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Effect of Soybean (*Glycin max Merril*) Irrigation with Reclaimed Wastewater on Seed Yield and Quality

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Abstract: Field trials were conducted in summer season in two soil types (loamy sand) and (sandy soil). The trials aimed to evaluate the impact of soybean irrigation with reclaimed wastewaterRWW on yield, quality and heavy metal content of soybean seeds. Reclaimed wastewater supplied soybean with 35, 43 and 156% of the recommended requirements of N, P and K, respectively in the sandy soil while the corresponding values in the loamy sand soil were 79, 96 and 191% for N, P and K, respectively. The results clearly showed that soybean crop was less productivity in sandy soil as the crop produced 20% and 32% with reclaimed water irrigation only and reclaimed water when combined with NPK of the seed yield achieved at the fertile soil. There were significant increases in seed yield, straw and biological yields due to NPK application in both sites. Oil yields were 0.414 and 0.540 t ha^{-1} on sandy and loamy sand 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. The results of heavy metals transolcation to soybean seeds did not appear high heavy metal translocation values from irrigated soil reclaimed water in the two soil types and were wihin the permesable levels. Regarding the translocation of heavy metals from soil to loamy sand soil the results indicated that they were in the order Zn< Cd <Ni <Cu <Cr <Pb in loamy sand soil while greater heavy metal concentrations in the soybean seeds in the sandy soil compared with loamy sand soil and they were in the order Zn< Cd <Cu <Cr <Pb <Ni in sandy soil. Generally, the TF values were > 1 for all heavy metals except one occusion when soybean was irrigated with reclaimed wastewate in sandy soil.

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

INTRODUCTION

The reclaimed wastewater generated from Greater Cairo is about 3.5 million m^3/day / day, from environmental point of view such quantities should be disposed off safely. Under limited water resources and drought conditions wastewater has been used to support the agricultural production in many countries such as 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]. However, under Egyptian conditions many restrictions have been adopted on wastewater reuse and it is only permitted for wooden trees production. 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, reclaimed wastewater reuse increases agricultural production in regions suffer from water shortages, thus contributing to food safety [10]. Depending on the nutrients, wastewater may be a

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potential source of macro- (N, P and K, Ca B, Mg,) and micronutrients (Fe, Mn, Cu, or Zn) [11-12]. Reclaimed water reuse has been proven to improve crop yield [12-13] and result in the reduced use of fertilizers in agriculture [14]. Since soybean is considered an important crop in Egypt and it needs processing before consumption, it may fit irrigation with reclaimed wastewater. Therefore, the aim of this work is to evaluate the effect of reclaimed wastewater on soybean yield and quality under two types of Egyptian soils.

MATERIALS AND METHODS

Two demonstration field trials were carried out in summer season in two sites located about 20 km north east of Cairo; Gabal Asfar farm (fertile soil) and Berka site (virgin soil). The trials aimed to evaluate the impact of soybean irrigation with secondary reclaimed wastewater on yield, quality and heavy metal content. The area of each trial the was 1 hectar close to the new Gabal El- Asfar wastewater treatment plant and the soil could be classified as loomy sand soil. The same area was chosen in the second site and located inside El- Berka wastewater treatment plant; the soil is gravelly sand and could be classified as virgin soil. The soil analysis owas done according to Jackson [15] and the results are presented in Table 1.

Both experimental sites were 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. Soybean seeds (Pactol variety) were grown. In Gabal El Asfar site, surface irrigation was used; while in El Berka site sprinkler irrigation was used. 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. Samples of reclaimed wastewater from Gabal El-Asfar and El-Berka were taken during crop cycle and analysed for a range of agronomic parameters and the Chemical analyses of wastewater Irrigated in the experimental sites was done according to APHA 1992 [16]. Nutrient and heavy metal loading rates to field trials were calculated according to the irrigation quantities applied to soybean. Soybean yields were determined, seed oil, nutrient and heavy metal content were determined. According to [17]. The heavy metals was carried out according to [18]. The obtained results were subjected to the proper statistical analysis using MSTAT-C package [19].

