Cairo East Bank Effluent Re-use Study 1-Response of Some Field Crops to Irrigation Method with Secondary Treated Wastewater in Desert Soil

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Abstract

In order to evaluate additional water resources under water scarce conditions, large scale field trials were conducted in virgin soil to investigate the effect of some field crops irrigation with secondary treated wastewater from wastewater treatment plant in Cairo .The trials were conducted in two successive seasons of summer 2000and winter2000/2001in Berka site (virgin soil) located about 20km north east of Cairo. Four summer crops (maize, cotton, sunflower and soybean) were rotated with other winter crops (wheat, faba bean, lupin and canola). Irrigation was carried out using surface, drip and sprinkler irrigation according to the crop.

The results showed that considerable amounts of macronutrients (NPK) were applied to the grown crops during treated wastewater irrigation i.e.; N (44-79%), P (72-181%) and K (99-248%) of the recommended fertilizer rates according to the crop and with the exception of cotton where higher NPK contents were applied. Heavy metals derived from treated wastewater were very small. Crop yields showed significant differences when treated wastewater was combined with the recommended fertilizer rates for most crops. Maize, cotton sunflower and wheat seemed to be better crops for irrigation with secondary treated wastewater and irrigation by surface was more efficiently used by the crops, compared with sprinkler and drip irrigation on area basis .However, At an individual plant level, drip irrigation produced larger yields than surface irrigation, although this method would not be employed commercially for such crops on economic grounds. It could be concluded from this study that it is still too early to irrigate with secondary treated wastewater although it is favoured for some field crops under drought conditions. From environmental and health concern, It is preferred to use high standard treated wastewater (tertiary treatment) even some processed crops after harvest are used.

Keywords : Field crops, irrigation , treated wastewater, nutrients ,heavy metals

Introduction

The current water budget in Egypt show that the annual water demand exceeds the available fresh water by 6 billion m^3/year(Abou-Zeid,1992). Water uses are rising because of the ambitious land reclamation programme ,growing population,steady rural development and urbanization plans and expanding the industrial sector. Therefore ,it is essential to develop water resources through untraditional ones.

Wastewater has been used to support the agricultural production in many countries such as USA, Germany, India, Kuwait, Saudi Arabia, Oman, Jordan and Tunisia(Rowe and Abd-El Magid,1995).The area of land to be irrigated with wastewater increased significantly over two past decades due to the constrains on water supply and increasing the concerns over the environmental implications (WRc,1999). Several investigators indicated the beneficial role of wastewater in increasing crop yields without or with minimal risks to the plant ,soil, groundwater and health(Oron *et al* ,1991;Oron *et al*,1992 ;Shatanawi and Fayyed ,1996; Vazquez-Montiel *et al* ,1996; Aissi *et al* ,1997 and Palacios *et al*,2000).

Currently , the secondary treated wastewater generated from Greater Cairo is about 1.85 million m^3 / day and it is estimated that the generated treated wastewater will eventually reach up to 3.5 million m^3/day by the year 2020. From environmental point of view such quantities should be disposed off safely. At the same time this quantity is a valuable resource and potentially sufficient to irrigate about 100,000 feddans(42,000 hectare). Agriculture is one of the proposed outlets with an identified benefit from the recycling the nutrients in wastewater. Recently ,WRc(2001) estimated that wastewater could offer about 30% of the crop requirements of N and 100% or more from crop requirements of K in sandy calcareous soil in Alexandria. However , they pointed out that in the long- term monitoring for potential toxic elements (mainly heavy metals) ,groundwater and pathogen survival is necessary to protect the environment and human health.

Therefore , the aim of this work is to evaluate the effect of treated wastewater on crop yield and quality under two types of Egyptian soils.

Materials and Methods

Large scale field trials were carried out in summer 2000 and winter of 2000/2001 seasons in El- Berka wastewater treatment plant and located inside ; the soil is gravelly sand and could be classified as virgin soil. The area of the site was 10 feddans(4.2 hectars) close to the new Gabal El- Asfar wastewater treatment plant

The experimental site was cultivated using fixed tine- harrow ,then leveling was carried out . The experimental area was divided to large experimental unites according to the crop and the irrigation method . The design of each trial was based on 16 large plots eight of which receive wastewater only and the other eight receive wastewater plus supplementary fertilizer to be adjusted for each crop according to the normal recommended rates and for each site conditions. Four crops were planned to grow in the site ,thus there were two replicate plots for each crop and treatment.

