PHYTOTOXIC EFFECT OF TREATED SEWAGE WATER AND OTHER TRADITIONAL IRRIGATION SOURCES ON SOME CULTIVATED PLANTS

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Abstract

This experiment was conducted to study the potential of using treated sewage water (TSW) for irrigation purpose and evaluate its side effect on the irrigated plant under different soil types, (loamy sand and silty loam soil).

The obtained data showed that irrigation with treated sewage water TSW increased total chlorophyll significantly in wheat and radish than other irrigation sources. Conversely, total chlorophyll content decreased significantly when wheat or radish was irrigated with ground water (GW). All irrigation water sources showed no great differences in chlorophyll a/b. Carotenoids differed significantly due to irrigation water source and reached its peak when plants were irrigated with TSW.

Also, irrigation with Nile water (NW) and TSW increased fresh and dry weight of wheat and radish plants significantly more than the other irrigation water sources while; they decreased significantly when plants were irrigated with agriculture drainage water (ADW). The highest fresh /dry weight ratio was obtained when plants were irrigated with NW followed by TSW, while ADW showed the lowest in this respect.

Key words: Treated sewage water, Phytotoxicity, wheat, radish.

INTRODUCTION

The Nile is the predominant source of fresh water in Egypt. Presently, its flow rate relies on the available water stored in Lake Nasser to meet needs within Egypt's annual share of water, which is fixed at 55.5 Billion Cubic Meters annually by an agreement signed with Sudan in 1959. Approximately, 86.1 % of this water withdrawal used in agricultural purpose which is available to irrigate not more than 95% of the agricultural area (7790400 fed. According to FAO, 1996) showing 5 % deficiency. By the year 2000, another 2208000 fed (28.3 % of total agricultural area) was reclaimed (Toshky, Ewainat and the East of El-Tafrea). Accordingly, the total estimate of 69.4 billion m^3 /year will be needed, increasing the deficiency of water requirement to 32.3 %. The additional water resources are expected to be available from Ground water, increasing use of agricultural drainage water and the treated sewage water. But these sources have many constrains. The main constrain is water pollution especially in Sewage water (SW) which had occurred highly contamination levels in the irrigated soil such as El-Gabal El-Asfar farms.

Accordingly, the present work aims to study the side effect of treated sewage water (TSW) on plants cultivated in different soil types which have been irrigated for many years with SW comparing to the different irrigation water sources.

MATERIALS AND METHODS

I- Experiment design:

Two soil types (have been irrigated from many years ago with sewage water), loamy sand and silty loam soil were collected from the rhizosphere zone of El-Gabal El-Asfar and Tahanoub agricultural area, Qualubia governorate. Each soil type was air dried, ground and passed through 2-mm sieve to remove rocks, plant residues, and other large particles. Soil sample of 5.0 kg was sub-divided and placed in polyethylene bags. Some physical, chemical properities, soil texture and organic matter percentage of the investigated soils are presented in Tables 1 and 2.

Table 1. Chemical characteristics of soil samples

Soil type	pH (1:2.5) Suspen	EC dsm^{-1} at 25 C	Soluble cations (meq/l)				Soluble anions (meq/l)			O.M* %	SP** %
			Ca^{++}	Mg^{++}	K^+	Na^+	HCO_3^-	Cl^-	SO_4^{--}		
Silty loam	7.5	2.1	2.43	4.43	0.4	21.2	7.75	14.79	5.92	3.27	60.00
Loamy sand	7.5	1.31	7.03	2.27	0.78	3.91	5.75	3.36	4.88	1.97	19.33

* Organic matter ** Saturation percentage

Table 2. Particle size distribution of soil samples (mm).

