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Some Agro-Environmental Studies on Sunflower (*Helianthus annuus*)

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Abstract: Field trials were conducted in two sites located about 20 km northeast of Cairo (clay soil) and (sandy soil). The trials aimed to evaluate the impact of sunflower irrigation with secondary treated wastewater (TWW) on water productivity, yield, quality and heavy metal content. Treated wastewater (TWW) supplied sunflower with 61, 72 and 99% of the recommended requirements of N, P and K, respectively in the sandy soil while the corresponding values in the clay soil were 40, 36 and 178% for N, P and K, respectively. The results clearly showed that the sunflower crop suited the sandy soil as the crop produced 29% increase more than the seed yield achieved in the clay soil. There were significant increases in seed yield, straw and biological yields due to NPK application. Oil yields were 1.82 and 1.71 t ha^{-1} on sandy and clay soils, respectively when the plants were irrigated with treated wastewater alone while they reached 3.03 and 2.22 when irrigation water was combined with NPK application in the sandy and clay soils, respectively. Seed analysis indicated that the ranges of heavy metals were within the normal ranges expected and were far below levels that would be of concern due to the high pH of both sites. Water productivity.

Key words: Sunflower · Wastewater · Yields · Oil content · Heavy metals

INTRODUCTION

Treated wastewater (TWW) generated from Greater Cairo is about 1.85 million m^3 day^{-1} and it is estimated that the generated treated wastewater reached up to 3.5 million m^3 day^{-1} in the year 2020. From an environmental point of view, such quantities should be disposed off safely. Under limited water resources and drought conditions wastewater has been used to support agricultural production in many countries such as the USA, Germany, India, Kuwait, Saudi Arabia, Oman, Jordan and Tunisia [1]. Several investigators indicated the beneficial role of wastewater in increasing crop yields without or with minimal risks to the plant, soil, groundwater and health [2-7]. One of the most recognized benefits of wastewater use in agriculture is the associated decrease in pressure on freshwater sources. Thus, wastewater serves as an alternative irrigation source [8], especially for agriculture, the greatest global water user, which consumes 70% of available water TWW provides a promising, unconventional water source for irrigation in Egypt [9]. Furthermore, wastewater reuse increases agricultural production in regions experiencing water shortages, thus contributing to food safety [10]. Depending on the nutrients, wastewater may be a potential source of macro- (N, P and K) and micronutrients (Ca, Mg, B, Mg, Fe, Mn or Zn) [11-12]. Indeed, wastewater reuse has been proven to improve crop yield [12-13] and result in the reduced use of fertilizers in agriculture [14]. However, under Egyptian conditions many restrictions have been adopted on wastewater reuse and it is only permitted for wooden trees production. Since oil crops production is considered very important to Egypt and it needs processing before consumption, they may fit irrigation with secondary treated wastewater and benefit from the nutrient additions of wastewater. Therefore, the aim of this work is to evaluate the effect of treated wastewater on sunflower yield and quality under two types of Egyptian soils.

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MATERIALS AND METHODS

Two field trials were carried out in two summer seasons in two sites located about 20 km northeast of Cairo; El Gabal El Asfar farm (clay soil) and Berka site (sandy soil). The trials aimed to evaluate the impact of sunflower irrigation methods with secondary treated wastewater on yield, quality and heavy metal content. The area of each trial was 10 feddans (4.2 hectares) close to the new El-Gabal El-Asfar wastewater treatment plant and the soil could be classified as clay soil. The same area was chosen for the second site and is located inside El- the Berka wastewater treatment plant; the soil is sandy soil.

Both experimental sites were cultivated using a fixed tine- harrow, then leveling was carried out. The experimental area was divided into large experimental units 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 (NPK) to be adjusted according to the normal recommended rates and for each site conditions. Sunflower seeds (Sakhs 53) were grown. drip irrigation was used and the irrigation water was measured by a 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 superphosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O), respectively. Samples of treated wastewater from El Gabal El Asfar and El Berka were taken during the crop cycle and analyzed for a range of agronomic parameters. Nutrient and heavy metal loading rates to field trials were calculated according to the irrigation quantities applied to each site. Sunflower yields were determined and seed, oil, nutrient and heavy metal content were determined. Nutrient and heavy metal loading rates for field trials were calculated according to the irrigation quantities applied to each crop. Treated wastewaters were analyzed according to [15]. Crop yields were determined and seed, nutrient and heavy metal content were determined by [16-17].