Crop selection included range of food ,fodder and industrial(fiber and oil) crops according to WHO(1989). For summer season 2000, soybean(Giza82 variety), maize(Single Hybrid 129 variety) sunflower(local variety) were grown. In winter season 2000/2001,wheat (Sakha 8 variety), faba bean (Giza 3 variety), lupine (Giza 1 variety) and canola (Pactol variety) were grown.

Irrigation systems were included in the trial to demonstrate and compare their respective effects on water use efficiency ,crop production and potential health and environmental hazards. Sprinkler irrigation was used for soybean and canola; drip irrigation for maize, sunflower ,lupin and fababean, as well as surface irrigation for cotton and wheat. The irrigation water was filtered in pressure filters to avoid emitters clogging. The irrigation water was measured by water meter for each plot .Fertilizers were applied according to the normal recommended rates in Egypt. Nitrogen ,phosphorus and potassium were applied as ammonium nitrate(33.5% N),calcium super phosphate(15.5%P_2O_5) and potassium sulphate (48%K_2O) ,respectively.

Crop growth and yield assessment

During the two crop cycles the crops were routinely inspected for diseases, pests and weed control. At crop maturity , the growth characteristics and yield components were assessed according to the type of the crop. The individual plant measurements included plant height and weight, number of branches or tillers per plant as well as number, weight and dimensions of fruiting organs(pods, capsules, cobs, bolls, spikes, etc.). The conventional assessment practices were followed to provide mean individual plot performance as well as biological, straw, and grain or seed yield /feddan.

Treated Wastewater analysis

Samples of treated wastewater from El Berka were taken during crop cycles and analysed for a range of agronomic and environmental parameters. Nutrient and heavy metal loading rates to field trials were calculated according to the irrigation quantities applied to each crop in order to assess the acceptability of these wastewaters for reuse in short and long-term of full-scale operation of the wastewater treatment plants. Another objective of these analyses was to determine wastewater compliance with the Egyptian limit values (Decree44/2000) .Treated wastewaters were analysed according to APHA(1992).

Statistical analysis

The obtained results were subjected to the proper statistical analysis using Cohort2 package, Costat programme.

Results and Discussion

1- Wastewater quality

Final wastewater samples collected El Berka WWTP over the period of the trials were routinely analysed for nutrients and heavy metals. All of the results are summarised in Table 1 giving means, minimum and maximum values, the number of analyses (n), and the coefficient of variation (CV%) to indicate the overall variability of the data. Since these analyses are based on grab samples, the CVs would be expected to be relatively large, and particularly for those parameters (e.g. heavy metals) where the concentrations were close to their analytical detection limits.

Table 1 Mean Concentrations of Treated Wastewater Chemistry from El Berka WWTP

Parameters	Mean	Min.	Max.	n	CV
pH	7.78	7.65	7.86	9	0.8
Total N	12.8	7.4	18.7	25	23.9
Total P	3.4	1.2	5.3	26	29.3
K	13.8	8.3	24.1	27	23.3
B	0.4	0.4	0.4	1	-
Fe	0.577	0.064	0.980	13	54.8
Mn	0.115	0.010	0.320	11	67.4
Cr	0.027	0.006	0.087	11	120.0
Ni	0.039	0.007	0.082	11	68.7
Zn	0.094	0.011	0.180	11	67.7
Cu	0.049	0.014	0.093	11	56.2
Cd	<0.005	<0.005	<0.005	13	-
Pb	0.079	0.031	0.130	13	31.7
Mo	<0.01	<0.01	<0.01	11	-
Co	<0.005	<0.005	<0.005	11	-

Units: All determinands in mg/l except: pH

The pH of the wastewaters was within the acceptable range for reuse, normally 6.5 – 8.5.

The nutrient contents of the wastewater were broadly as may be expected. Based on these analyses, El Berka treated wastewater had a superior nutrient content and NPK ratio in relation to general crop requirements.

The heavy metal concentrations were very small, and are well below the limit values for secondary wastewater reuse, usually by at least one order of magnitude. Most of heavy metals occur at comparable concentrations, the zinc content was high, but still well below the limit value for reuse of 2 mg/l. Since zinc deficiency is widespread in Egyptian agriculture, wastewater may provide useful alternative source of this essential trace element.

2- Wastewater and Chemical Additions

Irrigation quantities were accurately recorded for each plot at both sites during the summer and winter seasons.Table 2 summarises the amounts of wastewater irrigated to each crop and fertilizer treatment, as means of the plots of each treatment. Although a fixed irrigation schedule was envisaged, this had to be adapted according to crop water requirements as observed in the field. As anticipated, the irrigation requirement was much greater than the capacity of this soil, and need for more leaching to control salinization of the soil surface.