Assessment of Translocation of Potentially Toxic Heavy Metals

Translocation Factor: Translocation of heavy metals from the soil to the edible parts of the crop was determined by [20].

$$TF = C\ seeds\ /\ C\ soil$$

where, C seeds is the concentration of the element in the seeds or edible parts and C soil is the concentration of same element in the soil on dry weight basis.

Table 1: Physical and chemical characteristics of loamy sand and sandy soil sites (Means to 30 cm depth)

(A) Physical

Coarse sand (%)	Fine sand (%)	Silt (%)	Loamy sand (%)	Texture class	WHC (%)	Particle density (g/cm^3)	SBD (g cm^{-3})	
				Loamy sand soil				
0	58.9	22.5	7.9	10.6	Loamy Sand	40.6	2.38	1.37
				Sandy soil				
67.2	23.2	5.6	4.0		28.5	2.56	1.56	

(B) Chemical

PH	EC (dS/m)	HCO_3 (meq/l)	OM (%)	CEC (meq/ 100g)	NO_3 (mg/kg)	N (mg/kg)	P (mg/kg)	K (mg/kg)
				Loamy sand soil				
8.87	0.27	0.74	4.29	34.5	106	2826	1737	1996
				Sandy soil				
8.16	0.79	0.98	0.79	13.4	24	901	229	1506

RESULTS

Data presented in Table 2 shows wastewater qualities applied to soybean in both sites, All of these parameters are well within the maximum limit values set by the Egyptian Decree [21] for wastewater reuse. The amounts of wastewater irrigated to each crop and fertilizer treatment at both sites were recorded accurately. Mean RWW irrigation was 6438 m^3/ha for surface irrigation in loamy soil and 6792m^3/ha in sandy soil. 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 percentage of the fertilizer recommended rates indicated that reclaimed wastewater supplied soybean with 54, 88 and 174 % of the recommended requirements of N, P and K, respectively in the sandy soil while the corresponding values in the loamy sand soilwere 50, 61 and 223%for N, P and K, respectively.

Data presented in Table 3 indicate that fertilizer increased soybean yields (seeds, straw and biological) significantly at both sites. The oil content of soybean seed at sandy soil was slightly larger (39.5%) than at loamy sand soil (38.2%), giving a reversal magnituide of oil production 0.343 and0.165 t/ha with reclaimed water irrigation only compared with 0.541 and0.414 t/ha with reclaimed water and fertilizer application in loamy sand and sandy soil, respectively. Soybean seeds were analysed for heavy metal content. Seed analysis presented in Table 3 indicate that the ranges of heavy metals were within the normal ranges expected and were far below levels that would be of concern (Table 4).

Table 2: Chemical analyses of wastewater Irrigated in the experimental sites. (All parameters mg/l except pH)

Parameters	pH	Tot.N	Tot P	K	B	Fe	Mn	Cr	Ni	Zn	Cu	Cd	Pb	Co	Mo
Loamy sand 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	0.4	0.577	0.115	0.027	0.039	0.094	0.049	<0.005	0.079	<0.01	<0.005

Table 3: Soybean yields (ton/ha) as affected by fertilizer and RWW Irrigation in two soil types

		Treatment	
Soil Type	Yield component	RWW- NPK	RWW+NPK
Loamy sand	Seed	1.725b	2.76 a
	Straw	7.728b	10.128a
	Biological	9.453b	13.04a
	Oil	0.343b	0.541a
Sandy	Seed	0.35b	0.88a
	Straw	1.50b	3.51a
	Bioloigical	1.84b	4.39a
	Oil	0.165b	0.414a

Table 4: Mean Concentrations (mg/kg) of Heavy Metals in Soybean seeds at Gabal El-Asfar and El-Berka

Soil type	Zn	Cu	Cr	Cd	Pb	Ni
Loamy sand	61.4	5.40	1.04	0.07	0.22	1.26
Sandy	64.7	13.74	1.82	0.24	0.14	0.11

