8.05	4.64	5.81	0.98	95	4.85	460
	20-40	8.00	5.00	6.50	0.92	92	4.30	520
LSD 0.05		0.23	0.17	0.85	0.08	12	0.67	58
Wheat Soil								
FW	0-20	7.95	3.50	4.56	0.94	79	3.90	400
	20-40	8.00	3.65	5.10	0.90	85	3.50	460
TWW	0-20	8.15	6.80	6.63	1.40	115	5.85	600
	20-40	8.00	7.00	7.25	1.18	110	5.10	680
1:1 FW/TWW	0-20	8.25	5.16	6.13	1.10	95	5.50	560
	20-40	8.30	5.65	7.00	1.00	96	5.40	660
LSD 0.05		0.23	0.13	0.75	0.08	16	0.69	48

The average values of relative increase in the amount of available N in cultivated lacustrine soil were higher in faba bean and wheat soils (25.1 and 25.2%, respectively) than in soybean and corn soils (23.2 and 21.0%, respectively). Also, these values in cultivated calcareous soil were higher in faba bean and wheat soils (33.6 and 26.8%, respectively) than in soybean and corn soils (27.5 and 18.3%, respectively). These data point out to the stimulating role of plant species in improving the availability of N in soils irrigated by TWW and 1:1 FW/TWW.

Available P in Soil: As shown in Tables 3 and 4, significant increase in the amounts of available P were found in cultivated lacustrine and calcareous soils as a result of TWW irrigation as compared to those irrigated by FW. The range of the amounts of available P in lacustrine soil was from 7.70 to 9.50 mg Kg^{-1} in soybean soil, from 7.70 to 9.35 mg Kg^{-1} in corn soil, from 7.90 to 11.35 mg Kg^{-1} in faba bean soil and from 8.00 to 10.00 mg Kg^{-1} in wheat soil. These values are considered beyond the adequate range of available P in soils (10 mg Kg^{-1}) as reported by Chapman (1966). These amounts in calcareous soils varied from 3.60 to 6.25 mg Kg^{-1} in soybean soil, from 3.30 to 5.75 mg Kg^{-1} in corn soil, from 3.50 to 6.50 mg Kg^{-1} in faba bean soil and from 3.50 to 5.85 mg Kg^{-1} in wheat soil. These values are considered beyond the deficient range of available P in most soils (Chapman, 1966). These data indicate that irrigation of calcareous by TWW had improved slightly the levels of available P in the soil but did not increase it to the sufficient or adequate level. On the other hand, irrigation of lacustrine soil by TWW had improved the levels of available P in soil to the sufficient or adequate level. Studies carried out by Rusan *et al*. (2007) and Kiziloglu *et al*. (2008) showed that irrigation by wastewater had increase the amounts of available P in soils, and these amounts were higher in soils of the upper layer than in those of the lower layer.

The values of relative increase in the amounts of available P in soils irrigated by TWW were higher in soil of the upper layer than in those of the lower layer. On the average, these values in cultivated lacustrine soils were 23.1 and 10.3% for the two layers, respectively. It is also clear that the higher average values of relative increase in available P in TWW irrigated lacustrine soils were recorded in faba bean and wheat soils (average values of 19.1 and 18.6 %, respectively), and the lower were in soybean and corn soils (average values of 16.1 and 13.0, respectively). This points out that winter field crops had slight effect to improve the levels of available P in lacustrine soil as compared to that of summer field crops. The values of relative increase in available P in cultivated calcareous soil irrigated by TWW were higher in soils of the upper layer than in those of the lower layer with average values of 64.6 and 50.1%, respectively. In the case of 1:1 FW/TWW irrigated calcareous soils, these average values were 28.9 and 25.8% in the upper and lower soil layers, respectively. On the average, these values were almost higher in soils cultivated with faba bean and wheat than with soybean and corn. The highest average values of relative increase in available P in cultivated calcareous soils irrigated by TWW and 1:1 FW/TWW were recorded in those of faba bean and wheat (46.1 and 47.8%, respectively) and the lowest were in those of soybean and corn (39.4 and 33.1%, respectively). These data point out the stimulating effect of winter field crops in improving the levels of available P in calcareous soils as compared to that of summer field crops.