Oil Yield: Oil yield (kg ha^{-1}) was calculated by seed yield (kg fed^{-1}) × seed oil content (%). Seed oil %: was determined by Soxhlet apparatus using petroleum ether (40°C - 60°C b.p) according to [16].

Water Productivity of Sunflower Seed: WP sunflower seed, straw, biological and oil are indicators of effective use of irrigation treated wastewater for crop production. Water productivity seed was calculated according to [18] as follows:

WP sunflower = Ey/Ir

where: WP sunflower seed is the water productivity of crop seed (kg seed m^{-3} irrigation water), Ey is the economical yield (kg sunflower seed ha^{-1}) and Ir is the amount of applied irrigation water (m^{-3} irrigation water ha^{-1} $season^{-1}$).

Statistical Analysis: The data were subjected to statistical analysis of variance of split-plot design was carried out using MSTAT-C Computer Software [19]. Since the trend was similar in both seasons the homogeneity test Bartlet's equation was applied and the combined analysis of the two seasons was done. Means were compared by using the least significant difference (LSD) at 5%.

RESULTS

Data presented in Table (1) show wastewater qualities applied to sunflower in both sites, all of these parameters are well within the maximum limit values set by the Egyptian Decree 44/2000 for wastewater reuse. The amounts of wastewater irrigated to each crop and fertilizer treatment at both sites were recorded accurately. The quantities of wastewater applied were broadly in line with normal farmer practice in the district. Calculating the major nutrients (NPK) supplied by wastewater as a percentage of the fertilizer recommended rates indicated that treated wastewater supplied sunflower with 35, 43 and 156% of the recommended requirements of N, P and K, respectively in the sandy soil (Sandy soil site) while the corresponding values in the clay soil (Clay soil site) were 79, 96 and 191% for N, P and K, respectively (Fig. 1).

Data presented in Table (2) and Fig. (2) indicate that fertilizer increased sunflower yields (seeds, straw and biological) significantly in clay and sandy soils. The data also show that there were highly significant effects of NPK fertilizer application on all of the yield parameters of sunflower, with substantial increases in seed and straw yields, compared with those achieved with only treated wastewater (TWW). 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 TWW which closely met with recommended amounts of fertilizer for this crop. The oil content was also increased

Table 1: Chemical analyses of wastewater Irrigated in the experimental sites. (All parameters mg l^{-1} except pH)

Parameters	pH	Tot. N	Tot. P	K	B	Fe	Mn	Cr	Ni	Zn	Cu	Cd	Pb	Co	Mo
Clay soil	7.83	9.7	2.6	19.0	0.34	0.362	0.113	0.021	0.025	0.162	0.043	<0.005	0.069	<0.01	0.01
Sandy soil	7.78	12.8	3.4	13.6	0.40	0.577	0.115	0.027	0.039	0.094	0.049	<0.005	0.079	<0.01	<0.005

Table 2: Sunflower yields (t ha^{-1}) as affected by fertilizer and wastewater Irrigation in two soil types

Yield component	TWW	TWW+NPK
Clay soil		
Seed	5.13 b	6.62 a
Straw	18.89 a	17.35 b
Biological	24.02 a	23.98 a
Oil	1.72 b	2.22 a
Sandy soil		
Seed	5.41 b	9.04 a
Straw	26.83 b	64.72 a
Biological	32.25 b	73.76 a
Oil	1.81 b	3.03 a

Note: Numbers in each column followed by different letters are significantly different at P<0.05 between pairs of fertilizer treatments (No F and With F) within each irrigation treatment, crop and site