Table 2Mean Quantities of Wastewater Irrigated according to Crop Type and Treatment (m^3/fd)

Crop	Irrigation method	Fertilizer	
		None	Applied
Summer crops			
Maize	Drip	3554	3591
Cotton	Surface	10053	10564
Soya bean	Surface	2197	2831
Sunflower	Drip	2829	2884
Winter crops			
Lupin	Drip	3204	2749
Lupin	Surface	3177	2858
Wheat	Surface	3570	1959
Wheat	Sprinkler	3157	2679
Canola	Surface	3393	1972
Canola	Sprinkler	3051	2609
Faba bean	Drip	3041	2693
Faba bean	Surface	3001	2742

The quantities of wastewater applied are broadly in line with normal practice, with exceptions, and these are related to the basic water requirement which varies between crops and the length of the growing season. For instance, cotton requires a long season to mature and consequently this had the largest amount of wastewater applied. Conversely, faba bean has a small water requirement, as indicated by the quantities irrigated in order to achieve satisfactory growth.

Table 3 lists the normally recommended application rates of inorganic fertilizer to the range of crops tested in these trials. The recommendations for some crops are different according to the fertility level of the soil, and recommended rates may be greater where modern high yielding varieties are grown.

Nevertheless, the wastewaters provide a significant proportion of the normal recommended fertilizer rates under infertile soil conditions. With only one exception, the amounts of nitrogen applied in wastewater were less than the recommended rates (range 44 – 79%). However, cotton received 176% of its recommended N rate, but this was an exception due to the high irrigation demand of this crop on desert soil and would not normally be grown under these conditions. These observations are important because one of the problems encountered by wastewater reuse in other countries has been the over-supply of nitrogen at normal crop irrigation duties due to the high concentrations in the wastewater. This can lead to luxurious growth at the expense of economic yield and give rise to nitrate leaching and pollution of groundwater. This is not likely to occur in Egypt as wastewaters generally have relatively low nitrogen contents.

The addition of phosphorus by the wastewaters were closer to the recommended rates for the crops, with excess being applied only to cotton and maize. However, surplus P addition is not a significant environmental concern since this element is readily fixed in the soil, particularly under calcareous conditions where it forms insoluble calcium phosphate.

The potassium contents of the wastewaters was large relative to crop requirements, compared with those for N and P. Consequently, crop requirements for potassium (as K_2O) were general exceeded by large margins for most crops. However, potassium is held strongly by soils, particularly those with high cation exchange capacities, and even where this is exceeded and leaching occurs, this will be adsorbed further down the soil profile. In the long-term, groundwater quality could be affected but not adversely as there are no environmental problems associated with this, other than its contribution to salinity levels.

Table 3 Proportion of Nutrients supplied by El Berka Wastewaters to the Field Trials compared with Generally Recommended Rates of Fertilizer for Summer and Winter Crops on Desert Soil.

Crop	Fertilizer recommended (kg/fd)			Addition in wastewater (kg/fd)			Nutrients supplied by wastewater as % of fertilizer		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Summer crops									
Maize	105	15.5	24	45.8	28.0	59.4	44	181	248
Cotton	75	22.5	48	132.3	80.9	171.3	176	360	357
Soya bean	60	22.5	24	32.3	19.7	41.8	54	88	174
Sunflower	60	31	48	36.7	22.4	47.5	61	72	99
Winter crops									
Wheat	100	22.5	24	36.5	22.3	47.2	36	99	197
Faba bean	60	31	48	36.8	22.5	47.7	61	73	99
Lupin	60	31	24	38.5	23.5	49.8	64	76	208
Canola	45	22.5	24	35.4	21.6	45.8	79	96	191

The data of of chemical additions through treated wastewater varies according to crop water requirements at the duration of cropping. The data show that under such version soils small additions of heavy metals were received; moreover some elements as Cd, Mo and Co were below the detection limit as shown in Table 1. These results clearly reflect minimum pollution in the short and long terms and indicate the suitability of Cairo wastewater for reuse on the agricultural land. Similar results were obtained by Mahmoud et al (1998) in Jordan and (WRc,2001) and abd El Lateef et al(2006) in Egypt.

3- Crop Yields

A. Summer Crops

The overall growth performance and yield criteria of summer crops showed statistically significant increases due to the addition of fertilizer. The coefficients of variation of the means of data derived from individual plant measurements were quite small, but the CVs of the yields derived from area assessments were relatively large due to crop variability

Application of recommended fertilizer rates to maize significantly increased all growth and yield characters. Maize grain yields were large for this soil type, and the addition of fertilizer increased yields by 52%, approaching the national average yield of 2.3 t/fd. The grain to straw ratio was 1:3.5, indicating that a greater proportion of the nutrients were supporting grain production, rather than straw. These ratios were the same whether fertilizer was applied or not, which suggests that maximum potential grain yields for these sites may not have been achieved, as an increased straw production may be expected relative to grain if excessive levels of nutrients are applied.