The overall average values of relative increase in available P in cultivated lacustrine and calcareous soils were 16.7 and 41.6%, respectively. These data indicate relatively higher response of calcareous soil than lacustrine soil to irrigation by TWW and by 1:1 FW/TWW with respect to the increased percentages of available P in soils.

Available K in Soil: Tables 3 and 4 showed significant increase in the amounts of available K in cultivated lacustrine and calcareous soils as a result of irrigation by TWW as compared to those irrigated by FW. The amounts of available K, in the two soil types, were higher in soils of the lower layer than in those of the upper layer, and were higher in lacustrine soil than in calcareous soil. In general, these amounts were almost higher than the adequate level of available K (200 mg Kg^{-1}) in most soils (Chapman, 1966). These high levels could be due to both mineral fertilizer application and to K addition from irrigation by TWW. It has been reported by Rusan *et al*. (2007) and Kiziloglu *et al*. (2008) that irrigation by wastewater had increased the amounts of available K in soils as compared with those irrigated by normal water and the highest amount was found in the upper soil layer.

The values of relative increase in the amount of available K, with reference to FW irrigation, were higher in soils irrigated by TWW than by 1:1FW/TWW. In cultivated lacustrine soil irrigated by TWW, the values of relative increase in available K were higher in soils of the upper layer than in those of the lower layer, with average values of 57.8 and 50.5% for the two soil layers, respectively, while in soils irrigated by 1 : 1 FW/TWW these average values were 22.3 and 27.7%, respectively. In concern with TWW irrigated cultivated calcareous soil, the average values of relative increase in the amounts of available K in soils of the upper and lower layers were 80.2 and 74.6 %, respectively while in soils irrigated by 1:1 FW/TWW these average values were 48.4 and 50.3%, respectively.

On the basis of overall average values of relative increase in available K, higher value was recorded in calcareous soil (63.4 %) than in lacustrine soil (39.6 %). These data indicate higher response of calcareous soil to irrigation by TWW, with respect to the increase in the percentages of available K, than that of lacustrine soil. It is also clear that there were no marked variations in the values of relative increase in the amounts of available K in soils due to the effect of cultivated plant species. These data indicated out that the variations in percentages of available K in soils were not influenced by both growth seasons and plant species.

Effect of Irrigation Water on Plant

i. Macronutrients Contents:

Nitrogen: Table 5 showed significant increase of N contents in leaves of plants grown on lacustrine and calcareous soils as a result of irrigation by TWW and by 1:1 FW/TWW as compared with those irrigated by FW. The N contents in leaves of soybean and corn plants grown on lacustrine and calcareous soils and irrigated by TWW and 1:1 FW/TWW were within the adequate range (1.25-3.00% according to Chapman, 1966). On the other hand, the levels of N in leaves of faba bean and wheat grown on lacustrine soil irrigated by TWW were within the adequate range and those grown on calcareous soil were within the deficient range (less than 1.25%). Irrigation of faba bean and wheat plants grown on calcareous soil by 1:1 FW/TWW did not supply these two plant species by the adequate amounts of N, and therefore, the N contents in leaves of these plants are in the deficient range (Chapman, 1966).