Soil sample	Particle size distribution of the studied soil		
	Clay (<0.002)	Silt (0.002-0.02)	Sand (>0.02)
Silty loam	23.10	65.70	11.20
Loamy sand	10.42	5.98	83.60

Wheat (*Triticum aestivum*) and radish (*Raphanus sativus*) was seeded in winter and in summer, respectively, during 2004–2005, 2005/2006 & 2006/2007 growing seasons. Wheat and radish were thinned to 3 and 5 plants per pot after 21 or 15 d from sowing, respectively.

Different irrigation water sources, Nile water (NW), ground water (GW), and agricultural drainage water (ADW) were collected monthly during winter and summer seasons from Tahanoub, while sewage water (SW) and treated sewage water (TSW) were collected from El-Gabal El - Asfar Station. The pesticides and heavy metal contamination levels of the collected water are shown in Tables 3 & 4.

Table 3. Mean concentration of detected pesticides in different irrigation water sources at Qualubia governorate during winter and summer season, 2005 & 2006.

	Sources*	Pesticide (ppb)										
Sampling time	of Irrigation Water	α-HCH	β-HCH	D-HCH	p,p-DDD	O,P-DDT	P,P-DDT	P,P-DDE	endrin	*trans*-chlordan	choro-thalonil	Total OC**
winter season	N.W	0.12	0.01	ND	ND	0.06	ND	ND	0.01	ND	ND	0.20
	G.W.	0.01	ND	0.19	ND	0.40	0.18	ND	ND	0.03	ND	0.81
	A.D.W.	0.23	0.09	0.05	ND	0.30	0.19	ND	0.02	ND	ND	0.88
	S.W.	0.13	0.05	ND	ND	0.26	0.05	ND	ND	ND	ND	0.49
	T.S.W.	ND	ND	ND	ND	0.16	ND	ND	ND	ND	ND	0.16
summer season	N.W	ND	0.02	0.04	0.06	0.59	0.06	0.12	3.66	ND	0.43	4.98
	G.W.	ND	0.02	0.02	ND	1.66	0.13	0.14	3.62	ND	0.45	6.04
	A.D.W.	ND	ND	0.05	ND	0.54	ND	0.25	3.88	ND	0.40	5.12
	S.W.	ND	ND	0.02	ND	0.40	ND	0.11	4.00	0.02	0.25	4.80
	T.S.W.	ND	ND	0.02	ND	0.21	ND	0.11	3.19	0.02	0.17	3.72

* NW= Nile water, GW= Ground water, ADW= Agricultural drainage water, SW= sewage water and TSW= treated sewage
** Total organochlorine pesticide residues ND = not detected

During the experiment, fertilizers (urea 46 %, and super- phosphate 16 %) were added to the pots with the rate of 0.6 and 0.35 g/pot of wheat and 0.6 and 0.9 g/ pot of radish, respectively. Irrigation was practiced to keep soil almost at their field capacity for a period of growing season.

Table 4. Average concentration of heavy metals in different irrigation water at Qalubia governorate during winter & summer season, 2005 & 2006.

Sample	Irrigation water	Heavy metal concentration (mg/L)				Total conc
time	Sources*	Cd	Pb	Ni	Co	(mg/L)
Winter season	NW	0.001	0.066	0.569	0.003	1.380
	GW	0.001	0.060	0.747	0.005	4.063
	ADW	0.004	0.062	0.525	0.010	3.004
	SW	0.006	0.189	0.627	0.012	4.168
	TSW	0.004	0.149	0.504	0.007	3.319
Summer season	NW	0.315	0.344	0.313	0.014	0.986
	GW	0.431	0.360	0.537	0.006	1.335
	ADW	0.449	0.309	0.591	0.021	6.848
	SW	0.008	0.708	0.313	0.019	5.235
	TSW	0.002	0.618	0.248	0.012	4.399

*NW= Nile water, GW= Ground water, ADW= Agricultural drainage water, SW= sewage water and TSW= treated sewage water

Phytotoxicity measurements: -

Chlorophyll and carotenoids contents: -

According to Hiscox and Israelstam 1979, 100 mg of leaf tissue in fraction were placed in a test tube containing 7-ml dimethyl sulphoxide (DMSO). Chlorophyll and carotenoids were extracted into the fluid without grinding at 55 °C by incubating overnight. The extracted liquid was filtered and transferred to a graduated tube and completed up to a total volume of 10 ml with DMSO. Absorbance was measured by Spectronic 20 at 644 and 662 nm for chlorophyll determination, and 470 nm for carotenoids.

