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Agronomic and Economic Benefits of Reuse Secondary Treated Wastewater in Irrigation under Arid and Semi-arid Region

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Abstract

In many arid and semi-arid countries water is becoming an increasingly scarce resource and planners are forced to consider any sources of water which might be used economically and effectively in developing agriculture programs. Therefore, it is essential to develop water resources through untraditional ways. One of these resources is reuse wastewater. The area of land to be irrigated with wastewater increased significantly over two past decades. Wastewater must be treated before it is released back into the environment begins with primary treatment, where solids are separated from liquids. The next phase was secondary treatment, by activating living microorganisms. Currently, the wastewater generated from Alexandria City is about 1. 5 million m3/day and the expected amount by the year of 2020 is 2.5 million m^3/day. Long term, field experiments were conducted at calcareous sandy soil in western Delta Region (El-Noubaria) 40 Km. south of Alexandria in summer and winter seasons from 2000 to 2003. The objective of these trials are pointed out the proper management of wastewater, which is discharged into the Mediterranean Sea, for increasing yield and quality of some oil crops as well as heavy metal content in harvested seeds. Wastewater was transported from Alexandria to the experimental field through special tankers, compared with traditional fresh water using for irrigation (canal water). Irrigation system was surface flow irrigation system. Results worthy indicates that crops irrigated with secondary treated wastewater perform equally or significantly better than that irrigated with canal water. Heavy metal concentrations were very small, and are of no concern to crop quality or animal and human dietary intake. There were no detectable effects of wastewater on soil quality. Results also indicate that wastewater could offer adequate amount of crop requirements from N and more crop requirements of K.
Key word: secondary treated wastewater, activating living microorganisms and using treated wastewater in crop production.

Introduction

Sustainable agricultural development, in arid and semi-arid is influenced to a great extent by sources of water that might be used economically and effectively in developing agriculture programs and the state of soil supplying with organic materials. Whenever good quality water is scarce, water of marginal quality will have to be considered for use in agriculture. The dissolved organics in wastewater is generated as sludge mainly during primary and secondary treatment of municipal wastewater. During recent years the methodology of reuse wastewater management has shifted from conventional disposal strategies into value added products Liang *et al.,* (2003).

The trials of Sudha Bansal and Kapoor (2000) pointed out the usage of wastewater effluent by recycling can supply nutrients to different crops and also improve soil physical conditions and its fertility.

In Egypt, the plan for reuse municipal wastewater for irrigation is not new concept, but it has been practiced since 1911 on the sandy soil of EL-Gabal EL-Asfar farm, which consists of an area of 3000 faddan (approximately 2.4 faddan equal 1 ha.), 25 Km. North east of Cairo, it has been irrigated by wastewater from Cairo treatment plants and producing citrus, date palm and pecan nuts in addition some field crops.

Utilizing of wastewater for agricultural and landscape irrigation has been practical in many countries such as USA, Germany, India, Kuwait, Saudi Arabia, Oman, Jordan and Tunisia. Rowe and Abd-elMagid,(1995). The area of land to be irrigated with wastewater increased the concerns over the environmental implications WRC, (2001).

Several investigators indicated the beneficial role of reuse wastewater in increasing crop yield without or with minimal risks to the plant, soil, groundwater and health. Shatanawi and Fayyed., (1996);Vazquez-Montiel et al., (1996); Aissi et al., (1997) and Palacios et al., (2000) and AbdEL-Lateef ., (2003).

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. Even if the new guideline for treated wastewater quality is not fully met, it may still be possible to irrigate selected crops without risk to consumer.

Therefore, the aim of the present studies are pointed out the proper management of wastewater, which is discharged into the Mediterranean Sea, for increasing yield and quality of some oil crops as well as pathogenic effect in harvested seeds.