The average values of relative increase in N contents in leaves of the four plant species grown on lacustrine and calcareous soils as a result of irrigation by TWW were higher (average values of 79.7 and 85.6%, respectively) than in those irrigated by 1:1 FW/TWW (average values of 49.0 and 60.0%, respectively). It is clear that the values of relative increase of N contents in leaves of the four plant species had been varied markedly and were almost higher in leaves of faba bean plants grown on the two soil types and irrigated by TWW or by 1:1 FW/TWW, while those of the other three plant species (soybean, corn and wheat) had varied markedly and were higher in plants grown on calcareous soil than on lacustrine soil. The average values of relative increase of N in leaves of the four plant species grown on lacustrine soil and irrigated by TWW and 1:1 by FW/TWW were 79.7 and 49.0%, respectively while those grown on calcareous soil and irrigated by TWW and by 1:1 FW/TWW were 85.6 and 60.0%, respectively. In addition, the overall average values of relative increase of N contents in leaves of plants grown on lacustrine and calcareous soils were 64.4 and 72.8%, respectively. These data indicate higher response of the four plant species to irrigation by TWW and by 1:1 FW/TWW when grown on calcareous soil than on lacustrine soil with respect to the values of relative increase of N percentage in plant leaves. This points out that irrigation by TWW could be a supplemental source of N especially to plants grown on calcareous soil as compared to those grown on lacustrine soil.

Phosphorus: Table 5 showed significant increase in P contents in leaves of the four plant species grown on lacustrine and calcareous soils as a result of TWW and 1:1 FW/TWW irrigation as compared with those of FW irrigation. The levels of P in leaves of plants grown on the two soil types and irrigated by TWW were within the sufficient and adequate range (0.2-0.5%, according to Chapman, 1966), except faba bean and wheat grown on calcareous soil since P contents in their leaves were within the low range (0.15-0.20%). Also, irrigation by 1:1 FW/TWW increased the levels of P in leaves of soybean, corn and faba bean plants grown on lacustrine soil, which were within the adequate range of P in plant leaves (Chapman, 1966). Also, the P contents in leaves of soybean and corn plants grown on 1:1 FW/TWW irrigated calcareous soil were within the adequate range (0.2-0.5%).

The average values of relative increase in P contents in leaves of the four plant species grown on lacustrine soil and irrigated by TWW and by 1:1 FW/TWW were 103.3 and 61.6%, respectively, and of those grown on calcareous soil were 107.2 and 64.6%, respectively. However, the overall average values of relative increase of P contents in leaves of the four plant species, grown on lacustrine and calcareous soils irrigated by TWW or 1:1 by FW/TWW were very close (84.0 and 84.4%, respectively). This points out that the response of the four plant species to P applied from irrigation by TWW or 1:1 FW/TWW was nearly similar for plants whether grown on lacustrine or calcareous soils.

Table 5. The concentrations of N, P and K (%) in leaves of plants grown on lacustrine or calcareous soil as influenced by FW, TWW and 1:1 FW/TWW irrigation treatments

Water of irrigation	Lacustrine soil			Calcareous soil		
	N	P	K	N	P	K
	Soybean					
FW	3.56	0.29	1.15	2.30	0.19	0.94
TWW	5.38	0.53	2.93	4.42	0.40	1.64
1:1 FW/TWW	4.19	0.42	1.87	3.88	0.32	1.33
LSD 0.05	0.27	0.02	0.07	0.5	0.03	0.05
	Corn					
FW	1.91	0.13	1.54	1.82	0.17	0.38
TWW	3.21	0.30	2.43	2.17	0.38	1.61
1:1 FW/TWW	2.76	0.24	1.98	1.97	0.26	1.31
LSD 0.05	0.04	0.02	0.03	0.05	0.03	0.03
	Faba bean					
FW	0.74	0.10	2.20	0.48	0.08	1.04
TWW	1.86	0.24	3.42	1.16	0.18	3.18
1:1 FW/TWW	1.48	0.20	2.99	0.97	0.14	2.90
LSD 0.05	0.03	0.01	0.03	0.11	0.02	0.07
	Wheat					
FW	1.06	0.12	0.97	0.46	0.10	0.85
TWW	1.57	0.24	1.86	0.87	0.17	1.75
1:1 FW/TWW	1.37	0.18	1.47	0.74	0.15	1.47
LSD 0.05	0.03	0.18	0.07	0.04	0.02	0.05