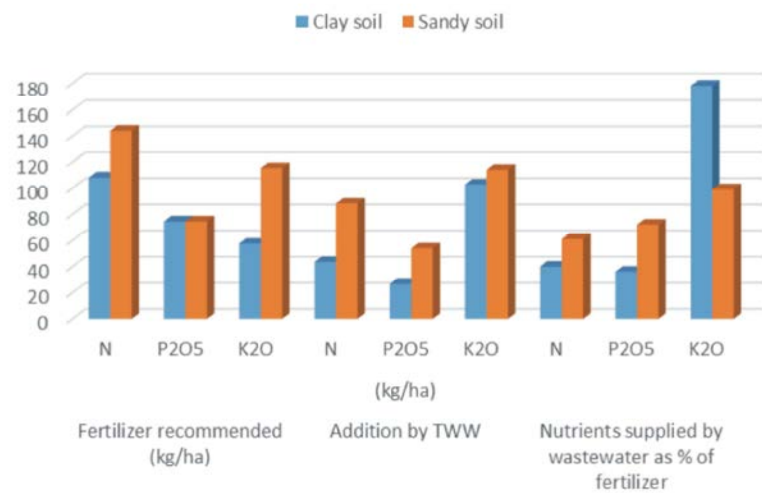

Fig. 1: Major nutrients (NPK) supplied by treated wastewater (TWW) as a percentage of the fertilizer recommended rates

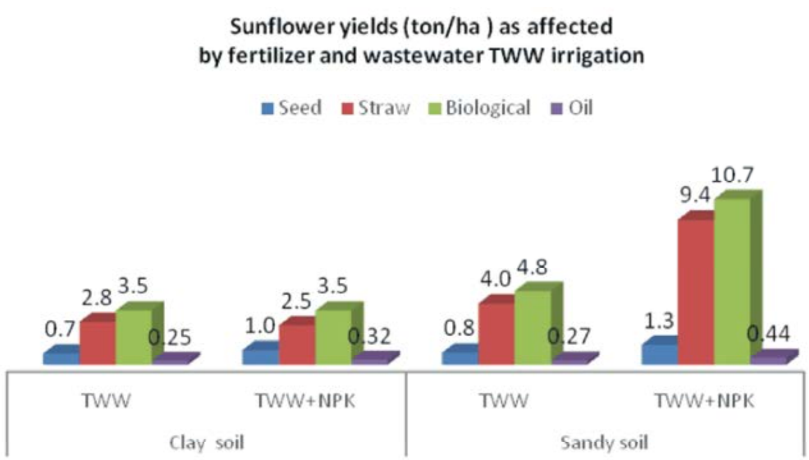

Fig. 2: Sunflower yields (t ha^{-1}) as affected by fertilizer and wastewater irrigation in two soil types