Materials and Methods

Large-scale field trials were carried out in a rotation of summer and winter from 2000 to 2003. Crop selected according to WHO (1989) i.e., in winter season crops were (wheat, faba bean and berseem) were sown in November 1999/2000 and in summer season of 2000, sunflower, sesame, millet and maize (white type) were sown. The present studies will discuss the results of yield and quality of sunflower and sesame. The main objective of this study is to manipulate the effects of using secondary treated wastewater compared with canal water along with application different fertilization treatments i.e., control (without application), NPK fertilizers according to the crop recommended, organic manure by the rate of $20m^3$/fad. and organic manure in the presence of recommended dose of chemical fertilizers. Chemical analyses of the organic manure are presented in Table 1. The soil was calcareous loam ($CaCO_3$ 34.62 %), the analyses of the experiment soil sites was presented in Table 2a and 2 b Samples of treated wastewater were taken during crop season and analyzed according to APHA (1992). Results presented in Table 3. The design of the trial was split plot design in four replications. Water source was in main plot and fertilization treatments were assigned randomly in sub-plots. Each experiment included 8 treatments 2 water resource (secondary treated wastewater, canal water) and 4 fertilization treatments. Seeds used sunflower c.v. fedok and sesame c.v. Giza 9.The experimental area was ploughed twice ridged and divided to experimental unites each of $21m^2$. Organic manure rates were applied after manually calibration on a volumetric basis to the assigned plots. In order to secure homogenous incorporation with the soil surface layer, a rotary cultivator was used. The irrigation method was surface flow irrigation system. The irrigation water was measured by the volume of tanker used and was calculated over the growth period according to crop water requirements as observed in the field. (the quantity of water are nearly equal in both methods and are broadly in line with normal practice) .

At harvest time, two inner rows were randomly pulled from each plot for determined seed yield Kg. per faddan. Sub sample of ten plants was taken for determining yield component characters and data presented in Table 4. Seed quality i.e., oil and protein percentage in absolutely dry seeds as well as macro and micronutrients contents were also determined according to the methods described by **A.O.A.C**. (1984).

The obtained data for each crop as well as each season were statically analyzed by analysis of variance according to Gomez and Gomez ,(1984). The trend of the three seasons were nearly similar. Then uniformity test was done and combined analyses for the three seasons were calculated Means of the treatment were compared by the new least significant difference (new LSD) at 5% level of significance.

Table 1.Chemical analysis of the organic manure used in the experimental

Total N %	C/N Ratio	Organic carbon	Total P	Total K	Fe	Zn	Mn
		%			ppm		
0.87	28.6	24.9	0.28	1.2	158	38	78

Table 2a Chemical Properties of the soil sites

Depth	SP	pH	EC dS/m	Soluble Cations (meg/L)				Soluble Anions (meg/L)				$CaCO_3$ %
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{-}	HCO_3^{-}	Cl^{-}	SO_4^{--}	
0-25	53.3	8.30	4.34	11.1	7.9	22.4	2.0	0	1.2	23.5	18.7	28.46
25-70	48.3	8.20	3.63	10.5	7.2	16.9	1.7	0	1.0	22.9	12.4	30.77
70-120	50.0	8.17	2.50	8.1	6.0	9.7	1.2	0	0.9	14.3	9.8	34.62

Table 2b: Available nutrients of the experimental soil site

Depth	Total N ppm	Available P ppm	Available Fe ppm	Available M ppm	Available Zn ppm	O.M %
0-25	4.17	2.5	3.1	3.9	1.5	1.7

Table 3: Chemical composition of treated wastewater used

Constituent	Unit	concentration	Constituent	Unit	concentration
Ec	DS/m	3.10	SO_4^{2-}	me/I	35.00
pH		7.8	CO_3	me/I	1.10
SAR		9.30	HCO_3^-	me/I	6.60
$Na_2^{\ +}$	me/I	24.60	NH_4	mg/I	2.50
Ca_2^+	me/I	1.50	NO_3	mg/I	10.10
Mg	me/I	3.20	P	mg/I	8.50
K^+	me/I	1.80	Mn	mg/I	0.20
CL^-	me/I	62.00	Cu	mg/I	1.10
			Zn	mg/I	0.80