Table 6. The shoot dry weight (g plant^{-1}) of plant grown on lacustrine or calcareous soil as influenced by FW, TWW and 1:1 FW/TWW irrigation treatments

Water of irrigation	Lacustrine soil				Calcareous soil			
	Soybean	Corn	Faba bean	Wheat	Soybean	Corn	Faba bean	Wheat
FW	4.98	52.55	10.41	12.06	4.15	4.15	44.68	6.98
TWW	8.45	93.47	19.16	21.40	6.91	6.91	86.41	13.10
1:1 FW/TWW	6.54	80.03	15.30	17.36	5.49	5.49	73.31	14.37
LSD 0.05	1.52	7.70	5.20	5.70	1.60	6.10	5.70	3.90

With respect to the response of the four plant species to irrigation by TWW or 1:1 FW/TWW, faba bean plant grown on lacustrine or calcareous soil showed the highest response to P applied from TWW and 1:1 FW/TWW irrigation since the overall average values of the relative increase in P content in plant leaves were 125.7 and 100%, respectively. The descending order of the average values of the relative increase in P contents in leaves of the four plant species grown on lacustrine soil irrigated by TWW and 1:1 FW/TWW was: faba bean (125.7%), corn (107.7%), soybean (63.8%) and wheat (38.7%), and those for plants grown on calcareous soil was: faba bean

(100.0%), corn (88.2%), soybean (89.5%) and wheat (60.0%). These data indicate that the highest response, to P utilization from TWW or 1:1 FW/TWW irrigation, was by faba bean, then corn and soybean while the lowest was for wheat whether grown on lacustrine or calcareous soil.

Potassium: Table 5 showed significant increase in the amounts of K in leaves of plants grown on lacustrine and calcareous soils as a result of irrigation by TWW and 1:1 FW/TWW as compared to those irrigated by FW. The concentration levels of K in leaves of the four plant species are within the adequate range (0.15-0.3% according to Chapman, 1966). These data point out that TWW and 1:1 FW/TWW irrigation can be supplemental source of K to plants grown on lacustrine and calcareous soils.

The values of relative increase of K were almost higher in leaves of plants irrigated by TWW (average values of 90.0 and 178.2% for plants grown on lacustrine and calcareous soils, respectively) than in those irrigated by 1:1 FW/TWW (average values 44.7 and 135.7% for plants grown on the two soils, respectively). It is also clear that these values were almost higher in leaves of plants grown on calcareous soil (average values of 178.2 and 135.7% for TWW and 1:1FW/TWW irrigation, respectively) than in those of plants grown on lacustrine soil (90.0 and 44.7% for these two waters, respectively). On the basis of overall average values, the values of relative increase of K in leaves of the four plant species grown on lacustrine and calcareous soils and irrigated by TWW or 1:1 FW/TWW were 67.3 and 156.2% for the two soils, respectively. These data indicate higher response of plants grown on calcareous soil to K applied from irrigation by TWW and 1:1 FW/TWW than of those grown on lacustrine soil.

With respect to the response of the four plant species to K applied from TWW or 1:1 FW/TWW, it is clear that soybean grown on lacustrine soil had the highest relative increase of K in its leaves (average value of 108.7%) as compared with soybean grown on calcareous soil (average value of 60.4%). On the other hand, leaves of corn and faba bean plants grown on calcareous soil had the highest relative increase of K (average values of 284.2 and 193.8%, respectively) as compared with those grown on lacustrine soil (43.2 and 45.7%, respectively). However, the values of relative increase in leaves of wheat were higher when grown on calcareous soil than when grown on lacustrine soil (average values of 89.4 and 71.7%, for the two soil types, respectively). These data indicate that irrigation by TWW or 1:1 FW/TWW would be valuable sources of K for plants grown on calcareous soil more than for plants grown on lacustrine soil.

ii. Shoot Dry Weight:

Table 6 showed significant increase in the dry weight of shoot of plants grown on lacustrine and calcareous soils as a result of irrigation by TWW or by 1:1 FW/TWW as compared with those irrigated by FW. It is also clear that the shoot dry weight, of each plant species, was higher when grown on lacustrine soil than on calcareous soil whether irrigated by FW, TWW or 1:1 FW/TWW. Also, these shoot dry weights were almost higher when plants were irrigated by TWW than by 1:1 FW/TWW.