Total chlorophyll, chlorophyll a, or b was calculated using Arnon equation (1949), while Cañal *et al.,* (1985) was used for carotenoids.

Arnon equation: -

Chl. a = 12.7 x O.D 662 – 2.69 x O.D 644 mg/l

Chl. b = 22.9 x O.D 644 – 2.69 x O.D 662 mg/l

Chl. A+b = 20.2 x O.D 644 + 8.02 x O.D 662mg/l

Cañal equation: -

$$\frac{A470 - 1.28\ (\text{Chl. a mg/l}) + 56.7\ (\text{Chl. b mg/l})}{256 \times 0.906}$$

Fresh / dry weight: -

Fresh weight and dry mater content of the different plants were recorded.

5. Statistical analysis: -

Statistical analysis of all data was carried out using the "Costat" program (ANOVA).

RESULTS AND DISCUSSION

Phytotoxicity of different irrigation water sources on cultivated plants

1. Chlorophyll and carotenoids content: -

Data presented in Tables 5 and 6 shows that total chlorophyll and chlorophyll a/b ratio or carotenoids of wheat and radish leaves differed according to irrigation water sources during the growing seasons.

Wheat plant: -

As shown in Table 5, irrigation with TSW increased total chlorophyll significantly in wheat than other irrigation sources when planted in the different soil types. Conversely, total chlorophyll content decreased significantly when wheat was irrigated with GW. All irrigation water sources showed no great differences in chlorophyll a/b. Carotenoids differed insignificantly due to irrigation water source and reached its peak when plants were irrigated with TSW in all tested soil types during the two cultivated seasons.

Radish plant: -

As wheat plants, total chlorophyll of radish leaves (Table 6) shows that irrigation with TSW also increased total chlorophyll significantly over the other irrigation water sources when grown in silty loam and loamy sand soil. Conversely, total chlorophyll content decreased significantly when radish was irrigated with GW. All irrigation water sources showed no great differences in chlorophyll a/b ratio. The higher chlorophyll a/b ratio occurred in radish irrigated with ADW during the 1st growing season and with TSW in the 2nd season. Carotenoids content showed the same trend as in wheat leaves. The highest caroteniods content was found in plant irrigated with TSW in both silty clay and in loamy sand soil.

From the above mentioned results, plants which were irrigated with TSW showed the highest total chlorophyll and carotenoids content among the other irrigation sources. That may be due to the low level of pesticide residues and to high organic wastes content of TSW which has been recognized as a possible important source of the major plant nutrients, such as N, P, K which induced plant growth and chlorophyll content (Lapeña *et al.*, 1995). In this respect, Yadav *et al.*, 2002, indicated that, the use of sewage water for irrigation improved the organic matter and fertility status of soils and build up the total N, available P and K in surface. The high content of Cd, Pb and Ni in plant irrigated with GW could also decrease the total chlorophyll content, (Shukla *et al.,* 2002).

Furthermore, different organochlorine pesticides as DDT, HCH and herbicide like metribuzin decreased chlorophyll content of the contaminated plant (Sinha, 2002).

