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Estimation of the Agro-Monetary Value of Irrigation with Treated Wastewater of Soybean and Sunflower

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Abstract: This study was conducted to evaluate the agro-economic value of wastewater reuse in sandy soil. Demonstration field trials were conducted in sandy soil to evaluate the effect of irrigation with secondary treated wastewater from El Berka wastewater treatment plant on processed oil food crops .The results showed that considerable amounts of macronutrients (NPK) were applied to both crops through the treated wastewater irrigation: N (54, 61%), P_2O_5 (88, 72%) and K_2O (174, 99%) of the recommended fertilizer rates for soybean and sunflower, respectively. Crop yields showed significant differences when treated wastewater was combined with the recommended fertilizer rates for both crops. The calculation of fertilizer value in EGP on the basis of market prices in Egypt showed that nitrogen addition value estimated by 433and 492 EGP, P between273, 310 EGP while K ranged between3762 and 4275 EGP for soybean and sunflower, respectively. The Economic value of fertilizer inputs applied to the field crops indicate that the total NPK value was 4469.and 5073 LE for soybean and sunflower, respectively. It could be concluded from this study that treated waste water has substantial agronomic value for most of the field crops studied. Wastewater irrigation could save partial NPK crop requirements and needs fertilizer compensation. The advantage of field crop irrigation with treated wastewater is evident from the agronomic and economic scene.

Key words: Oil crops · Sandy soil · Wastewater reuse · NPK · Monetary value

INTRODUCTION

Water crisis are rising sharply all over the world with special refrence to Egypt, whwe the the annual water demand exceeds the available fresh water. The findings indicated that water shortage in 2025 would be 26 BCM/yr in case of continuation of current policies [1]. Water reuse is arising because of water crisis with Nile basin countries, ambitious land reclamation programs, growing populations, increasing rural development and crop demands. Egypt is one of the most arid countries in the world, where the water gap amounts to a shortage of 90% of renewable resources. The ministy said that Egypt is attempting to fill this gap through importing 54% of its water and reusing 42% of the reusable water. He also reviewed Egypt's plan to deal with the water crisis [2].

However, there are attendant risks involved with reuse to the plant, soil, groundwater and health [3-6]. One of the most recognized benefits of wastewater use in agriculture is the associated decrease in pressure on freshwater sources [7]. Thus, wastewater serves as an alternative irrigation source [8], especially for agriculture, the greatest global water user, which consumes 70% of available water [9]. Furthermore, wastewater reuse increases agricultural production in regions experiencing water shortages, thus contributing to food safety [9].

Under Egyptian conditions it have been 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 [10]. Additionally, the nutrients naturally present in wastewater allow savings of fertilizer expenses to be

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realized [8, 11-13], thus ensuring a closed and environmentally favorable nutrient cycle that avoids the indirect return of macro- (especially nitrogen and phosphorous) and microelements to water bodies. Depending on the nutrients, wastewater may be a potential source of macro- (N, P and K Ca, Mg, B, Mg,) and micronutrients (Fe, Mn or Zn) [14, 15]. Evidently, wastewater reuse has been proven to improve crop yield and result in the reduced use of fertilizers in agriculture [16].

Therefore, the aim of this work is to evaluate the effect of treated wastewater on irrigation of oil crops yields and the agronomic and economic value of the nutrients applied through wastewater irrigation in sandy soil .

MATERIALS AND METHODS

Demonstration field trials were carried out in winter and summer season in El Berka site located about 20 km north east of Cairo. As it was intended to use secondary treated wastewater and to be secured the experimental site was located inside El Berka wastewater treatment plant; the soil is gravelly sand and could be classified as sandy soil. The experimental area was divided into 16 large experimental units 8 allocated for each crop selected according to the crop and the irrigation method. The design of each trial was Complete Randomized Block Design with 4 replicates where 4 plots received wastewater only and the other 4 received wastewater plus supplementary fertilizer to be adjusted for each crop according to the normal recommended rates. Crop was according to [17] where soybean (Giza82) variety and sunflower (local variety) were grown. The experimental plot area was 200m^2 (10x20m). Fertilizers were applied according to the normal recommended rates in Egypt for each crop. 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: At crop maturity, the growth characteristics and yield components were assessed crop. The individual plant measurements included plant height and weight, as well as number, weight and dimensions of fruiting. The conventional assessment practices were followed to provide mean individual plot performance as well as biological, straw and seed yield /feddan. This research will focus only on the economic yield parameters.

