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EFFECT OF POLLUTED IRRIGATION WATER ON FABA BEAN VARIETIES, SOIL PROPERTIES AND THEIR CONTENTS OF HEAVY METALS

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ABSTRACT

Two Lyzimeter experiments were conducted at Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt, for two seasons, 2007/2008 and 2008/2009. Lyzimeters (100 x 70 x 90 cm) were filled with clayey soil and irrigated with three water treatments since twenty years ago.

The present study aimed to investigate the effect of irrigation water quality for long-term on productivity of four Faba bean varieties (Sakha 2, Giza 461, Giza 3 and Giza 843). Three irrigation water qualities; Nile water (W_1), polluted drainage water (W_3) and mixed water; W_2 (50% W_1 + 50% W_3) used for irrigation to study its effects on faba bean contents from four heavy metals Ni, Cd, Pb and Cu and some soil characteristics. A split–plot design with four replicates was used where, water treatments and varieties were allocated to main and sub-plots, respectively.

The obtained results showed that:

- Using poor water quality for irrigation increased ECe, SAR, soluble cations and anions in soil paste extract and DTPA extractable heavy metals in soils (Cu, Ni, Cd and Pb) than that of mixed or good water quality.
- Highly significant differences of yield and yield components between faba bean verities were found due to irrigation water treatments and its contents of heavy metals.
- Content of the studied heavy metals were in the following order; roots > leaves > coat of seed >cover of pod > seeds.
- The results showed that Sakha 2 was more tolerant variety to drainage and mixed water and its contents of Ni, Pb and Cu were lower than Giza 3, Giza 843 and Giza 461.
- No significant differences were found between all studied faba bean varieties used for Cd content.
- The content of seed faba bean varieties from heavy metals can be arranged as follow:

  With Pb: Sakha 2 = Giza 3 < Giza 461 < Giza 843
  With Cu: Sakha 2 < Giza 843 < Giza 3 < Giza 461
  With Ni: Sakha 2 < Giza 3 < Giza 843 < Giza 461

Keywords: Water quality, productivity, heavy metals, Faba bean varieties, soil characteristics.

INTRODUCTION

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 Nile and/or agricultural drainage water when they mixed.

When water containing these metals as pollutants used for irrigation, it will contaminate and enrich soils and crops which may be risks for human food and animal fooder (Zein *et al.,* 1998).

A recent study showed a remarkable increase in levels of heavy metals in some Egyptian soils (especially soils lies in the extreme North Delta) in addition appreciable amount of these metals are found in vegetation, water bodies and aquatic organisms in western and Middle areas of the Nile delta (El-Sanafawy, 2002).

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 (Omer *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).

Once the ions have been absorbed through the roots or leaves 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). Mn, Zn, Cd, B, Mo and Cu were classified as intermediate and Cr, Pb and Hg were translocated to least extent. Faba bean (*Vicia faba* L.) is the most important legume crop in Egypt, due to its high nutritive value for human food and its role break crop in cereal rotation system. The planted area was about 216.000 feddans in the last five seasons. In northern parts of Egypt the planted faba bean area represent about 85% of the total planted faba bean area. (El-Galay, Ola *et al*., 2008).

The objectives of the present work are to assess the effect of irrigation water quality for long-term on productivity, heavy metals contents of Faba bean varieties and some soil characteristics.

MATERIALS AND METHODS

Two lyzimeter experiments were carried out at Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt, for two seasons 2007/2008 and 2008/2009 to study the effect of irrigation water quality for long –term on the productivity of four faba bean varieties, (Sakha 2, Giza 461, Giza 3 and Giza 843) and the content of their leaves, roots, pod cover, seeds and seed coat of heavy metals; Pb, Cd, Ni and Cu.

The study was conducted in concrete Lyzimeters (100 x 70 x 90 cm) Filled with clayey soil science 1987.

The four faba bean varieties were planted on 15 November in two seasons at 20 plants / Lyzimeter.

Three water treatments were used for irrigation; Nile water W_1 polluted drainage water W_3 and mixed water W_2; (50% W_1 + 50% W_3). Some characteristics of the used irrigation water are presented in Table 1.

The treatments were incorporated in a split –plot design with four replicates. Irrigation treatments and varieties were allocated the main and sub plots, respectively. Phosphorus was applied as super phosphate (15.5% P_2O_5) in one dose before sowing at the rate of 30Kg P_2O_5/Fed.

Nitrogen was applied as urea (46.5 N%) at the rate of 15 Kg N/fed. in one dose after thinning and potassium fertilizer was added in the form of potassium sulphate (48% K_2O) at the rate of 24 kg K_2O/ fed. after one month of planting. All other agronomic practices were followed as recommended. Plants were harvested at 15 May. Seed, straw weights in Kg/fed., number of pods/plant, weight of pods, number of seeds/plant and number of branches were recorded. Representative seed and straw, pods, were collected for analysis, dry aching 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 chemical analysis; total soluble salts, soluble cations & anions in soil paste extract were determined according to Richards (1969). Soil samples were DTPA extracted and Pb, Cd, Ni and Cu were determined using an Atomic Absorption Spectrophotometer. Soil chemical analysis before sowing and after harvesting (according to Lindsay and Norvell, 1978) are presented in Table (2). Statistical analysis was carried out using Irristat- Software, Computer Program.

