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Soil properties, flax varieties production and their heavy metals content under irrigation with low quality water

Atwa A.A.E.[1], Abou-Baker N.H.[2]* and Nassr M.M.I.[1]
[1]Soils, Water and Environment Research Institute, Agriculture Research Center and [2]Soils and Water Use Department, National Research Centre, Giza, Egypt.
*Corresponding author: nesreenhaa@yahoo.com

Abstract

A lyzimeter experiment was carried out at Sakha Agricultural Research Station, Kafr El-Sheikh governorate, Egypt and repeated in two seasons 2011/2012 and 2012/2013 Lyzimeters (100 x 70 x 90 cm) were filled with clayey soil and irrigated with three water treatments since twenty seven years ago, to study the effect of irrigation by different water quality (fresh water, drainage water and blended water) on soil properties, productivity of flax varieties (Sakha1, Sakha2, Sakha 101, and Sakha 102) and their contents of heavy metals (Pb, Cd, Ni and Cu). The obtained results showed that, using poor water quality for irrigation increased ECe, soluble cations and anions in soil paste extract and DTPA extractable heavy metals (Cu, Ni, Cd and Pb) than that of blended or good quality water. Highly significant differences of yield and yield components among flax varieties were found due to irrigation water treatments and its contents of heavy metals. Heavy metals content was higher of the straw than that of seeds. No significant difference were found among Cd content for all studied flax varieties. No significant differences were found among Cu, Pb and Cd content of straw with all studied flax varieties. Cadmium content in studied flax varieties decreased as follow: Sakha 2 < Sakha 1< Sakha 101 < Sakha 102, while the order was Sakha 1 < Sakha 2 < Sakha 101 < Sakha 102 for Pb, Cu and Ni. So, Sakha 1 was more tolerant variety to the irrigation with drainage and blended water

Keywords: Water quality, Heavy metals, Flax varieties, Soil characteristics.

Introduction

Egypt is almost solely dependent on the river Nile as the main fresh water source. Approximately 96% of Egypt's water supply is from that main source. Nearly 85% of the available supply, (approximately 55.5 billion cubic meters annually) is consumed by the agriculture sector (Mona El-Kady and Sameh, 2003). The possibility to increase water supply is limited and conditioned. Moreover the competition for limited water resource is increasing among urban, industrial, and agricultural interests. The drainage water is considered as an important source, which has been used by many countries after mixing with freshwater (El-Nagaawy, 2000). However, great amounts of various pollutants affect the quality of drainage water, which is mostly composed of domestic, industrial and/or agricultural effluents. The major types of toxic pollutants are the heavy metals of Pb, Cd, Zn, Ni, Co, Cr, Mn and Fe which come from industrial processes and agricultural practices (Khan *et al.*, 2007).

Use of low quality water in irrigation could be an important consideration when the disposal is being planned in arid and semi-arid regions. Using drainage water in irrigation caused high increase in EC and SAR of saturated soil paste extract (Omar *et al.*, 2001). Meanwhile, using drainage water in irrigation significantly increase the total and DTPA extractable heavy metals compared with Nile water (Zein *et al.*, 2002). Aboulrous *et al.* (1991) showed an increase in levels of heavy metals in soil irrigated with waste water. Once the ions have been absorbed through the roots or straw and have been transported to the xylem vessels there is the possibility of movement throughout the whole plants. The rate and extent of movement within plants depend on the metal concerned, the plant organ and the age of plant (Chaney and Giordano, 1977). Pollution is defined as any change in physical, chemical or biological conditions of the environment which may harmfully affect the quality of human life including effects upon animals and plants. The untreated industrial drainage waters contain little or more amount of heavy metals, which may cause enhancement of their level in the fresh and/or agricultural drainage water when they mixed. Toxic metal pollution of waters and soils was a major environmental problem. The mean problem concerned with water pollution was heavy metals when water containing these metals, as a pollutants, used for irrigation, it will contaminate and enrich soils and crops (Mireles *et al.*, 2004).