However, reduction in chlorophyll content with the toxic pollutants (heavy metal or pesticide) may be due to (a) formation of enzymes such as chlorophyllase which is responsible for chlorophyll degradation (Majumdar *et al.*, 1991). (b) Retardation of chlorophyll synthesis under the effect of heavy metals or due to changes in the endogenous cytokinins in leaves (Čizkovä, 1990) which are responsible for stimulation of chlorophyll synthesis (Banerji and Laloraya, 1967). (c) Enhancement of chlorophyll loss due to increases in the endogenous abscisic acids (ABA) in the leaves (Čizkovä, 1990) which are reported to accelerate the chlorophyll destruction and inhibits plastid differentiation and chlorophyll synthesis (Le Page-Degivery *et al.*, 1987), (d) damage the structure of chloroplasts as manifested by the disturbed shape and the dilation of the thylakoid membranes (Ouzounidou *et al.,* 1997). From the data, it is revealed that there was a relation between carotenoids and total chlorophyll content. The obtained results are in agreement with Cañal *et al.*, 1985, who mentioned that since the role of carotenoids as protectors of chlorophyll from light, chlorophyll reduction should follow the reduction of carotenoids level.

2- Dry and fresh weights: -

Data in Tables 7 and 8 show that dry and fresh weight of wheat shoots and radish leaves differed according to irrigation water sources during the two growing seasons.

Table 5. The effect of irrigation water sources on total chlorophyll and carotenoids contents in wheat leaves at 2004-2005 and 2005-2006 field growing seasons (mg/g fw).

Soil type	sources* of irrigation water	2004 - 2005					2005 - 2006				
		chl a	chl b	chl t	a/b	caroten	chl a	chl b	chl t	a/b	caroten
Silty loam	NW	1.34 ab	1.18 a	2.49 bc	1.14	0.28 a	1.61 c	1.38 b	3.02 c	1.17	0.55 b
	GW	1.28 b	1.15 a	2.40 c	1.11	0.23 a	1.41 d	1.25 c	2.67 e	1.13	0.47 b
	ADW	1.36 ab	1.16 a	2.51 ab	1.17	0.28 a	1.77 b	1.56 a	3.34 b	1.13	0.64 a
	TSW	1.41 a	1.18 a	2.58 a	1.19	0.29 a	1.94 a	1.59 a	3.54 a	1.22	0.67 a
	SW	1.35 ab	1.15 a	2.49 bc	1.17	0.26 a	1.53 c	1.35 b	2.89 d	1.13	0.51 b
Loamy sand	NW	1.05 c	0.64 bc	1.68 c	1.64	0.15 b	1.50 bc	1.15 c	2.64 c	1.30	0.59 b
	GW	0.81 d	0.52 d	1.34 d	1.56	0.13 b	1.34 d	1.12 c	2.45 d	1.20	0.46 c
	ADW	1.15 b	0.71 b	1.86 b	1.62	0.16 b	1.54 b	1.22 b	2.79 b	1.26	0.67 a
	TSW	1.49 a	0.88 a	2.35 a	1.69	0.21 a	1.74 a	1.30 a	3.06 a	1.34	0.71 a
	SW	1.03 c	0.60 c	1.67 c	1.72	0.14 b	1.45 c	1.13 c	2.58 c	1.28	0.56 b

* NW= Nile water, GW= Ground water, ADW= Agricultural drainage water, TSW = treated sewage water, SW= sewage water

The Figuers followed by the same letters are insignificant.

Table 6. The effect of irrigation water sources on total chlorophyll and carotenoids contents in radish leaves at 2005-2006 and 2006-2007 field growing seasons (mg/g fw).