Table 4 Effect of treated wastewater and fertilizer application on yield and yield components of maize

Treatment	Crop height (cm)	Stem diameter (cm)	Ear weight (g)	Ear diameter (cm)	Grain weight per ear (g)	100 grain weight (g)	Grain yield (t/fd)	Straw yield (t/fd)	Biological yield (t/fd)
Treated wastewater	200.3	2.03	83.83	3.91	61.8	22.20	1.290	4.585	5.876
Treated wastewater +F	215.8	2.26	94.18	5.36	69.6	28.86	1.956	6.940	8.897
Significance	***	***	*	***	*	***	**	***	***
Probability	0.0007	0.0005	0.0304	<0.0001	0.0343	<0.0001	0.0012	<0.0001	<0.0001
CV%	6.8	9.1	16.5	19.4	17.6	16.3	38.2	24.3	25.3
$LSD_{0.05}$	8.2	0.12	9.27	0.36	7.1	1.90	0.037	0.491	0.708

Cotton responded well to irrigation with treated wastewater and the addition of fertilizer resulted in significant small increases in only number of branches and seed yield per plant as well as straw and biological yields per feddan(Table 5). Seed cotton yield per plant (total of two picks), as measured on an individual plant basis, was increased significantly by the addition of fertilizer (P<0.0001), with yields of fertilizer treatments being three times that from the treated wastewater only ,however the large CV indicates the high variability of these data. When yields were measured on an area basis, there were no significant effects on seed cotton yield at either picks. Straw yield was significantly increased by fertilizer application to wastewater , the increase was similar to that observed for seed cotton (19% vs 13%). The first pick accounted for 75% of the total yield on both treatments

Table 5 Effect of treated wastewater and fertilizer application on yield and yield components of cotton

Treatment	Plant height (cm)	No. of branches per plant	No. of bolls per plant	Seed cotton yield per plant (g)	Yield 1st pick (t/fd)	Yield 2nd pick (t/fd)	Seed cotton yield (t/fd)	Straw yield (t/fd)	Biological yield (t/fd)
Treated wastewater	101.6	7.56	21.75	5.93	0.602	0.193	0.794	2.245	3.040
Treated wastewater +F	112.1	8.13	22.43	16.79	0.674	0.221	0.895	2.684	3.579
Significance	ns	*	ns	***	ns	ns	ns	**	***
Probability	0.0598	0.015	0.5668	<0.0001	0.0715	0.1802	0.0876	0.0015	0.0008
CV%	10.1	6.5	10.8	52.4	10.8	24.4	12.7	13.2	11.2
$LSD_{0.05}$	-	0.42	-	2.11	-	-	-	0.22	0.25

Highly significant increases in all of the growth and yield parameters of soybean characters were achieved by the addition of fertilizer over those achieved by the treated wastewater on its own (Table 6). Clearly, the treated wastewater alone provided insufficient nutrients since fertilizer increased the measured parameters by about 150%. Seed yield increased from 0.35 t/fd to 0.88 t/fd, and the latter compares favourably with the national average yield of 1.1 t/fd, considering the poor quality of this soil. Straw yield also increased substantially with the addition of fertilizer but the seed : straw ratio was slightly smaller, indicating that optimum yield had not been reached

Table 6 Effect of treated wastewater and fertilizer application on yield and yield components of soybeane

Treatment	Plant height (cm)	No. of pods per plant	Pod weight per plant (g)	Seed yield per plant (g)	100 seed weight (g)	Seed yield (t/fd)	Straw yield (t/fd)	Biological yield (t/fd)
Treated wastewater	59.5	53.5	55.9	30.00	18.68	0.347	1.495	1.841
Treated wastewater +F	69.7	135.8	172.0	84.68	20.33	0.884	3.508	4.393
Significance	***	***	***	***	**	***	***	***
Probability	<0.0001	<0.0001	<0.0001	<0.0001	0.0051	<0.0001	<0.0001	<0.0001
CV%	26.6	53.8	66.3	57.1	6.8	49.6	44.4	45.3
$LSD_{0.05}$	5.11	22.4	41,.7	12.42	1.01	0.117	0.297	0.389

Table 7 Effect of treated wastewater and fertilizer application on yield and yield components of sunflower