Results and Discussion

1. Growth, yields and yield component characters as well as seed quality of sunflower:

Data summarized in Table (4), clearly show that irrigation with secondary treated wastewater was more efficiently than that irrigation with canal water in growth, yield and yield component characters as well as seed quality of sunflower plants grown in calcareous soil. Such increment in studied parameter, relating to type of irrigation, considering the amounts of water applied are nearly equal in both methods may be due to the nutrient content in wastewater. In addition to it was expected under such condition of the experimental soil sites, which characterized with low fertile soil. The previous results of higher growth accompanying irrigation with treated wastewater are in line with the findings of Campbel, et al., (1983) who reported that weekly application of 25 mm of wastewater was enough to supply 40-80 % of corn requirements from N and all of P requirements. However, the amount of potassium supplied was approximately equal to, or in excess of, crop requirements. In addition to the trials of Shatanawi, et al.,(1996),Vasquez-Montiel ,et al.,(1996)and Palacios, et al.,(2000) pointed out that the increase in growth of some crops was due to enhancement of nutrients uptake and the improve of the physical properties of the soil . Such effect on growth parameter viz., plant height, leaf area per plant and dry matter accumulation might have increased the rate of photosynthesis, better translocation of photosynthatees from stem and leaves to the sink and finally reflected on yield and yield component characters as well as seed quality. As presented in Table (4), yield of sunflower seeds was increased by14.77 % by using secondary treated wastewater in irrigation as compared with irrigation with canal water. Data in Table (5), clearly demonstrates that application of each of the recommended rate of chemical fertilizers or organic manure sole or in combination had a significant effect on most growth parameters as well as yield and yield component characters compared with control treatment. The most effective one was observed in application organic manure and chemical fertilizers in combination. This is logic and expected due to the state of the experimental soil sites which have low organic matter and thus dose not matches crop nutrient requirement during growth stages. The previous application (organic manure + chemical fertilizers), increased seed yield by 26.57 % over the control treatment. Moreover, results in the same table showed that added chemical fertilizers to wastewater were more efficiently than application wastewater alone or than application the same fertilizers to canal water. The increments in seed yield were 22.83 %and 10.70 %, respectively. Concerning the concentration of heavy metal in seeds. Data obtained in Table (6), showed that there are no constant effect and statistically no significant difference between fertilization treatments or their interactions with water sources. In addition to, the differences between irrigation are within the normal ranges. Such results may be due to the time of the experiments not enough to accumulate more concentration of heavy metal reached to the high level or up to the level of toxicity. Moreover, the high leaching rate of soil may be also shares in the previous results.

Table (4): Growth, yield and yield component characters as well as seed quality of sunflower as affected by irrigation with wastewater, fertilization treatments and their interactions (Average of three seasons)

Irrigation	Fertilization Treatment	Growth Parameters			Yield and yield component and seed Quality			
		Plant Height, cm.	Leaf area /plant dm^2	Dry matter accumulation, gm.	Head diameter, cm.	Seed weight/ Head, gm.	Seed yield Kg./fad.	Oil %
wastewater	F_1	195.0	19.5	145.7	21.7	47.2	854.8	41.2
	F_2	195.3	19.8	154.7	24.2	55.4	1056.7	41.6
	F_3	200.7	20.2	156.8	23.9	57.2	1045.5	41.5
	F_4	210.6	20.4	160.6	25.6	58.5	1090.0	41.9
General Mean		200.9	20.0	154.5	23.9	54.6	1011.8	41.6
Canal	F_1	182.7	17.6	120.7	19.8	41.4	674.5	40.0
	F_3	192.4	18.6	135.2	20.8	44.7	946.6	40.2
	F_3	190.7	18.2	133.5	20.0	45.3	920.8	40.4
	F_4	198.6	18.9	140.7	21.9	49.6	984.6	40.6
General Mean		191.1	18.3	132.5	20.6	45.3	881.6	40.3
LSD for :								
Irrigation (A)		8.63	1.44	12.4	2.10	7.12	30.5	1.
Fertilization T.(B)		4.68	n.s	10.7	1.24	1.28	12.7	2
Interaction AxB		6.22	1.23	1.86	1.16	2.62	10.8	n.s n.s

F_1: control (without application) , F_2: Recommended NPK, F3: Oranic manure , F_4: Organic manure + recommended NPK