Treated Wastewater Analysis: Samples of treated wastewater from El-Berka were taken during crop cycles and analyzed 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. Another objective of these analyses was to determine wastewater compliance with the Egyptian limit values [18]. Treated wastewaters were analyzed according to [19].

Wastewater Fertilizer Inputs to Field Crops: It was calculated from total water quantity irrigated to each crop and nutrient concentration in wastewater according to [10].

The Economic Value of Nutrient Addition: It was calculated from nutrient addition to each crop on fertilizer prices basis in Egypt (LE).

Statistical Analysis: The obtained results were subjected to the proper statistical analysis using MSTAT-C package, program according to MSTAT-C [20]. For means comparison LSD at 5% was used.

RESULTS

Treated Wastewater Quality: Final wastewater samples collected from El Berka WWTP over the period of the trials were monthly routinely analysed for nutrients and heavy metals (Table 1). The results showed that the pH of the wastewaters was within the acceptable range for reuse, normally 6.5-8.5 according to the Egyptian decree for wastewater reuse [18]. It is apparent that the nutrient contents of the wastewater was broadly similar in their suitability for reuse. The heavy metal concentrations were very small in wastewater and are well below the limit values for secondary wastewater reuse, usually by at least one order of magnitude where the limit values of the heavy metals according to the Egyptian decree for wastewater reuse [18] are (0.01 for Cd and Cr; 0.2 for Cu, Ni and Mn, 0.05 for Co and 5 mg kg^{-1} for Fe). The numbers of faecal coliforms found in treated wastewater were at 10^6 MPN/L, far in excess of that permitted by the guidelines of [17] and salmonella were present in all samples. Nematode ova were found in all samples of treated wastewater in excess of the limit value for reuse (mean 49 ova/L). Table 1 presents the mean concentrations of treated wastewater chemistry and microbiology.

Table 1: Mean concentrations of treated wastewater chemistry and microbiology from El Berka WWTPs

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
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	-
Salmonella	1.8	1	2	26	26.1
F. coliforms	35	3	82	24	71.7
Helminth	49	5	202	25	103.1

Units: All determinants in mg/L except: *EC* (dS/m); salmonella qualitative range 0 = absent, 1 = low, 3 = high; faecal coliform bacteria 10^5 MPN/100 ml; helianthus ova/L.

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

	NPK	
Crop	-	+
Soya bean	2197	2831
Sunflower	2829	2884

fd =feddan = 4200m^2

Wastewater Fertilizer Inputs to Field Crops: 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 four replicate 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.

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.

Table (3) lists the normally recommended application rates of inorganic fertilizer to the range of crops tested in these trials. The recommendations oil crops are different according to the fertility level of the soil and recommended for each crop.

Nevertheless, the wastewaters provide a significant proportion of the normal recommended fertilizer rates. Soybean received 54% of its recommended N rate, but this was due to the high irrigation demand of this crop on desert soil and would not normally be grown under these conditions (Fig. 1). 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 wastewater was closer to the recommended rates for the crops, with excess being applied only to soybean. However, surplus P addition is not a significant environmental concern since this element is readily fixed in the soil 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 level.

The data of of chemical additions through treated wastewater varies according to crop water requirements at the duration of cropping. The data show that sandy soil received small additions of heavy metals; 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 [21] in Jordan and [10] in Egypt. Barreto et al and Liu *et al*. [14, 22] indicated that depending on the nutrients, wastewater may be a potential source of (N, P and K) and micronutrients (Ca, Mg, B, Mg, Fe, Mn or Zn). Also [23, 24] came to similar results.