Treatment	Plant height (cm)	Stem diameter (cm)	Head diameter (cm)	Head weight per plant (g)	Yield per plant (g)	Seed yield (t/fd)	Straw yield (t/fd)	Biological yield (t/fd)
Treated wastewater	161.2	1.78	15.23	157.3	122.80	0.941	4.661	5.602
Treated wastewater +F	226.3	2.60	23.75	734.1	176.43	1.573	11.241	12.814
Significance	***	***	***	***	***	***	***	***
Probability	<0.0001	0.0002	<0.0001	<0.0001	0.0002	0.0003	<0.0001	<0.0001
CV%	18.1	22.2	24.1	68.1	26.4	40.1	46.7	43.4
$LSD_{0.05}$	10.4	0.32	2.04	55.6	20.50	0.257	1.281	1.465

Data presented in table 7 indicate that tere were highly significant effects of fertilizers on all of the growth and yield parameters of sunflower, with substantial increases in plant height, stem and head diameter, head weight and seed and straw yields, compared with those achieved with only treated wastewater . The addition of fertilizer increased seed yield by 67%, but increased straw yield by 141%. . This may be attributed in part to the nutrient supply from El Berka effluent which closely met with recommended amounts of fertilizer for this crop.

B. Winter Crops

It is worthy to mention that the design of the trial was enhanced and more irrigation systems were applied in winter season to provide direct comparisons of more different irrigation systems with the same crops.

The results of lupin growth and yield parameters are summarised in Table 8. . The addition of fertilizer increased crop performance of all parameters, with significant effects being recorded for plant height, number of branches and pods per plant and 100 seed weight. The results showed that the performance of individual plants under drip irrigation were superior to those under flood irrigation, but on an area basis reversible magnitude was reported although none of the effects were statistically significant. This was due to the large difference in plant densities: there were 26,000 plants per feddan due to the wider row spacing to allow for drip irrigation, compared with 49,600 plants per feddan under surface irrigation.

There were no significant interactions between irrigation method and fertilizer addition, but the means reported in Table 8 show that under either irrigation system, fertilizer increased crop performance.

Data presented in Table 9 show that all of wheat yield parameters were larger under surface irrigation, although only plant height, straw and biological yields were significantly greater (P=0.0062; 0.0014; 0.0074, respectively). The harvest index was greater under sprinkler irrigation (i.e. relatively more grain was produced relative to straw yield), although grain yield was 88% of that under surface irrigation. This was despite the fact that the crop under sprinkler irrigation received on average slightly more water than under surface irrigation (2918 m^3/fd compared with 2764 m^3/fd), and may be explained by greater evaporative losses from sprinkler irrigation .The addition of fertilizer increased crop response for all of the crop parameters measured, although only plant height, spike length and grain yield were significantly different (P=0.0217; 0.0063; 0.0109, respectively). There were no significant interactions between irrigation method and fertilizer regime.

These results emphasise that the recommended amounts of fertilizer are necessary to achieve adequate yields of wheat on this type of soil, even when irrigated by treated wastewater. This is may be due to that the addition of nutrients by treated wastewater irrigation is cumulative over the growing period of the crop, whilst fertilizer is applied in several doses, planned according to the growth of the crop to ensure appropriate nutrition throughout. This is demonstrated by the improved harvest indexes where fertilizer was applied.

Table 8 Effect of treated wastewater irrigation and fertilizer application on yield and yield components of lupain

Treatment	Plant height (cm)	No. of branches per plant	No. of pods per plant	Pod weight (g/plant)	Seed yield (g/plant)	100 seed weight (g)	Plant weight (g)	Plant stand/fd (x1000)	Seed yield (kg/fd)	Straw yield (t/fd)	Biological yield (t/fd)	Harvest index
CV%	17.1	50.99	59.2	47.8	48.11	13.21	48.32	42.15	50.56	72.555	61.73	30.58
Irrigation mean												
Surface	62.2	3.0	9.9b	23.8b	14.1	32.5	42.8	49.6a	0.252	0.834	1.086	0.337
Drip	69.7	5.2	18.2a	32.7a	18.2	35.3	60.7	26.0b	0.164	0.434	0.597	0.316
Probability	-	-	0.032	0.0483	-	-	-	0.0074	-	-	-	-
Significance	ns	ns	*	*	ns	ns	ns	**	ns	ns	ns	ns
$LSD_{0.05}$	-	-	7	8.81	-	-	-	11.555	-	-	-	-
Fertilizer mean												
Treated wastewater	62.1b	3.7b	12.2b	25.6	14.6	31.5b	46.9	39.6	0.189	0.476	0.664	0.318
Treated wastewater +F	69.8a	4.5a	15.8a	30.9	17.7	36.3a	56.6	36.0	0.227	0.793	1.020	0.336
Probability	0.0031	0/0202	0.037	-	-	0.045	-	-	-	-	-	-
Significance	**	*	*	ns	ns	*	ns	ns	ns	ns	ns	ns
$LSD_{0.05}$	4	0.61	3.3	-	-	4.64	-	-	-	-	-	-
Interaction (irrigation x fertilizer)												
Surface -F	56.6	2.4	7.5	23.0	13.3	30.9	41.0	53.9	0.231	0.522	0.753	0.335
+F	67.8	3.6	12.2	24.5	14.9	34.1	44.7	45.3	0.272	1.147	1.419	0.340
Drip -F	67.6	5.0	17.0	28.2	15.8	32.1	52.8	25.3	0.146	0.428	0.574	0.301
+F	71.9	5.4	19.5	37.3	20.6	38.6	68.5	26.7	0.181	0.439	0.620	0.332
Probability	-	-	-	-	-	-	-	-	-	-	-	-
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
$LSD_{0.05}$	-	-	-	-	-	-	-	-	-	-	-	-