Table (5): Effect of fertilization treatments on Growth, yield and yield component characters as well as seed quality of sunflower grown on calcareous soil. (Average of three seasons)

Fertilization Treatment	Growth Parameters			Yield and yield component and seed Quality			
	Plant Height, cm.	Leaf area/plant dm^2	Dry matter accumulation, gm.	Head diameter, cm.	Seed weight/ Head, gm.	Seed yield Kg./fad.	Oil %
F1	188.9	18.6	133.2	20.8	44.3	761.7	40.6
F2	193.9	19.2	144.9	22.5	50.1	1001.7	40.9
F3	195.7	19.2	145.2	21.9	51.3	983.2	40.9
F4	204.6	19.7	150.7	23.8	54.1	1037.3	41.3

Table (6):Mean concentration of heavy metals in sunflower seeds grown under calcareous sandy soil and irrigated with treated wastewater (Average of three seasons)

Irrigation	Zn	Cu	Cr	Cd	PB	Ni
Wastewater	32.5	3.71	0.23	0.028	0.74	0.22
Canal water	28.66	3.20	0.12	0.020	0.33	0.16

2. Growth, yield and yield component characters as well as seed quality of sesame:

The present study explained that similar view was also reported in growing sesame under calcareous sandy loam soil and treated plants with the same treatments followed in growing sunflower. Results in Table (7) worthy clear that, positive effect due to irrigation with secondary treated wastewater on growth and yield of sesame. Plant height, number of branches /plant and dry matter accumulation were increased by 12.87,47.27 and 13.91 %, respectively by using secondary treated wastewater in irrigation as compared with canal water. The increase in growth parameters may be due to the content of nutrient in treated wastewater. Where as the increment in seed yield and number of capsules/plant as well as oil percentage were 32.03,8.83 and 18.18 %, respectively resulting with irrigation plants with secondary treated wastewater compared with irrigation with canal water. The study of Pescod,(1992) on treated wastewater effluent concluded that concentration of nutrients in treated wastewater were 50 mg/l of N ,P 10mg/l and K 30 mg/l . Concerning the effect of fertilization treatment, results showed that the most effective treatment was application recommended rate of chemical fertilizers in the presence of organic manure. The analyses of the concentration of heavy metals in seeds which demonstrated by the data in table (9), hich reveal that the concentration within normal level . Such results may be clear that heavy metal in soil are not readily bio available for crop uptake and do not represent a threat to quality of crop consumption .

Table (7): Growth, yield and yield component characters as well as seed quality of sesame as affected by irrigation with wastewater, fertilization treatments and their interactions (Average of three seasons)

Irrigation	Fertilization Treatment	Growth Parameters			Yield and yield component parameters		
		Plant height, cm.	No. of branches/plant	Dry matter, g/plant	No. of capsules/plant	Seed yield Kg./faddan	Oil %
wastewater	F_1	111.5	7.5	36.7	115.7	497.5	61.2
	F_2	114.5	8.2	37.5	125.4	546.7	61.2
	F_3	125.4	7.7	40.5	115.9	540.8	60.4
	F_4	125.5	8.9	42.2	114.6	564.2	61.7
General Mean		119.3	8.1	39.3	117.9	537.3	61.1
Canal	F_1	98.3	4.3	30.8	83.8	413.6	50.7
	F_2	100.6	5.4	32.9	86.4	500.2	50.5
	F_3	110.7	6.2	36.1	88.2	520.7	52.7
	F_4	112.9	6.2	37.9	98.7	540.2	52.7
General Mean		105.7	5.5	34.5	89.3	493.7	51.7
LSD for :							
Irrigation (A)		10.66	1.44	3.43	12.5	33.36	8.44
Fertilization T.(B)		8.23	n.s	1.22	2.18	46.72	0.44
Interaction AxB		2.26	1.32	1.64	1.22	13.98	1.18

F_1: control (without application) , F_2: Recommended NPK, F3: Oranic manure , F_4: Organic manure + recommended NPK