The values of relative increase of shoot dry weight were almost higher for plants irrigated by TWW than for those irrigated by 1:1 FW/TWW.

The average values of relative increase of shoot dry weight, of the four plant species grown on lacustrine soil irrigated by TWW or 1:1 FW/TWW, were 77.4 and 43.7%, respectively, and of those grown on calcareous soil were 82.1 and 59.0%, respectively. The average values of relative increase of shoot dry weight of the four plant species grown on TWW irrigated lacustrine and calcareous soils were 77.4 and 82.1%, respectively and of those irrigated by 1:1 FW/TWW were 43.7 and 59.0%, respectively. The overall average values of relative increase in shoot dry weight of soybean, corn, faba bean and wheat plants irrigated by TWW and 1:1 FW/TWW grown on lacustrine and calcareous soils were 60.5 and 70.5 %, respectively. These data point out to the stimulating action of TWW or 1:1 FW/TWW irrigation on plant growth and this was generally more effective on plants grown on calcareous soil than on lacustrine soil.

With respect of the response of the four plant species to irrigation by TWW or 1:1 FW/TWW, it clear that faba bean showed relatively higher response (average values of 65.5 and 83.3% in lacustrine and calcareous soils, respectively) than soybean (average values of 50.7 and 49.4% in lacustrine and calcareous soils, respectively), Also, corn and wheat plants showed relatively higher values when grown on calcareous soil than on lacustrine soil. These data indicate that plants grown on calcareous soil showed relatively higher response to irrigation by TWW or 1:1 FW/TWW than those grown on lacustrine soil.

Effect of Irrigation Water on Drainage Water Quality

Water pH: Table 7 showed significant increase in the pH values of drainage water from cultivated lacustrine and calcareous soils as a result of irrigation by TWW. The pH values of drainage water from cultivated lacustrine soils were within the range 7.50 – 7.83, and those from cultivated calcareous soils were within the range 7.88 – 8.37. These pH values, in general, were within the normal range (6.5-8.4) of water of irrigation according to Ayers and Westcot (1985). It is clear, therefore, that the pH values of drainage water from the two cultivated soils were changing within a narrow range as a result of irrigation by TWW or 1:1 FW/TWW.

Water TDS: There were significant increases in the levels of TDS in the drainage waters of cultivated lacustrine and calcareous soils as a result of irrigation by TWW and 1:1 FW/TWW (Table 7). It is also clear that the levels of TDS of drainage water from cultivated calcareous soil were almost higher than of those from cultivated lacustrine soil. Also, the drainage waters of soils irrigated by TWW contained higher levels of TDS than of those irrigated by 1:1 FW/TWW. Study carried out by Weber and Junico (1996) showed that irrigation by wastewater has negative effects on the quality of drainage water which is due mainly to accumulation of high concentration of salts especially Na^+ and Cl^- in drainage water.

In the case of TWW irrigation, the values of relative increase in TDS of drainage waters from cultivated lacustrine soil were, on the average, higher (91.1%) than of those from cultivated calcareous soil (79.8). However, in the case of 1:1 FW/TWW irrigation, these values were 28.0 and 42.2%, for the two soil types, respectively. On the basis of overall average values, the values of relative increase in TDS due to TWW and 1:1 FW/TWW irrigation were 59.5 and 61.0% in drainage water from cultivated lacustrine and calcareous soils, respectively.

It is also clear that the values of relative increase of TDS in drainage water from soils irrigated by TWW were higher than in those irrigated by 1:1 FW/TWW, and were 91.0 and 28.0%, respectively from lacustrine soil and were 79.8 and 42.2%, respectively from calcareous soil. These data point out that irrigation by TWW would increase salinity of drainage water from cultivated lacustrine soil relatively more than from cultivated calcareous soils.