All of the yield parameters of canola under surface irrigation were greater than under sprinkler irrigation (Table 10), despite the fact that a larger quantity of treated wastewater was irrigated by sprinkler (mean of 2830 m^3/fd compared with 2682 m^3/fd). This indicates greater water efficiency under surface irrigation and may be due to larger evaporative losses from sprinkler irrigation. However, statistically significant differences were only detected for number of seed per pod, straw and biological yields. The harvest index was greater under surface irrigation, without significant differences

Table 9 Effect of treated wastewater irrigation and fertilizer application on yield and yield components of wheat

Treatment	Plant height (cm)	No. of tillers per plant	No. of spikes/ m^2	Spike weight (kg/m^2)	Spike length (cm)	1000 grain weight (g)	Grain yield (t/fd)	Straw yield (t/fd)	Biological yield (t/fd)	Harvest index
CV%	8.1	65.6	20.3	31.4	11.4	11.6	25.25	30.86	26.66	21.878
Irrigation mean										
Surface	83.1a	8.3	462	0.842	10.2	35.8	1.127	4.634a	5.761a	0.198
Sprinkler	73.3b	4.0	367	0.603	9.4	37.3	0.992	2.986b	3.978b	0.251
Probability	0.0062	-	-	-	-	-	-	0.0014	0.0074	-
Significance	**	ns	ns	ns	ns	ns	ns	**	**	ns
$LSD_{0.05}$	4.53	-	-	-	-	-	-	0.459	0.873	-
Fertilizer mean										
Treated wastewater	75.9b	4.8	401	0.667	9.2b	37.2	0.912b	3.413b	4.324	0.218
Treated wastewater +F	80.5a	7.5	428	0.778	10.4a	35.9	1.208a	4.207a	5.415	0.235
Probability	0.0217	-	-	-	0.0063	-	0.0109	-	-	-
Significance	*	ns	ns	ns	**	ns	*	ns	ns	ns
$LSD_{0.05}$	3.7	-	-	-	0.71	-	0.2	-	-	-
Interaction (irrigation x fertilizer)										
Surface –F	80.4	6.2	444	0.765	9.9	37.4	1.009	4.165	5.173	0.194
+F	85.9	10.4	480	0.920	10.5	34.1	1.246	5.104	6.349	0.202
Sprinkler -F	71.4	3.4	358	0.569	8.5	37.0	0.814	2.661	3.476	0.241
+F	75.2	4.6	376	0.637	10.3	37.6	1.171	3.310	4.481	0.267
Probability	-	-	-	-	-	-	-	-	-	-
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
$LSD_{0.05}$	-	-	-	-	-	-	-	-	-	-

Table 10 Effect of treated wastewater irrigation and fertilizer application on yield and yield components ofcanola