Table (8): Effect of fertilization treatments on Growth, yield and yield component characters as well as seed quality of sesame grown on calcareous soil. (Average of three seasons)

Fertilization Treatment	Growth Parameters			Yield and yield component parameters		
	Plant height, cm.	No. of branches/plant	Dry matter, g/plant	No. of capsules/plant	Seed yield Kg./feddan	Oil %
F_1	104.9	5.9	33.8	99.8	455.6	56.0
F_2	107.6	6.8	35.2	105.9	523.5	55.9
F_3	118.1	7.0	38.3	102.1	530.8	56.6
F_4	119.2	7.6	40.1	106.7	552.2	57.2

Table (9):Mean concentration of heavy metals in sesame seeds grown under calcareous sandy soil and irrigated with treated wastewater (Average of three seasons)

Irrigation	Zn	Cu	Cr	Cd	PB	Ni
Wastewater	40.53	3.82	0.22	0.026	0.84	0.22
Canal water	30.12	3..33	0.18	0.024	0.38	0.16

Conclusion

In view of the shortage in water resources it can be concluded that wastewater reclamation and reuse can play a major role in alleviating the problem, and hence, wastewater reuse should be considered within the framework of the overall water master plan. However, monitoring of the effect on public health and environment analyses of the reuse have been sufficiently covered.

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الاستفادة الاقتصادية والزراعية من إعادة استخدام مياه الصرف المعالجة فى الري فى المناطق الجافة وشبة الجافة

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المركز القومي للبحوث– قسم بحوث المحاصيل الحقلية – الجيزة – مصر

فى كثير من البلاد الجافة وشبة الجافة التي تتميز بندرة مصادر المياه ترتبط برامج التنمية ارتباط وثيق التي ترتبط بوجود مصادر للمياه صالحة يمكن استغلالها اقتصادياً فى برامج التنمية بالزراعة.لذلك كان من الضروري البحث عن مصادر غير تقليدية للمياه .و أحد هذه المصادر معالجة مياه الصرف . وخلال العقدين الأخيرين زادت مساحة الأراضي التي تروى بمياه الصرف المعالجة التي تتوافر فيها الشروط البيئية لإعادة تدويرها مرة أخري فى النظام البيئي والتي تبدأ بالتخلص من المواد الصلبة (المعالجة الأولية) يليها دفع غاز الأوكسجين الذي يعمل على تنشيط البيئة الميكروبية للبكتريا الهوائية و اللاهوائية (المعالجة الثانوية) . وتصل كمية المياه الناتجة من محطة الصرف الصحي لمدينة الإسكندرية حوالي 1.5 مليون متر مكعب يوميا ومتوقع أن تصل فى سنة 2020 الى حوالي 2.5 مليون متر مكعب يوميا تزداد وتقل فى بعض فترات السنة .لذلك أقيمت تجربة حقلية فى منطقة النوبارية على بعد حوالي 40 كيلوا متر من مدينة الإسكندرية فى ارض رملية جيرية نسبة كربونات الكالسيوم بها 36 % خلال الموسم الشتوي و الصيفي للسنوات من 2000 وحتى 2003 بهدف التوصل إلى منظومة لإدارة المياه المعالجة للاستفادة منها بدل من صرفها فى مياه البحر واثر ذلك على محصول البذور ونسبة الزيت وجودة البذور ومحتواها من بعض العناصر الثقيلة لبعض محاصيل الزيت الهامة . أظهرت النتائج تساوى أو تفوق محصول البذرة معنوياً للنباتات المروية بمياه الصرف المعالجة مقارنة بالنباتات التي رويت بمياه ري عادية . كما تشير نتائج التحليل الكيماوي للبذور أن المحتوى من العناصر الثقيلة كان فى حدود قليلة جداً والتي لم تؤثر على جودة البذور واستخدامها للإنسان أو الحيوان . كما لم يلاحظ أي تأثير للرى بمياه الصرف المعالجة على خواص التربة . وتبين من الدراسة أن مياه الصرف المعالجة يمكن أن تمد النباتات بجزء من احتياجاتها من النيتروجين أو الفوسفور واكثر من احتياجاتها من البوتاسيوم.