Also, as a result of water shortage, an available alternative is to use of low quality water in irrigation of fiber crops. Generally, fiber crops are non-food crops. Flax "*Linum usitatissimum* L." is a winter fiber and seeds crop. Flax is considered one of the most promising fiber and oil crops in Egypt. It is proposed to close up the gap of oil consumption by planting flax. Also, flax plant can be used successively as a phytoremediation in cleaning the polluted soils with Ni, Pb and Cd. The removal of Ni, Pb and Cd by flax was more pronounced than by jute plants. Whereas flax plant can be removed about 2 times higher for Ni, 7 times higher for Pb and 4 times higher for Cd than that by jute plant (Zein, 2004).

The objectives of the present work are to assess the effect of irrigation water quality on productivity, heavy metals contents of flax varieties and some soil characteristics.

Materials and Methods

A lyzimeter experiment was carried out at Sakha Agricultural Research Station, Kafr El-Sheikh governorate, Egypt and repeated for two seasons 2011/2012 and 2012/2013, to study the effect of irrigation by different water quality on soil properties, productivity of some flax varieties (Sakha 1, Sakha 2, Sakha 101, and Sakha 102) and their contents of heavy metals (Pb, Cd, Ni and Cu) for soil, seed and straw. Three water treatments were used for irrigation; fresh water, polluted drainage water and blended water (50% fresh water + 50% drainage water). The study was conducted in concrete Lyzimeters (100 x 70 x 90 cm) filled with clayey soil since 1987. Some characteristics of the used irrigation water are presented in Table (1).

The four flax "*Linum usitatissimum* L." varieties were planted on 25th of November in two the seasons at the rate of seeds 60kg/fed. Phosphorus was applied as super phosphate (15.5% P_2O_5) before sowing at rate of 15.5Kg P_2O_5/ fed. Nitrogen was applied as urea (46.5% N) at rate of 60 Kg N/fed. in two dose and potassium fertilizer was added in the form of potassium sulphate (48% K_2O) at rate of 24 kg K_2O/ fed. after one month of planting. All other agronomic practices were carried out according to Ministry of Agriculture recommendations. Plants were harvested in 15 May, straw and seeds yields were weighted in Kg/fed, weight of seed/plant, weight of 1000 seeds, technical length, top capsule zone length and number of capsule were recorded. Representative seed and straw samples were collected for analysis. Weighted technique was used for samples digestion as described by Chapman and Pratt (1961). Soil samples were taken from each Lyzimeter before planting and after harvesting, for analysis of total soluble salts, soluble cations and anions in soil paste extract according to Richards (1969), and extracted by DTPA to determined Pb, Cd, Ni and Cu using an Atomic Absorption Spectrophotometer, according to Lindsay and Norvell (1978). Translocation coefficient from straw to seeds (TC%) was calculated as follow: TC % = Content of heavy metal in seeds (mg/kg)/ Content of the same heavy metal in straw (mg/kg) x 100.

A split–plot design with four replicates was used. The irrigation treatments and varieties were allocated the main and sub plots, respectively. Statistical analysis was carried out using Irristat-Software, Computer Program (Duncan, 1965).

Table (1): Chemical characteristics of used water during the two seasons.

Water qualities	EC, dS/m at 25°C	pH	Cation, meq./l				Anion, meq./l				Water class
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$	
Fresh water	0.50	7.5	1.9	1.27	1.53	0.30	-	2.51	1.41	1.08	C_2-S_1
Drainage water	1.80	8.30	5.70	2.8	9.02	0.48	-	4.30	8.3	5.40	C_3-S_2

	Heavy metal content (mg/l)			
	Cu	Ni	Cd	Pb
Fresh water	0.018	0.007	0.008	0.09
Drainage water	0.280	0.301	0.037	0.900
Critical limits according FAO (1989)	0.200	0.200	0.010	5.000