Treatment	Plant height (cm)	No. of branches per plant	No. of pods per plant	Pod weight (g/plant)	Seed yield (g/plant)	No. of seed per pod	Plant weight (g)	Plant stand/fd (x1000)	Seed yield (kg/fd)	Straw yield (t/fd)	Biological yield (t/fd)	Harvest index
CV%	14.65	28.97	48.06	54.66	23.2	8.77	66.82	19.54	59.1	54.61	48.015	52.68
Irrigation mean												
Surface	103	33.2	555	79.4	30.5	25.4a	141.7	48.5	282.8	2.675 a	2.958 a	0.320
Sprinkler	96	34.5	471	57.8	24.2	22.2b	111.1	42.7	195.1	2.008 b	2.202 b	0.274
Probability	-	-	-	-	-	0.004	-	-	-	0.0185	0.0083	-
Significance	ns	ns	ns	ns	ns	**	ns	ns	ns	*	**	ns
$LSD_{0.05}$	-	-	-	-	-	1.28	-	-	-	0.455	0.385	-
Fertilizer mean												
Treated wastewater	93	33.6	493	69.7	24.3b	23.1b	131.2	44.0	206.2 b	2.104 b	2.311 b	0.276
Treated wastewater +F	106	34.1	532	67.5	30.5a	24.5a	121.6	47.2	271.5 a	2.577 a	2.849 a	0.317
Probability	0.0082	-	-	-	0.0093	0.0132	-	-	0.0206	0.0416	0.031	-
Significance	**	ns	ns	ns	**	*	ns	ns	*	*	*	ns
$LSD_{0.05}$	8.33	-	-	-	3.94	1.04	-	-	51.2	0.448	0.47	-
Interaction (irrigation x fertilizer)												
Surface –F	99	33.4	565	84.3	27.4	24.6	155.1	45.7	236.7	2.711 a	2.947 a	0.294
+F	107	33.1	545	74.5	33.5	26.2	128.2	51.5	328.9	2.639 a	2.968 a	0.344
Sprinkler -F	87	33.8	422	55.0	21.1	21.5	107.3	42.4	175.7	1.499 b	1.675 b	0.258
+F	104	35.1	520	60.5	27.2	22.8	114.9	43.1	214.2	2.515 a	2.730 a	0.289
Probability	-	-	-	-	-	-	-	-	-	0.0249	0.0359	-
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	*	ns
$LSD_{0.05}$	-	-	-		-	-	-	-	-	0.448	0.47	-

From the same table, significant increases in yield response due to the addition of fertilizer were observed for plant height, number of seed per pod, and seed, straw and biological yields. There were small but significant interactions between irrigation method and fertilizer treatments for straw and biological yields . Yields under sprinkler irrigation with fertilizer added were also smaller than the corresponding yields from the surface irrigation treatment, although not significantly, despite the fact that this treatment received 32% more treated wastewater

Data presented in table 11 show that there were no significant effects of irrigation method on the yield parameters of faba bean. The quantities of treated wastewater irrigated by both methods were similar (about 2870 m^3/fd). As expected, the lower plant density under drip irrigation produced larger individual plants with more pods, but seed weight was smaller. Consequently, the harvest index was better under surface irrigation (normal method of irrigation), and had the largest seed and straw yields on an area basis.

The addition of fertilizer increased all yield parameters insignificantly except for plant height and seed yield (P=0.0012 and 0.0409, respectively). There were insignificant interactions between irrigation method and fertilizer addition.

Surface irrigation on an area basis produced greater yields of faba bean than drip irrigation, but this was principally due to the different crop densities as the crop rows under drip irrigation were spaced more widely than under surface irrigation, and as a result had about half the number of plants per unit area. Both methods of irrigation applied similar quantities of wastewater and at an individual plant level, drip irrigation produced larger plants than surface irrigation. Considering the large difference in plant stands, drip irrigation performed well, although this method would not be employed commercially for such crop on economic grounds.

These results drived from all crops clearly show that some field crops respond well to irrigation with treated wastewater i.e.; maize, cotton, wheat and fababean . However, other crops like lupin, canola and soybean showed less response for irrigation with treated wastewater under the poor desert conditions. Several investigators obtained yield increases due to wastewater application (Vazquez-Montial et al, 1996; Shahlam et al, 1998; Al-Dadah,1999; Palacios et al, 2000 and WRc, 2000 and 2001). Such increase in crop yields due to wastewater irrigation could be attributed to the nutrient content in relation to specific crop requirements. In this respect, Campbell,et al ,(1983) stated that weekly application of 25 mm wastewater was enough to supply 40-80% of corn requirements and all of P requirements while other researchers pointed out that the increase in corn yield was due to the enhancement of nutrient uptake and the improvement of the physical properties of the soil.

Table 11 Effect of treated wastewater irrigation and fertilizer application on yield and yield components of fababean