The general chemistry of the treated wastewater does not impose any constraints on the types of crops that may be grown or the types of soil to which it may be applied. Beneficial additions of NPK to the grown crops were evident and in accordance with the results of [10]; they showed that these treated wastewaters would generally provide approximately 50% of N and about 70%

Table 3: Proportion of Nutrients supplied by Wastewaters to the soybean and sunflower compared with Generally Recommended Rates of Fertilizer in sandy Soils

Crop	Fertilizer recommended (kg/fd)			Addition in wastewater (kg/fd)			Nutrients supplied by wastewater as % of fertilizer		
N, P, K	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
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

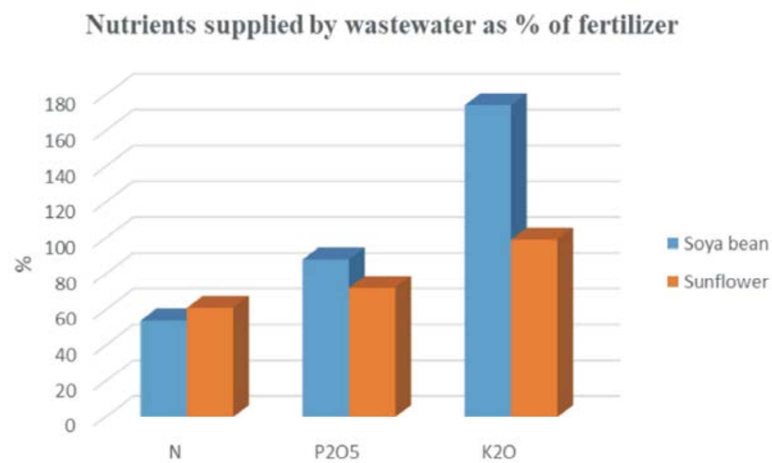

Fig. 1: Macronutrient additions of treated wastewater to soybean and sunflower as a percentage of the recommended NPK rate for each crop in sandy soil

of P requirements but about 200% of K requirement, although this varied widely according to the specific crop and whether this was calculated for a fertile or infertile soil.

The potential long-term consequences to soil quality of irrigating these treated wastewaters were modelled in other studies [10] which showed that it would take several hundred years to reach precautionary soil limit concentrations, but if crop off-take is taken into account, then heavy metal input and output would be more-or-less in balance and there would be minimal net impact on soil quality. Similar results were obtained by [21]. WRc (2001)) [10] in Egypt reported that the concentrations were variable and clearly reflect minimum pollution in the short and long terms and indicate the suitability of Cairo wastewater for reuse on the agricultural land. In another studied [24-26] the researchers came to similar conclusion.

Crop Yields: Data presented in Table 4 and Fig. 2 show the overall yield criteria of soybean and sunflower showed statistically significant increases due to the addition of fertilizer. The coefficients of variation of the means of data derived the yields area assessments were relatively large due to crop variability.

Highly significant increases in all of yield parameters of soybean characters were achieved by the addition of fertilizer over those achieved by the treated wastewater on its own (Table 4 and Fig. 2). 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.

Data presented in Table 4 and Fig. 2 indicate that tere were highly significant effects of fertilizers on all of the yield parameters of sunflower, with substantial increases in 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. Similar results were reported by [21] and [24] on maize, cotton and mungbean .They added that crops irrigated with secondary treated wastewater perform equally as well as, or significantly better than, with canal water.

These results derived from all crops clearly show that some field crops respond well to irrigation with treated wastewater Several investigators obtained yield increases due to wastewater application [27] and [10, [25-27].

Table 4: Effect of treated wastewater irrigation and fertilizer application on yield and yield ccomponents soybean and sunflower irrigated with treated wastewater

Crop	Soybean			Sunflower		
Treatment	Seed yield (t/fd)	Straw yield (t/fd)	Biological yield (t/fd)	Seed yield (t/fd)	Straw yield (t/fd)	Biological yield (t/fd)
Treated wastewater	0.347	1.495	1.841	0.941	4.661	5.602
Treated wastewater +F	0.884	3.508	4.393	1.573	11.241	12.814
Significance	***	***	***	***	***	***
Probability	<0.0001	<0.0001	<0.0001	0.0003	<0.0001	<0.0001
CV%	49.6	44.4	45.3	40.1	46.7	43.4
$LSD_{0.05}$	0.117	0.297	0.389	0.257	1.281	1.465