Soil type	sources* of Irrigation water	2005 - 2006					2006 - 2007				
		chl a	chl b	chl t	a/b	caroten	chl a	chl b	chl t	a/b	caroten
Silty loam	NW	0.86 c	0.54 c	1.40 c	1.59	0.14 bc	0.86 c	0.74 bc	1.60 c	1.16	0.18 ab
	GW	0.44 e	0.33 d	0.78 e	1.33	0.10 d	0.77 d	0.67 c	1.42 e	1.15	0.14 b
	ADW	0.62 d	0.34 d	0.94 d	1.82	0.12 cd	0.87 bc	0.66 c	1.52 d	1.32	0.17 ab
	TSW	1.24 a	0.74 a	1.96 a	1.68	0.19 a	1.05 a	0.85 a	1.87 a	1.24	0.21 a
	SW	1.03 b	0.64 b	1.68 b	1.61	0.18 ab	0.94 b	0.77 b	1.71 b	1.22	0.20 a
Loamy sand	NW	0.67 c	0.45 c	1.12 c	1.49	0.11 b	0.86 b	0.71 ab	1.57 c	1.21	0.15 bc
	GW	0.43 e	0.34 d	0.79 e	1.26	0.05 c	0.71 d	0.60 c	1.31 e	1.18	0.12 c
	ADW	0.59 d	0.36 d	0.96 d	1.64	0.35 a	0.80 c	0.65 bc	1.49 d	1.23	0.13 c
	TSW	0.95 a	0.61 a	1.55 a	1.56	0.16 b	0.97 a	0.78 a	1.74 a	1.24	0.20 a
	SW	0.83 b	0.53 b	1.35 b	1.57	0.13 b	0.91 b	0.74 a	1.64 b	1.23	0.19 ab

* NW= Nile water, GW= Ground water, ADW= Agricultural drainage water, TSW = treated sewage water, SW= sewage water

The Figuers followed by the same letters are insignificant.

Wheat plant: -

Fresh and dry weights of wheat plants (Table 7) show that irrigation with NW and TSW increased fresh and dry weight significantly compared with the other irrigation water sources when plants were grown in the different soil types, while, it decreased significantly when wheat was irrigated with ADW. Plant irrigated with NW showed the highest fresh/dry weight ratio followed by TSW, while ADW was the lowest, during the two growing seasons.

Radish plant: -

Similar to wheat plants, data of radish plant (Table 8), show that irrigation with NW increased fresh weight significantly over the other irrigation water sources when grown in silty loam or loamy sand soil at the two studied seasons. Dry and fresh weights were increased significantly when radish was irrigated with NW and TSW. Conversely, irrigation with ADW decreased fresh or dry weight to be the lowest in each of silty loam or loamy sand soil at the 1st and the 2nd seasons.

From the above mentioned results it is clear that, plant irrigated with ADW showed the lowest fresh and dry weights. That because ADW contained the highest contamination level of Ni, Cd and Co or total pesticide residues compared to NW, GW or SW, which decreased fresh or dry weight as reported by Koul *et al.*, 2001. Conversely, TSW and NW highly increased fresh or dry weight due to result of the lowest contamination level of the total heavy metal such as Cd in TSW which could increase total amino acid level (Costa and Morel, 1994). Decreasing Fresh/dry weight ratio in plant irrigated with ADW than the other irrigation resulting from the high salinity of ADW which decrease the ability of roots to take water from the soil (Romero *et al.*, 2001) or to the high toxic pollutants which could reduce the ability of leaves to retain water, (Cañal *et al.*, 1985).

Finally, this study confirms that SW and ADW showed highly contaminated soil, plant and showed high phytotoxic effect compared with NW, TSW or GW. According to that, GW and TSW can effectively increase water resource for irrigation especially in light soil, but there is a need for continuous monitoring of the concentrations of potentially toxic contaminants in soil, plants and ground water.

Table 7. The effect of irrigation water sources on fresh and dry weight of wheat plant at 2004-2005and 2005-2006 growing seasons (g/plant).