Results and Discussion

Fresh and drainage water evaluation: According to Richard's classification and the data presented in Table (1), fresh water was classed in (C2-S1) medium salinity and low sodicity, while, drainage water was classed in (C3-S2) high salinity and medium sodicity which cannot be used for soils with restricted drainage and crop with good salt tolerance should be selected (Richards, 1969). It can be concluded that fresh water is a good quality, drainage water is a poor quality for irrigation and the blended water is an intermediate between them. Also data in Table (1) showed that the studied heavy metals Cd, Pb, Ni and Cu content of drainage water were greater than both of Nile water and the critical limits, according to FAO (1989), i.e., 0.01, 5.00, 0.2 and 0.2 for Cd, Pb, Ni and Cu mg/l, respectively. The high heavy metal contents in drainage water could be attributed to the pollution sources of industrial and municipal wastes discharged to the drainage system. These results are in agreement with those obtained by El-Mowelhi *et al.*, (1995).

Effect of water qualities on some chemical properties of clay soils:

A- Soil salinity and soluble ions: The changes in electrical conductivity of soil paste extract (dS/m), soluble cations (Ca^{+2}, Mg^{+2}, Na^{+} and K^{+} meq./l) and soluble anions (HCO_3^-, Cl^- and SO_4^{--}meq./l) before planting and after harvesting are listed in Table (2). The data show that EC values decreased from 4.70 to 4.20 by using fresh water but increased from 5.13 and 5.40 dS/m to 5.35 and 6.26 dS/m as affected by blended water and drainage water treatments, respectively. The obtained data showed also, that utilization of drainage water for irrigation purposes tend to increase soluble cations and anions Na^{+}, Mg^{++}, So_4^{--} and Cl^- than before planting. All soluble anions were higher in soil irrigated with poor water quality and in harmony with those obtained by Zein *et al*. (2012).

B- DTPA- extracted heavy metals from studied soil: Data in Table (3) show that all values of DTPA extractable heavy metals of soils can be discendingly arranged according to the effect of water treatments as follow: Drainage water > blended water > fresh water before flax planting and after harvesting. Soil content of heavy metals has followed the sequence Cu > Pb > Ni > Cd in case of fresh water. This trend was different under using drainage and mixed water Pb > Cu > Ni > Cd. This may be due to the behavior of available Pb changed to these findings. The obtained results are in agreement with those of Aboulroos *et al*. (1991) who found that the behavior of Cu and Pb differ from that of Cd, CO and Ni in soils irrigated with sewage effluent, they added that in Cd, Cu and Ni metals, the percentages held in primary minerals fraction were increased with time on the expense of the percentage of other fractions, especially that organically complexes. Although the studied soils were still beyond the critical levels, it could be reached this point upon the continuous using of polluted drainage water.

Effect of water quality on yield and yield components: The seed yield of flax (kg fed^{-1}) was affected significantly with flax varieties and water quality (Table 4). The highest seed yield (689, 690 kg/fed.) were gained by Sakha 1 under fresh water, while the lowest seed values (276 and 272 kg/fed.) were obtained by Sakha 102 under drainage water in first and second seasons, respectively. Both fresh and blended water gave the highest straw yield of Sakha 1 and Sakha 2, while, irrigation of Sakha 102 by drainage water gave high straw yield in two seasons without significant difference between all of them. Irrespective of water quality, Sakha 1 gave the highest No. of seed/plant in both seasons under all water treatments. Weight of 1000 seeds values in second season confirm that of first season where it take the same trend. Few differences in top capsule zone and technical length were observed between flax varieties under all water quality treatments.

Table (2): Soil chemical analysis before planting and after harvesting under three irrigation water quality.