Treatment	Plant height (cm)	No.of branches per plant	No.of pods per plant	Pod weight (g/ plant)	Seed yield (g/plant)	100 seed weight (g)	Plant weight (g)	Plant stand/fd (x 1000)	Seed yield (t/fd)	Straw yield (t/fd)	Biological yield (t/fd)	Harvest index
CV%	17.86	11.71	28.19	25.04	27.27	6.82	26.99	47.17	41.51	56.47	49.2	27.73
Irrigation mean												
Surface	87.6	3.4	13.3	59.7	48.6	95.8	116.0	45.9a	0.884	1.524	2.408	0.437
Drip	93.5	3.9	18.0	65.6	43.6	91.8	130.7	24.6b	0.695	1.205	1.906	0.336
Probability	-	-	-	-	-	-	-	0.0394	-	-	-	-
Significance	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns
$LSD_{0.05}$	-	-	-	-	-	-	-	19.348	-	-	-	-
Fertilizer mean												
Treated wastewater	81.7b	3.7	14.3	57.7	43.1	92.8	114.9	34.6	0.701b	1.221	1.922	0.378
Treated wastewater +F	99.5a	3.6	17.0	67.5	49.1	94.8	131.8	35.9	0.878a	1.507	2.392	0.395
Probability	0.0012	-	-	-	-	-	-	-	0.0409	-	-	-
Significance	**	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns
$LSD_{0.05}$	7.57	-	-	-	-	-	-	-	0.167	-	-	-
Interaction (irrigation x fertilizer)												
Surface -F	77.1	3.4	13.0	56.6	45.9	93.6	109.9	46.2	0.785	1.314	2.100	0.418
+F	98.2	3.4	13.7	62.8	51.3	97.9	122.1	45.5	0.983	1.734	2.717	0.455
Drip -F	86.3	3.9	15.6	58.9	40.3	92.1	119.8	22.9	0.617	1.128	1.745	0.338
+F	100.8	3.8	20.4	72.1	46.9	91.6	141.6	26.3	0.772	1.281	2.067	0.334
Probability	-	-	-	-	-	-	-	-	-	-	-	-
Significance	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
$LSD_{0.05}$	-	-	-	-	-	-	-	-	-	-	-	-

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دراسة اعادة استخدام مياه الصرف الصحى للضفة الشرقية بالقاهره
1- استجابة بعض محاصيل الحقل للرى بالمياه المعالجة ثنائيا فى ارض صحراويه

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الملخص

اجرى هذا العمل بهدف تقييم استخدام مصادراضافية لمياه الرى يمكن استخدامها تحت ظروف ندرة المياه حيث قمح، فول بلدى، ترمس ، كانولا)واضيفت مياه الرى منفردة او متحدة مع الكميات الموصى بها للمحاصيل اجريت تجارب حقلية موسعة فى ارض بكر(رمليه حصويه) لم يسبق زراعتها لدراسة تأثير رى بعض المحاصيل الحقلية بمياه الصرف الصحى المعالجة ثنائياوالناتجة من محطة معالجة مياه الصرف الصحى بالقاهرة واقيمت التجارب فى موسمى صيفى 2000 و شتوى2001/2000 حيث تبادلت اربعة محاصيل صيفيه(الذرة، القطن، عباد الشمس،فول الصويا)مع اربعة محاصيل شتوية (واختبرت فى هذه التجربة نظم الرى السطحى والرى بالرش والرى بالتنقيط. واشارت النتائج الى ان الرى بالمياه المعالجة ادى الى اضافة كميات ملموسة من العناصر الغذائية الكبرى النيتروجين والفوسفور والبوتاسيوم الى المحاصيل الحقلية بلغت(44-79 %) من عنصر النيتروجين، (72-181 %)من عنصر الفوسفور ، (99-248%) من عنصرالبوتاسيوم كنسبة مئويه من الاحتياجات السمادية الموصى باضافتها للمحاصيل المختبره وطبقا لنوع المحصول باستثناء القطن . واظهرت التحاليل ان كمية العناصر الثقيلة المضافة عن طريق الرىكانت صغيرة جدا، كما اشارت النتائج الى حدوث فروق جوهرية فى انتاجية المحاصيل نتيجة الرى بالمياه المعالجة و اتضح ايضا ان محاصيل الذرة الشامية والقطن وعباد الشمس كانت افضل المحاصيل ملاءمة للرى بالمياه المعالجة ثنائياوان طريقة الرى بالغمر كانت اكثر فعالية من الرش والتنقيط .ويستنتج من هذه الدراسة انه على الرغم من عدم وجود دلائل للتلوث الميكروبى او الطفيلى نتيجة التحليل الميكروبيولوجى لتلك المحاصيل الا انه لا يزال من المبكر جدا الرى بمياه الصرف الصحى المعالجة ثنائيا على الرغم من افضليتها لبعض المحاصيل تحت ظروف الجفاف

ويفضل من الوجهة الصحية والبيئية استخدام مياه ذات درجة معالجة اعلى(ثلاثية)حتى فى حالة استخدام محاصيل لا تؤكل ويتم استخدامها فى الصناعة.

الكلمات المفتاحية : محاصيل الحقل، رى، مياه معالجة، عناصر غذائية، معادن ثقيلة