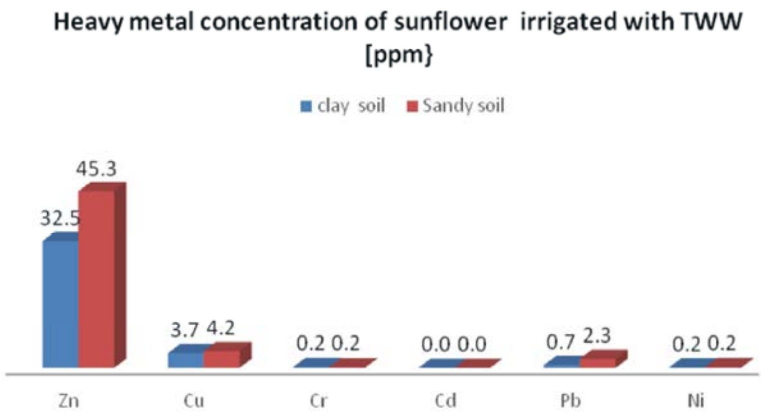

Fig. 3: Micronutrients and heavy metals in sunflower seeds irrigated with TWW

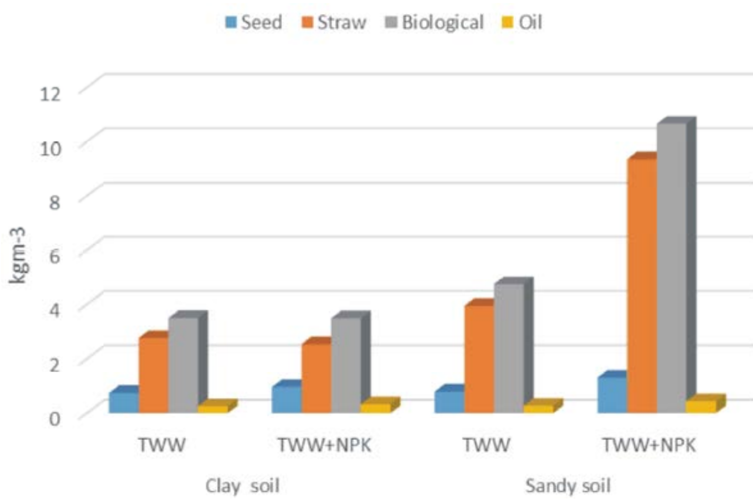

Fig. 4: Water productivity (kg m^{-3}) of sunflower yield components in clay and sandy soils

Table 3: Mean concentrations (mg kg^{-1}) of heavy metals in sunflower seeds at clay soil and El Berka

Soil type	Zn	Cu	Cr	Cd	Pb	Ni
Clay	32.5	3.71	0.23	0.028	0.74	0.16
Sandy	45.3	4.24	0.18	0.020	2.29	0.22

Note: Figures in bold for each element indicate the greater pairs of mean concentrations for each soil

Table 4: Water productivity kg m^{-3} of sunflower seeds in clay and sandy soils

Yield component	TWW	TWW+NPK
Clay soil		
Seed	0.797b	1.332 (167)a
Straw	3.952b	9.532 (241)a
Biological	4.750b	10.864 (229)a
Oil	0.267b	0.446 (167)a
Sandy soil		
Seed	0.755b	0.957 (127)a
Straw	2.782a	2.507 (-9)a
Biological	3.538a	3.464 (-3)a
Oil	0.253b	0.321 (127)a

*Values between brackets refer to % of the non-fertilized treatment by fertilizer application by 30 and 70% in sandy and clay soils, respectively or surface irrigation was greater than sprinkler irrigation. The oil content of sunflower seed in sandy soil was slightly larger than in Clay soil, giving an oil production of 2.22 ha^{-1} in clay soil compared with 3.03 t ha^{-1} in sandy soil, respectively. Sunflower seeds were analyzed for heavy metal content. Seed analysis presented in Table (3) and Fig. (3) indicate that the ranges of heavy metals were within the normal ranges expected and were far below levels that would be of concern. There were only a few occasions where there were statistically significant differences in concentrations in sunflower irrigated by treated wastewater alone and those that had received additional fertilizer, but in general, the trend was for smaller concentrations in the fertilized sunflower due to the dilution effect of greater growth with the additional nutrients. Sunflower off-take of heavy metals would be much greater from these treatments despite the smaller crop concentration. There were no consistent effects on crop quality resulting from the differing soil concentrations of heavy metals on the two soils. Table (3) and Fig. (3) provides an even more condensed summary showing that there are only very small differences in overall crop quality between the sites.

Data presented in Table (4) indicate that there were highly significant effects of fertilizers on all of the water productivity parameters of sunflower, with substantial increases in water productivity for seed and oil compared with those achieved with only treated wastewater. The addition of fertilizer increased the water productivity of seeds and oil (WP_{seeds} and WP_{oil}) by 27% and 67% under both clay and sandy soils, respectively, but decreased straw water productivity by 9%.

DISCUSSION

The obtained results show that sunflower irrigation with wastewater provides a useful contribution to crop nutrient needs, these are applied uniformly throughout the growing period of the crop, whereas fertilizer (specifically nitrogen) is applied deliberately in targeted split applications according to the changing crop requirements during the growing cycle. Irrigation with wastewater alone, particularly in low fertility soils, results in poor early crop growth due to nutrient deficiency and normal levels of fertilizer should be applied during the early growth stages crops. Therefore, the yields achieved where fertilizer was applied were larger than from wastewater alone and were proportionately increased more on in sandy soil than at clay soil where nutrient demand would be greatest, although yields overall were generally much smaller than at clay soil. These results demonstrate the importance of applying supplementary fertilizer at appropriate levels for the crop and soil type. The small concentrations of heavy metals in the seeds were expected and attributed to the high pH of the Egyptian soil which makes the heavy metals are not readily bioavailable for crop uptake and do not represent a threat to the quality of the crops grown on this for human or animal consumption, (WRc, 2001) [20]. Sunflower is a relatively new crop in Egypt and so its yield characteristics are not yet fully evaluated under local conditions, but these results show clearly that sunflower is unsuited to in clay soil but can respond well to wastewater when grown on clay soil.