Water quality	Cation, meq./l				Anion, meq./l				ECe	pH	SP (%)	N	P	K
	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3-	Cl^-	So_4--	dS/m	1:2.5		ppm	ppm	ppm
Before Planting														
Fresh water	18.36	11.9	16.30	0.44	-	4.60	14.4	28.00	4.70	8.08	75.70	20	11	325
Blended water	20.20	11.0	19.70	0.40	-	4.20	16.70	30.40	5.13	8.15	76.60	26	12	401
Drainage water	21.40	11.50	20.58	0.52	-	4.80	18.10	31.10	5.40	8.21	78.20	27	15	415
After harvesting														
Fresh water	15.72	10.40	15.47	041	-	3.53	14.5	23.97	4.20	8.05	76.10	22	12	360
Blended water	20.15	11.90	21.06	0.39	-	4.75	17.12	31.63	5.35	810	76.80	27	14	460
Drainage water	21.30	11.60	29.20	0.50	-	5.15	23.24	34.21	6.26	8.20	77.60	28	17	490

Table (3): DTPA extractable heavy metal concentrations (mg/kg) before planting (2010) and after harvesting (2012) flax as affected by water quality.

Water quality	Heavy metal content (mg/kg soil)			
	Cd	Ni	Pb	Cu
	Before planting (2010)			
Fresh water	0.092	1.87	3.01	5.20
Blended water	0.145	2.05	8.10	6.56
Drainage water	0.165	2.78	10.20	7.13
	After harvesting (2012)			
Fresh water	0.094	1.61	3.58	5.30
Blended water	0.155	2.10	8.45	6.70
Drainage water	0.170	2.90	11.10	7.33

Table (4): Effect of water quality on yield and yield components of the tested flax varieties in two seasons.

Varieties	Water quality treatments					
	First season			Second season		
	Fresh Water	Blended water	Drainage water	Fresh water	Blended water	Drainage water
	Seed yield (kg/fed.)					
Sakha 1	689.0 a	555.5 a	525.0 a	690.0a	551.5 a	520.0 a
Sakha 2	624.0 b	553.0 a	392.5 b	630.0a	551.0 a	392.0 b
Sakha 101	510.0 c	460.0 b	362.5 b	520.1 b	461.0 b	362.0 b
Sakha 102	440.0 d	412.0 c	276.0 c	450.0 c	411.0 c	272.0 c
	Straw (kg/fed.)					
Sakha 1	4884.0 a	3862.5 a	3614.5 bc	4890.0 a	3862.4 a	3602.3 bc
Sakha 2	4519.8 b	4107.5 a	3801.0 ab	4525.8 b	4101.1 a	3800.0 ab
Sakha 101	3788.0 c	3531.0 b	3456.0 c	3770.0 c	3526.0 b	3426.0 c
Sakha 102	4282.0 b	4004.0 a	3924.0 a	4262.0 b	4000.3 a	3902.0 a
	Weight of seed/ plant					
Sakha 1	115.0 a	110.0 a	91.3 a	113.0 a	108.56 a	90.86 a
Sakha 2	78.5 b	74.8 c	63.0 c	79.1 b	75.10 c	62.45 c
Sakha 101	88.8 b	87.3 b	77.0 b	86.23 b	86.43 b	76.23 b
Sakha 102	87.0 b	82.8 bc	75.0 b	86.54 b	81.41 bc	74.56 b
	Weight-1000 seed (gm)					
Sakha 1	6.6 a	5.01 b	3.48 bc	6.52 a	4.99 b	3.33 bc
Sakha 2	6.23 ab	5.20 ab	5.05 a	6.12 ab	5.13 ab	4.85a
Sakha 101	5.85 bc	5.43 a	3.65 b	5.76 bc	5.42 a	3.55 b
Sakha 102	5.75 bc	4.38 c	3.12 c	5.44 bc	4.23 c	3.06 c
	Top capsule zone length					
Sakha 1	22.25 a	21.75 a	16.25 b	21.86 a	21.45 a	16.04 b
Sakha 2	20.00 a	20.00 a	19.25 a	19.88 a	19.56 a	19.09 a
Sakha 101	19.75 a	18.75 a	17.26 a	19.76 a	18.60 a	17.12 a
Sakha 102	17.25 a	16.75 a	16.50 a	17.20 a	16.43 a	16.23a
	Technical stem length (cm)					
Sakha 1	103.0 a	101.80 a	94.0 a	101.78 a	101.72 a	93.58 a
Sakha 2	99.50 a	97.50 b	91.0 b	98.76 a	96.45 b	90.55 b
Sakha 101	94.80 a	94.50 a	86.5 a	94.35 a	93.66 a	85.94 a
Sakha 102	98.30 a	101.3 a	79.0 a	97.87 a	101.22 a	78.96 a