Water SAR: Table 7 showed significant increase in the values of SAR of the drainage water from cultivated lacustrine and calcareous soils as a result of irrigation by TWW or 1:1 FW/TWW as compared to those of FW irrigation. The values of SAR, in general, of all drainage waters from all irrigation water treatments were less than the critical value (SAR= 15) which indicated that there was no sodium hazard when these waters are used for irrigation (Ayers and Westcot 1985).

Water Nitrate (NO_3^-): Table 7 showed significant increase in the concentrations of NO_3^- in the drainage water from cultivated lacustrine and calcareous soils as a result of irrigation by TWW or by 1:1 FW/TWW as compared to those irrigated by FW. The concentrations of NO_3^- in drainage water of soils irrigated by TWW were almost higher than of those irrigated by 1:1 FW/TWW or by FW. However, the concentrations of NO_3^- in drainage waters from TWW and 1:1 FW/TWW irrigated soils were almost greater than the normal and acceptable limit (30 mgl^{-1}) in water of irrigation (Ayers and Westcot 1985).

The values of relative increase of NO_3^- concentration in drainage water from TWW irrigated cultivated lacustrine and calcareous soils were almost higher than from those irrigated by 1:1 FW/TWW. Thus, the average values of relative increase of NO_3^- concentrations in drainage water from TWW and 1:1 FW/TWW irrigated lacustrine soils were 91.8 and 51.6%, respectively and from irrigated calcareous soils were 98.6 and 56.4 %, respectively. With respect to TWW irrigation, the average values of relative increase in NO_3^- concentration in drainage water were higher from calcareous soil (98.6%) than from lacustrine soil (91.8%), and with respect to 1:1 FW/TWW irrigation these values were 58.4% and 51.6%, respectively. The overall average values of relative increase of NO_3^- concentration in all drainage waters were higher from calcareous soils (78.5 %) than from lacustrine soil (71.7%). These data point out that in the case of irrigation by TWW or 1:1 FW/TWW, the rate of increase in NO_3^- concentrations in drainage water from cultivated calcareous soils is expected to be greater than from cultivated lacustrine soils.

Table 7. The chemical composition of drainage water from soybean, corn, faba bean and wheat cultivated lacustrine or calcareous soil as influenced by FW, TWW and 1:1 FW/TWW irrigation treatments

Water of irrigation	Lacustrine soil					Calcareous soil				
	pH	TDS ($mg\ l^{-1}$)	SAR	NO_3^- ($mg\ l^{-1}$)	Tot. P ($mg\ l^{-1}$)	pH	TDS ($mg\ l^{-1}$)	SAR	NO_3^- ($mg\ l^{-1}$)	Tot. P ($mg\ l^{-1}$)
	Soybean soil									
FW	7.93	820	1.88	29.51	3.50	8.20	2710	4.93	19.20	3.16
TWW	8.33	1900	5.94	44.71	7.83	8.36	3620	6.68	41.40	5.30
1:1 FW/TWW	8.13	1130	3.00	39.67	5.53	8.23	3000	5.22	32.36	4.52
LSD 0.05	0.10	130	0.14	4.78	0.15	0.14	180	0.45	3.60	0.39
	Corn soil									
FW	7.87	1130	5.12	21.50	5.18	8.13	2330	4.41	27.61	5.22
TWW	8.33	1435	4.22	42.56	9.19	8.37	4230	6.41	53.54	7.82
1:1 FW/TWW	8.13	1140	4.20	31.26	7.76	8.37	3150	4.84	44.24	6.35
LSD 0.05	0.13	120	0.13	4.34	0.18	0.10	215	0.69	5.70	0.46
	Faba bean soil									
FW	7.73	1050	3.32	29.79	4.28	8.07	2105	4.49	33.49	3.94
TWW	8.13	2475	5.51	56.22	9.91	8.27	3385	5.29	61.99	6.78
1:1 FW/TWW	8.07	1470	4.41	45.44	6.80	7.96	3135	6.94	52.27	4.92
LSD 0.05	0.10	170	0.16	5.48	0.27	0.11	180	0.82	5.65	0.40
	Wheat soil									
FW	7.50	980	3.28	22.42	6.82	8.03	1785	3.24	28.49	5.92
TWW	8.20	1665	4.76	51.34	11.53	8.26	4340	8.32	50.88	9.51
1:1 FW/TWW	7.90	1255	3.55	39.02	8.85	7.83	3090	4.52	42.34	7.75
LSD 0.05	0.14	160	0.35	5.42	0.13	0.11	190	0.74	4.65	0.62