Table (1): Chemical characteristics of Nile and drainage water used for irrigation during the two seasons.

Irrigation water	EC dS/m at 25°c	pH	Cation meq/L				Anion meq/L				SAR	Water class
			Ca^{++}	Mg^{+2}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$So_4^{=}$		
Nile water	0.48	7.40	1.60	1.68	1.70	0.28	-	3.45	1.11	0.70	1.33	C_2-S_1
Drainage water	1.98	8.30	4.80	2.43	12.07	0.60	-	4.15	11.08	4.01	6.34	C_3-S_2

Irrigation water	Heavy metal content mg/L			
	Cu	Cu	Cu	Cu
Nile water	0.016	0.016	0.016	0.016
Drainage water	0.260	0.260	0.260	0.260
Critical limits according FAO (1989)	0.200	0.200	0.200	0.200

RESULTS AND DISCUSSION

Nile and drainage water evaluation:

Chemical characteristics of Nile and drainage water used for irrigation of faba bean varieties are shown in Table (1) According to Richard's classification, Nile water C_2-S_1; medium salinity low sodicity (Richards, 1969). While, data of drainage water revealed that the water was in the class of (C_3S_2), high salinity and medium sodicity which can not be used for soils with restricted drainage and crop with good salt tolerance should be selected. It can be concluded that Nile water is of good quality and drainage water of poor quality for irrigation. The mixed water will be intermediate between them in relation to its chemical composition. Also data in Table (1) Show that the studied heavy metals Cd, Pb, Ni and Cu content of drainage water were greater than of Nile water and higher than 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 these obtained by El-Mowelhi *et al.*, (1995).

Effect of the studied irrigation water qualities on some chemical properties of clay soils:

A- Soil salinity, SAR and soluble ions:

Change 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) are listed in Table (2). Comparing the mean ECe values of the studied soils, before planting and after harvesting, the data show that EC values increased from 4.95, 5.62 and 6.56 dS/m to 5.05, 6.00 and 7.68 ds/m as affected by W_1, W_2 and W_3 water quality treatments, respectively. SAR mean values increased from 5.34 and 6.17 to 5.94 and 6.71 as affected by W_2 and W_3 water treatment. The obtained data showed also, that utilization of drainage water for irrigation purposes tend to increase soluble cations Na^{+}, Mg^{++} , So_4^{--} and Cl^{-} than before planting. The data also showed that all soluble anions, Cl^{-} and So_4^{--} mean values, were higher in soil irrigated with poor quality in harmony with those obtained by Zein *et al*. (1996).

Table (2): Soil chemical analysis before planting and after harvesting under three irrigation water quality (means of two seasons)

Water quality	Cation meq/L				Anion meq/L				ECe	pH	SAR	SP
	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCo_3-	Cl^{-}	So_4--	ds/m	1:2.5		%
Before Planting												
W_1	19.5	10.6	18.98	0.42	-	3.85	15.20	30.45	4.95	8.18	4.89	75.34
W_2	22.8	11.0	21.94	0.46	-	3.80	16.60	35.80	5.62	8.20	5.34	75.80
W_3	26.16	12.16	26.76	0.52	-	3.70	22.10	39.80	6.56	8.25	6.17	76.10
After harvesting												
W_1	19.72	10.96	19.34	0.48	-	3.90	15.60	31.00	5.05	8.10	4.95	75.40
W_2	23.42	11.32	24.76	0.50	-	3.75	17.96	38.29	6.00	8.00	5.94	75.85
W_3	31.56	13.00	31.66	0.58	-	3.80	25.22	47.68	7.68	8.30	6.71	76.22

B- DTPA- extracted heavy metals from studied soils:

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 : W_3 > W_2> W_1 before faba bean planting and after harvesting.

It seems that soil content of DTPA-extractable studied heavy metals has followed the sequence Cu > pb > Ni > Cd. This trend was different from that found under using drainage water and mixed water pb > Cu > Ni > Cd. This may be due to that some of available Pb changed to these findings. The obtained results are in agreement with those of Abou El-Roos *et al*. (1991) who found that the behaviour 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 complexed. 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 polluted irrigation water on yield and yield components:

Data in Table (4) show that the seed yield (Kg/fed.) of Faba bean were significantly affected with Faba bean varieties. The higher mean seed yields

(1722.5, 1717.5), (1615.0, 1622.5) and (1512.5, 1480) kg/fed. were obtained with Sakha 2 at W_1 , W_2 and W_3 in the two seasons, respectively.

Table (3): DTPA extractable heavy metal concentrations from 2007 to 2009 (mg/kg) before planting and after harvesting faba bean varieties (means of two seasons) as affected by water quality.