Heavy metals contents: Data in Table (5) show that the studied heavy metals Cd, Pb, Ni and Cu content of flax plant under drainage water were greatest than that of fresh water and blended water. This could be attributed to the pollution sources of industrial (oil and soap factory) and municipal wastes discharged to the drainage system. These results are in agreement with those obtained by Zein *et al*. (2002) and El-Mowelhi *et al*. (1995). Table (5) illustrate that the influence of water quality on the studied heavy metals means concentration in straw and seeds. The order of heavy metals content in both seeds and straw was Cu> Pb > Ni > Cd.

Highly significant effects of water quality (fresh water, blended water and drainage water) were obtained especially with Cu, Ni and Pb. The distribution of Cu within plants is highly variable within roots Cu is associated mainly with cell wall and it's largely immobile. Duneman *et al*. (1991) found that the concentration of Ni in plants, generally, reflects the concentration of the element in the soil, although the relationship is clearly more directly related to the concentration of soluble ions of Ni and rate replenishment of this mobile pool. As Ni is easily mobile in plant, berries and seeds are reported to contain elevated Ni concentration (Kabata-Pendias, 2000).

Cadmium content of seeds has the lowest values in all studied heavy metals (Table 5). This conclusion is in agreement with Alloway (1995) who found that the uptake of Cd decreased when pH was increased. Page *et al.* (1981) found that relative excess of Cu, Ni and Mn can reduce uptake of Cd by plants. The Cd in plants is relatively very mobilize, although the translocation of Cd through the plant tissues may be restricted because Cd is easily held mainly in exchange sites of active compounds located in the cell walls (Cunningham *et al.*, 1975).

Table (5): Effect of water quality on heavy metals content (mg/kg) of seeds and straw of flax varieties (Mean of two seasons) and translocation coefficient (TC %)

Varieties	Heavy metals content (mg/kg dry Wight)											
	Cu			Ni			Cd			Pb		
	Fresh water	Blended water	Drainage water	Fresh water	Blended water	Drainage water	Fresh water	Blended water	Drainage water	Fresh water	Blended water	Drainage water
	Seeds											
Sakha 1	4.05 c	6.00 c	8.03 a	0.16 c	0.21 c	0.32 b	0.08	0.10	0.16	0.11 c	0.12 c	0.21 d
Sakha 2	4.40 b	6.10b c	8.03 a	0.17bc	0.22 bc	0.35 a	0.08	0.10	0.14	0.13 b	0.22 b	0.30c
Sakha 101	4.60 a	6.20 ab	8.10 a	0.18 ab	0.23 ab	0.35a	0.09	0.11	0.16	0.14 ab	0.26a	0.39 a
Sakha 102	4.70a	6.30 a	8.12 a	0.19a	0.24 a	0.36 a	0.10	0.13	0.18	0.15 a	0.23b	0.36 b
	Straw											
Sakha 1	11.0	22.0	23.0	2.30 d	4.31 d	4.36 b	1.03	2.03	3.05	3.62	5.71	6.82
Sakha 2	12.0	23.0	24.0	2.31 c	4.33 c	4.34 c	1.13	2.05	3.04	3.65	5.76	6. 86
Sakha 101	13.0	24.0	25.2	2.36 b	4.41 b	4.42 a	1.23	2.10	3.12	3.71	5.85	6.93
Sakha 102	14.0	24.5	25.3	2.40 a	4.41b	4.43 a	1.30	2.15	3.16	3.72	5.82	6.97
	Translocation from straw to seeds (%)											
Sakha 1	36.81	27.27	34.91	6.95	4.87	7.33	7.76	5.91	5.24	3.03	2.10	3.07
Sakha 2	36.66	26.52	33.45	7.35	5.08	8.06	5.30	4.78	4.61	3.56	3.76	4.37
Sakha 101	35.38	25.83	32.14	7.62	5.12	7.91	7.31	5.23	5.13	3.77	4.51	5.62
Sakha 102	33.57	25.71	32.09	7.91	5.44	8.12	7.69	6.04	5.70	4.03	3.93	5.16
Range *		5-20			0.02-5			0.1-2.4			0.2-20	