Water Total P: There were significant increase in the concentrations of total P in the drainage water from cultivated lacustrine and calcareous soils as a result of irrigation by TWW and 1:1 FW/TWW as compared with those from FW irrigation (Table 7). The concentrations of total P in drainage waters from soils irrigated by TWW were significantly higher than in those from soils irrigated by 1:1 FW/TWW. It is also clear that, on the average, the concentrations of Total P in drainage waters from cultivated lacustrine soils were higher than from cultivated calcareous soil (Table 7).

The values of relative increase in the concentration of total P in drainage water from TWW irrigated cultivated soils were almost higher than in those from 1:1 FW/TWW irrigated soils. Thus, the average values of relative increase of total P in drainage waters from cultivated lacustrine soils were 100.4 and 49.1% from TWW and 1:1 FW/TWW irrigated soils, respectively. Also, these average values from cultivated calcareous soils were 62.5 and 30.1%, respectively. The average value of relative increase of total P concentrations in drainage water from TWW irrigated cultivated lacustrine soils was higher (100.4%) than that from cultivated calcareous soil (62.5 %), and with respect to 1:1 FW/TWW irrigated soils, these average values were 49.1 and 30.1% for the two soil types, respectively. On the basis of overall average values, the relative increases of total P in drainage water from cultivated soils irrigated by TWW and 1:1 FW/TWW were higher from cultivated lacustrine soil (74.7 %) than from cultivated calcareous soils (46.3%). These data indicate that reuse of TWW for irrigating cultivated lacustrine soil would cause relatively higher concentration of total P in the drainage water than occurred in drainage water from TWW irrigated cultivated calcareous soil.

CONCLUSION

Irrigation of cultivated lacustrine and calcareous soils by treated wastewater (TWW) had significantly increased the salinity (EC_e) of these soils as compared to those irrigated by fresh water (FW). However, the salinity increase of cultivated lacustrine soil was within the range of non-saline soil (EC_e less than $4dSm^{-1}$), but it was within the hazard category with respect to cultivated calcareous soil. In addition, higher values of EC_e were recorded in soils of the lower layer (20-40cm) than in those of the upper layer (0-20 cm) which indicate high rates of salts down ward transport and consequently salinization of soils of the lower layer due to irrigation by TWW. The values of relative increase in EC_e indicate that salinization of soil of the lower layer can be proceed with continuous irrigation by TWW. The results also showed that the rate of salinization can be expected to be greater in calcareous soil than in lacustrine soil as a result of irrigation by TWW.

Irrigation by TWW significantly increased the amounts of OM and amounts of available N, P and K in soils. However, the values of the relative increase in these characters were almost higher in calcareous soil than in lacustrine soil, which indicate relatively higher prediction of increasing the fertility of calcareous soils than that of lacustrine soil. As a result, there were significant increases in the concentrations of N, P and K in leaves of plants grown on the two soils as a result of irrigation by TWW. Of a great concern is that the values of relative increase in N, P and K in leaves of plants grown on calcareous soil were higher than in those grown on lacustrine soil. This points out to higher response of plants grown on calcareous soil to TWW irrigation, with respect to N, P and K contents, than that of plants grown on lacustrine soil. The same trend was found with respect to the dry weights of plants grown on the two soils since the values of relative increase in the dry weight of plants grown on calcareous soil were almost higher than of those grown on lacustrine soil.