Sunflower yields were larger on sandy soil compared with clay soil. With treated wastewater alone, seed yield in clay soil was similar to sandy soil, but the addition of fertilizer resulted in a greater response in sandy soil. Consequently, the combination of sandy soil and wastewater would apparently suit sunflower growth more than clay soil.

These results show that treated wastewater alone cannot provide adequate quantities of nutrients to achieve optimum crop yields. This is most pronounced in the infertile soil of Sandy soil where additional fertilizer is essential to achieve reasonable yields. On the fertile soil of clay soil, this is less crucial although the addition of fertilizer still provided useful yield increases.

The addition of fertilizer consistently increased the yields of all crops (Table 5) at both sites compared with those from treated wastewater alone. In clay soil, fertilizer increased total crop yields by 44% on average, whereas in sandy soil, the increase due to fertilizer was on average 81%. This reflects the relative fertility of the two sites: a larger response to fertilizer would be expected from the poor soil at Sandy soil compared with the relatively fertile conditions at clay soil. Also, recommended rates of fertilizer were applied to sandy soil, whereas rates were adjusted in clay soil to account for the assumed greater soil fertility. Comparisons of crop yields between the sites show some interesting effects. Surprisingly, when fertilizer was applied, the overall mean seed yield of all crops in Sandy soil was slightly larger than in clay soil, although straw yields were larger in clay soil. Without fertilizer, there was no overall difference between the sites for seed yield but the straw yield was much greater on clay soil. These results indicate that whilst clay soil is more fertile than sandy soil, near normal rates of fertilizer would be advised to achieve satisfactory yields.

Chemical analysis of crops provides an indication of the quality of the crop in terms of its agronomic nutritional status and its dietary quality for human and animal consumption. Crop growth and quality are controlled principally by soil quality (physical and chemical) and nutrient supply, in addition to an adequate amount of water. The interactions between these factors are complex and this is illustrated by the comparison of the crop qualities from these trials conducted under contrasting soil conditions. As demonstrated above, treated wastewater supplies only a proportion of the nitrogen and phosphorus requirements of the crop, but generally adequate levels of potassium. The crop yield responses showed conclusively that additional fertilizer is necessary to achieve reasonable crop growth response and economic yields. Chemical analysis of the economic components of the crops demonstrated that nutrient content did not necessarily increase with fertilizer addition and in many instances decreased (see summaries in Table 7), although few effects achieved statistical significance. However, this is explained by the fact that crop growth and yields were increased by the addition of fertilizer compared with wastewater alone, often substantially depending on the crop and site and this in effect diluted tissue concentrations. These results demonstrate the importance of applying supplementary fertilizer at appropriate levels for the crop and soil and emphasize that the nutrients naturally present in wastewater which allow savings on fertilizer expenses to be realized [21, 22, 8, 13]. 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 [20, 8]. Also, Liu and Haynes [23] and Barreto *et al.* [8] indicated that depending on the nutrients, wastewater may be a potential source of macro- (N, P and K) and micronutrients (Ca, Mg, B, Mg, Fe, Mn or Zn). This may be attributed in part to the nutrient supply from Sandy soil wastewater which closely met with recommended amounts of fertilizer for this crop.

The small concentrations of heavy metals in the seeds were expected and attributed to the high pH of the Egyptian soil which makes the heavy metals are not readily bioavailable for crop uptake and do not represent a threat to the quality of the crops grown on this for human or animal consumption [20]. These results clearly reflect minimum pollution in the short and long term and indicate the suitability of Cairo wastewater for reuse on agricultural land. Similar results were obtained by Mahmoud *et al*. [24] in Jordan and WRc [20], Ministry of Water Resources and Irrigation [25] in Egypt.

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