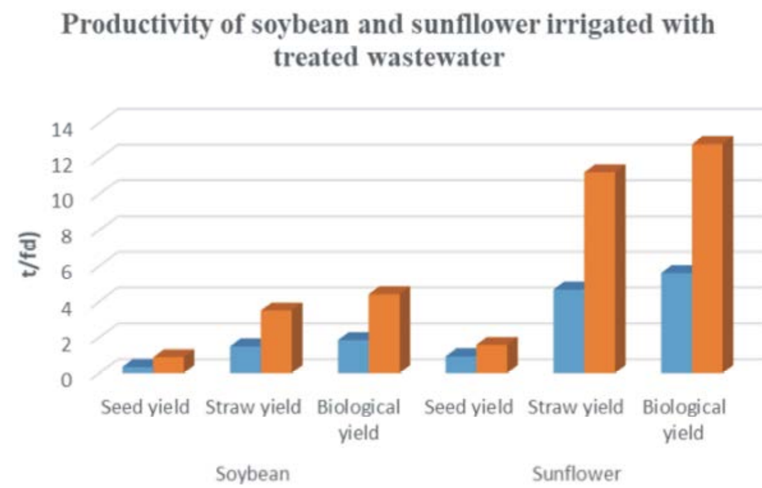

Fig. 2: Productivity of soybean and sunflower irrigated with treated wastewater

Table 6: Wastewater irrigation addition value of N for different crops (EGP)

Crop	N	P2O5	K2O	Total
Soya bean	433.6	273.3	3762.0	4469.0
Sunflower	492.7	310.8	4275.0	5078.5

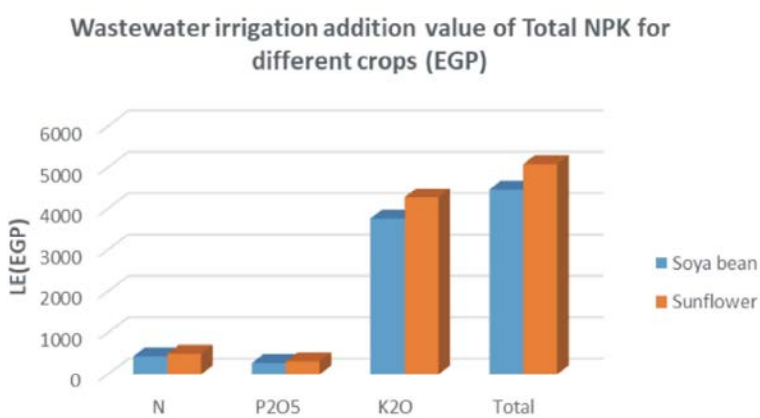

Fig. 3: Wastewater irrigation addition value of Total NPK for different crops (EGP)

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, [28] 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. Indeed, wastewater reuse has been proven to improve crop yield [13, 15] and result in the reduced use of fertilizers in agriculture [16].

Economic Value of Treated Wastewater: Considerable amounts of macronutrients (NPK) were applied to the grown crops through the treated wastewater irrigation. Table 6 show the calculation of fertilizer value in EGP on the basis of market prices in Egypt. Nitrogen addition ranged between nitrogen addition value estimated by 433 and 492 EGP LE, P between273, 310 while K ranged between 3762 and 4275 EGP according to the crop. The Economic value of fertilizer inputs applied to the field crops indicate that the total NPK value was 4469 and 5073 LE for soybean and sunflower, respectively (Fig. 3). The Economic input of fertilizer applied to oil crops indicate that the total NPK value ranged between 4469 and 6079LE for soybean and sunflower, respectively according to the crop NPK requirements and the duration of irrigation These results emphasize that the nutrients naturally present in wastewater allow savings on fertilizer expenses to be realized [11-13 and 23, 24].

The advantage of field crop irrigation with treated wastewater is evident from agronomic and economic scene .Several investigators assured that the nutrients naturally present in wastewater allow savings on fertilizer expenses to be realized [11-13].

CONCLUSIONS

It could be concluded from this study that treated waste water has substantial agronomic value for soybean and sunflower. Wastewater irrigation could save partial NPK crop requirements and needs fertilizer compensation. .The advantage of field crop irrigation with treated wastewater is evident from agronomic and economic scene.

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