*Kabata Pendias and pedias (1992)

Data in Table (5) indicate that the flax seeds generally had the lowest content of studied heavy metals under all water treatments. No significant difference in Cd for all treatments of water quality and flax varieties. Sakha 1 variety had the lowest content of Pb, Ni and Cu under all water treatments. Cadmium content in studied flax varieties decreased as follow: Sakha 2 < Sakha 1< Sakha 101 < Sakha 102, while the order was Sakha 1 < Sakha 2 < Sakha 101 < Sakha 102 for Pb, Cu and Ni. These results are very important for classified the more flax varieties tolerant to various heavy metals in polluted soils. From these sequences we can favor one variety in every soil polluted with one element. These may be due to the differences in genetic constitution of the studied genotypes and/or the dilution effect phenomenon. These results are in partial agreement with those obtained by Zein *et al*. (1996) in their study on soybean cultivars, and Shalaby *et al*. (1996) who concluded that increasing of heavy metals concentration in plants may attributed either to the higher amounts of these heavy metals added into the used soil through the applied wastes.

The data of translocation coefficient from straw to seeds also were presented in Table (5). Once the ions have been absorbed through the roots and have been transferred to the xylem vessels, there is possibility of movement throughout the whole plant, the rate and extent of movement within plants was studied by, Alloway (1995).

The studied heavy metals translocation from straw to seeds can be arranged according to mean values of translocation coefficient in the following the order: Cu > Cd > Ni > Pb. Cupper was the largest values of TC % while Pb was the least in translocation from straw to seeds in all types of water treatments (fresh water, blended water and drainage water). The results are in good agreement with those of Zein *et al*. (2002) and Chaney and Giordano (1977) who classified Pb as one of the least translocated elements with plant. They added that, under conditions of optimal growth, Pb precipitates on root cell wall in the insoluble amorphous form. Zhen – Guo Shen *et al*., (2009). found that application of EDTA (as an organic conditioner) to the soil significantly increased the concentrations of Pb and enhancing Pb accumulation in the plants while the Cu, Cd and Ni concentration and translocation coefficient indicate that Ni values increased due to drainage water treatment than other treatment due to its higher content of polluted drainage water from oil and soap factory (used Ni as a catalyst in one processes of manufacturing). The obtained results are in good agreement with that of Chancy and Giordano (1977) and Zein *et al*., (2012) for heavy metal translocation.

Conclusions

Considering the previous discussions, it seems that there is an obvious need for more research work to be carried out on the risk assessment of heavy metals contaminated soils. As mentioned by Eissa and El-Kassas (1999) the danger of distribution wastes by such factories containing high concentration of heavy metals affects the survival in the suffering areas. The safest policy would appear to minimize inputs of heavy metals to soil wherever to save our life and economy and restrict heavy metals bioavailability in the soil- plant- animal pathway. Abo El-Naga *et al*. (1999) and Zein *et al*. (1998 and 2009) recommended that attention must be earnestly given to protect the environment and commitments and the latest law issued 1994 in Egypt, must be obligatory under taken for these factories to prevent them from polluting agricultural soil by wastes. They added that apart from the roles played by pollution control and soil chemistry, plant breading can make a vital contribution through the selection and utilization of crop genotypes which accumulate the least heavy metals.

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