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

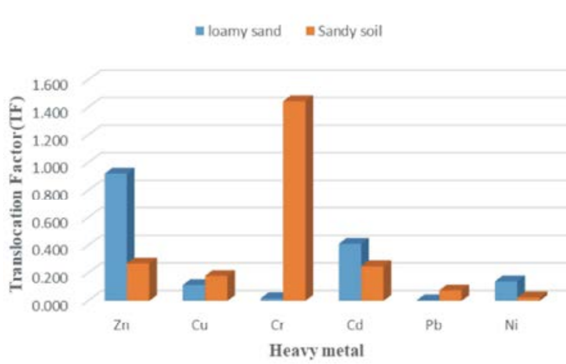

Fig. 1: Soil –seed Translocation Factor (TF) in soybean seeds irrigated with RWW in two soil types

Table 5: Soil – seed Translocation Factor (TF) in soybean seeds

TF	Zn	Cu	Cr	Cd	Pb	Ni
loamy sand soil	0.922	0.113	0.019	0.412	0.005	0.139
Sandy soil	0.269	0.179	1.445	0.250	0.074	0.024

Translocation of Potentially Toxic Heavy Metals from Irrigated Soil to Soybean Seeds: Soil –seed Translocation Factor (TF) in soybean seeds are presented in Table (5). Generally, soybean seeds did not appear heavy metal translocation from irrigated soil with reclaimed waste watter RWW in the two types of soils. The TF values were > 1 for all heavy metals except one occusion for Cr when soybean was irrigated with reclaimed wastewater in the sandy soil. The results indicated that heavy metal transolocation could be arranged in the following order Zn< Cd <Ni <Cu <Cr <Pb in loamy sand soil. Also translocation of heavy metals from sandy soil irrigated from RWW to soybean seeds was relatively highighr than the loamy sand Fig. 1. Meanwhile, Irrigation soybean with WWTPII resulted in greater heavy metal concentrations in the edible parts of soybean and could be arranged in the following order. Zn< Cd <Cu <Cr <Pb <Ni in sandy soil.

DISCUSSION

The obtained results show that soybean irrigation with wastewater provide 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 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 the infertile soil at El-Berka where nutrient demand would be greatest, although yields overall were generally much smaller than at Gabal El-Asfar. 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 soils which make 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, [22].

Soil –seed Translocation Factor (TF) values were > 1 for all heavy metals except one occusion when soybean was irrigated with reclaimed wastewater in the sandy soil. Also translocation of heavy metals from sandy soil irrigated from RWW to soybean seeds was relatively highighr than the loamy sand. This could be attributed to main two reasons, the high pH in both soils(>8) and the second is the higher OM in the loamy sand soil. Both factors prevent heavy metal transolcation to soybean seeds with hazard concentrations, therefore low translocation Factor values occurred. Thease results are in harmony with [23, 24, 5] 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). The small concentrations of heavy metals in the seeds were expected and attributed to the high pH of the Egyptian soil which make 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 [25]. 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 [26] in Jordan [25], [27] in Egypt. Naser *et al.* [28] studied the levels of heavy metals like Cd, Ni in tomato grown in wastewater polluted areas and found that Cd and Ni content was increased and ranged from 0.630-1.303 ppm and 2.031-4.957 ppm, respectively. Hasan, *et al.* [29] concluded that nutrient content of soil and above ground plant parts was higher in wastewater irrigated field compared to freshwater irrigated field. Heavy metals (Cd and Cr) were also higher in straw and grain grown under wastewater irrigation. However, the values of Cd and Cr were within the permissible limit. They concluded that municipal wastewater can be safely used as an alternative water source for the irrigation of rice field. Moreover they reported significant variations among four rice varieties regarding nutrient contents of straw as well as bioaccumulation and translocation of Cd in grain. Bioaccumulation factor was <1, indicating absorption only, not accumulation of Cd and Cr in straw or grain and municipal wastewater can safely be used as an alternate water source for irrigation.

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