Soil type	sources* of Irrigation water	Wheat shoot					
		2004 - 2005			2005 - 2006		
		fw	dw	fw/dw	fw	dw	fw/dw
Silty loam	NW	16.05 a	3.58 a	4.48	15.57 a	3.57 a	4.36
	GW	13.32 b	3.57 a	3.73	12.52 b	3.76 a	3.33
	ADW	9.53 d	2.69 c	3.54	8.62 c	2.75 b	3.13
	TSW	12.49 c	3.11 b	4.02	12.41 b	3.04 b	4.08
	SW	12.76 bc	3.80 a	3.36	12.79 b	3.78 a	3.38
Loamy sand	NW	16.67 a	3.90 a	4.27	16.35 a	3.87 a	4.22
	GW	13.74 b	3.79 a	3.63	13.50 b	3.75 a	3.60
	ADW	9.46 d	2.97 b	3.19	9.25 d	2.91 b	3.18
	TSW	12.95 c	3.19 b	4.06	12.57 c	3.23 b	3.89
	SW	13.60 b	4.10 a	3.32	13.30 b	4.05 a	3.28

* NW= Nile water, GW= Ground water, ADW= Agricultural drainage water, TSW = treated sewage water, SW= sewage water

The Figuers followed by the same letters are insignificant.

Table 8.The effect of irrigation water sources on fresh and dry weight of radish plant at 2005-2006 and 2006-2007 growing seasons (g/plant).

Soil type	sources* of Irrigation water	Radish					
		2005 - 2006			2006 - 2007		
		fw	dw	fw/dw	fw	dw	fw/dw
Silty loam	NW	5.36 a	0.75 a	7.15	5.16 a	0.72 a	7.17
	GW	4.70 b	0.74 a	6.35	4.50 b	0.69 a	6.52
	ADW	2.76 d	0.53 b	5.21	2.65 d	0.51 b	5.20
	TSW	3.59 c	0.52 b	6.90	3.45 c	0.51 b	6.76
	SW	4.54 b	0.77 a	5.90	4.44 b	0.75 a	5.92
Loamy sand	NW	5.63 a	0.78 a	7.22	5.42 a	0.75 a	7.23
	GW	4.93 b	0.75 a	6.57	4.70 b	0.74 a	6.35
	ADW	2.80 d	0.57 b	4.91	2.77 d	0.53 b	5.23
	TSW	3.75 c	0.55 b	6.82	3.65 c	0.53 b	6.89
	SW	4.78 b	0.80 a	5.98	4.63 b	0.77 a	6.01

* NW= Nile water, GW= Ground water, ADW= Agricultural drainage water, TSW = treated sewage water, SW= sewage water

The Figuers followed by the same letters are insignificant.

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التأثير السام لمياه الصرف الصحى المعالج و مصادر الرى التقليدية الأخرى على النبات

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أجريت هذه التجربة لدراسة مدى فاعلية إستخدام مياه الصرف الصحى المعالج فى أغراض الرى وتقييم تأثيرها الجانبى على النباتات المروية تحت ظروف أنواع التربه المختلفه.

أوضحت النتائج أن الرى بمياه الصرف الصحى المعالج أدى إلى زيادة الكلوروفيل الكلى للقمح والفجل زيادة معنوية عن مصادر الرى الأخرى. وعلى العكس من ذلك، إنخفض الكلوروفيل الكلى إنخفاضاً معنوياً عند الرى بمياه الآبار. كما لم تظهر جميع مصادر الرى إختلافاً كبيراً فى نسبة كلوروفيل أ/ب، بينما إختلفت الكاروتينات إختلافاً معنوياً تبعاً لمصدر الرى حيث بلغت أقصى زيادة معنوية لها عند الرى بمياه الصرف الصحى المعالج.

أيضاً، أدى الرى بمياه النيل ومياه الصرف الصحى المعالج إلى زيادة الوزن الجاف والوزن الرطب لكل من القمح والفجل زيادة معنوية مقارنة بمصادر الرى الأخرى، بينما أنخفضت معنوياً بالنباتات المروية بمياه الصرف الزراعى، كما سجلت النباتات المروية بمياه النيل أعلى نسبة للوزن الرطب/ الجاف يليها مياه الصرف الصحى المعالج ثم مياه الصرف الزراعى.