The concentrations of TDS, NO_3^- and total P in the drainage waters from cultivated lacustrine and calcareous soils irrigated by TWW were significantly higher than those from soils irrigated by FW. With respect to salinity hazard, on the average, drainage waters from TWW cultivated lacustrine soil is classified as C3 category and with respect to SAR is classified as S1 category. Thus, drainage waters from TWW cultivated lacustrine soils are classified, on the average, as C3S1 category. Similarly, drainage waters from TWW cultivated calcareous soils are classified, on the average, as C4S1 category. In addition, the concentrations of NO_3^- in drainage waters from TWW irrigated cultivated lacustrine and calcareous soils were greater than the normal safe level of NO_3^- (30 mgL^{-1}) which makes these waters, in general, are hazardous to the ecosystem.

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تأثير الرى بالمياه العادمة المعالجة على خواص الأرض ونمو النبات ونوعية ماء الصرف

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تهدف هذه الدراسة تقييم تأثير الرى بالمياه العادمة المعالجة على كل من بعض الخواص الكيميائية لأراضى بحيرية وجيرية مزروعة، وكذا نمو نباتات فول الصويا، الذرة، الفول والقمح ومحتواها من العناصر الغذائية الكبرى وكذلك التركيب الكيميائى لماء الصرف من هذه الأراضى.

أجريت تجارب أصص فى مزرعة البحوث الزراعية بكلية الزراعة – جامعة الإسكندرية حيث وضع خمسين كيلو جرام أرض فى أصص بلاستيكية ثم زرعت النباتات، أجرى الرى لمدة أسبوعين بالماء العادى (ماء ترعة المحمودية) ثم بعد ذلك الرى بالمياه المراد دراستها والتى شملت: الماء العادى، مياه عادمة معالجة، نسبة خلط 1 : 1 مياه عادمة معالجة : مياه عادية. جمعت عينات التربة والنباتات من كل أصص عند أسبوعين قبل الحصاد لتقدير بعض الخواص الكيميائية للأرض، والوزن الجاف للنبات ومحتواه من العناصر الغذائية الكبرى وكذلك جمعت عينات ماء الصرف من هذه الأراضى لتقدير خواصه الكيميائية.

أوضحت نتائج الدراسة وجود زيادة معنوية فى كل من قيم التوصيل الكهربائى، المادة العضوية، العناصر الغذائية الكبرى الصالحة للنبات (نيتروجين، فوسفور، بوتاسيوم) فى كلا الأرضين نتيجة الرى بالمياه العادمة المعالجة. كذلك وجدت زيادة معنوية فى تركيز هذه العناصر فى أوراق النبات وكذلك فى الوزن الجاف للنبات نتيجة الرى بالمياه العادمة بالمقارنة مع الرى بالمياه العادية. وكانت مستويات الاستفادة من الرى بالمياه العادمة المعالجة أكبر فى الأرض الجيرية المزروعة عن الأرض البحيرية المزروعة. كذلك وجدت زيادة معنوية فى تركيز كل من الأملاح الكلية الذائبة والنترات والفوسفور الكلى فى مياه الصرف نتيجة الرى بالمياه العادمة مع المقارنة بالرى بالمياه العادية. وقد وجد أن تركيز الأملاح الكلية الذائبة فى مياه الصرف من الأرض الجيرية المزروعة أكبر من تلك من الأراضى البحيرية المزروعة. وتوضح نتائج الدراسة وجود تأثيرات مفيدة لاستخدام

المياه العادمة المعالجة فى رى الأرض المزروعة وقد وجد كذلك أن هذه التأثيرات المفيدة أكبر فى حالة الأراضى الجيرية عن الأراضى البحيرية.

قام بتحكيم البحث

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