Irrigation water quality	Heavy metal content mg/kg soil			
	Cd	**Ni**	**Pb**	**Cu**
	Before planting (mg/kg soil)			
W_1	0.0920	1.61	3.77	5.80
W_2	0.1418	1.86	8.40	6.50
W_3	0.1620	2.23	10.40	7.1
	After harvesting (mg/kg soil)			
W_1	0.0940	1.82	3.7	5.9
W_2	0.1560	2.10	8.8	6.7
W_3	0.1731	2.40	11.02	7.3

Table (4): Effect of irrigation water treatments on yield and yield componentsof the tested Faba bean varieties in two seasons.

Varieties	First season Irrigation water			Second season Irrigation water		
	W_1	**W_2**	**W_3**	**W_1**	**W_2**	**W_3**
	Seeds kg/fed.					
Giza 3	1420.00 d	1213.8 c	1174.5 d	1440.0 c	1252.5 c	1177.5 c
Giza 461	1640.00 b	1123.3 d	945.3 d	1660.0 b	1133.3 d	948.00 d
Giza 843	1617.50 c	1368 5 b	1204.0 b	1637.5 b	1383.5 b	1221.3 b
Sakha 2	1722.50 a	1615.0 a	1512.5 a	1717.5 a	1622.5 a	1480.0 a
	Straw kg/fed.					
Giza 3	1903.8 c	1701.5 c	1642.5 b	2003.8 b	1801.5 b	1717.5 b
Giza 461	2349.5 a	2277.5 a	1962.3 a	2357.5 a	2280.0 a	1967.5 a
Giza 843	1735.8 d	1510.0 d	1460.3 d	1745.0 d	1512.5 c	1457.5 a
Sakha 2	1932.5 b	1828.5 b	1528.3 c	1947.5 c	1830.0 b	1525.0 c
	Number of pods/plant					
Giza 3	5.0 a	4.3 a	3.8 a	5.00 a	4.25 a	3.75 a
Giza 461	4.8 a	3.3 b	3.0 a	4.75 b	3.00 b	2.75 b
Giza 843	4.3 a	3.8 ab	3.3 a	4.75 b	4.00 ab	3.25 a
Sakha 2	4.3 a	3.8 ab	3.3 a	4.5 b	4.00	3.25 a
	Weight of pods (gm)					
Giza 3	2.74 b	2.49 c	2.35 c	2.77 c	2.49 b	2.35c
Giza 461	3.31 a	2.43 c	2.20 c	3.40 b	2.40 b	2.2 c
Giza 843	3.63 a	2.95 b	2.78 b	3.65 ab	3.3 a	3.25 a
Sakha 2	3.63 a	3.35 a	3.20 a	3.83 a	3.25 a	3.20a
	Number of seeds /pod					
Giza 3	2.5 b	2.0 b	1.8 b	3.00 c	2.25 b	1.75 bc
Giza 461	3.8 a	2.8 a	1.8 a	3.5 b	2.75 ab	1.5 c
Giza 843	3.8 a	3.3 a	3.0 a	4.00 ab	3.25 a	2.75 a
Sakha 2	4.3 a	3.3 a	3.0 a	4.5 a	3.25 a	2.8 a
	Number of branches					
Giza 3	1.8 a	1.5 a	1.5 a	1.75 a	1.75 a	1.5 a
Giza 461	1.8 a	1.5 a	1.3 a	1.75 a	1.50 a	1.25 a
Giza 843	1.8 a	1.5 a	1.5 a	1.75 a	1.75 a	1.5 a
Sakha 2	2.0 a	1.8 a	1.8 a	2.00 a	1.75 a	1.75 a

The obtained data show that Sakha 2 variety was the superior in its seed yield for all water quality treatments. In contrast the higher mean of straw yields (2349.5 , 2357.5) , (2277.5 , 2280) and (1962.3 , 1967.5) kg/fed. were obtained with Giza 461 variety for all water quality treatments in the two seasons, respectively.

Number of the pods / plant were insignificantly affected with Faba bean varieties under this studies, while weight of the pods/plant were significantly affected by Faba bean varieties. The higher means (3.63, 3.83), (3.35, 3.25) and (3.2, 3.2) gm were produced from Sakha 2 under W1, W_2 and W_3, respectively. Followed by (3.63, 3.65), (2.95, 3.3) and 2.78, 3.25) g with Giza 843 Faba bean variety in the first and second season, respectively.

Number of the branches / plant were insignificant affected with Faba bean varieties and water treatments in the two seasons. The highest numbers of seed/pod and weigh of pods (g) were attained by Sakha 2.

Heavy metals contents:

Data in Table (5) show that the studied heavy metals Cd, Pb, Ni and Cu content of faba bean plant under drainage water were greatest than that of Nile water and mixed 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 and Figs from, 1 to 4 illustrate the influence of water quality on the studies heavy metals means concentration in roots, coat seed, pod cover, leaves and seeds. On faba bean varieties especially with irrigated by drainage water (W_3) were as the following order:

Roots : Pb > Ni > Cu > Cd

Leaves : Pb > Cu > Ni > Cd

Seed coat : Ni > Pb > Cu > Cd

Pod cover : Ni > Pb > Cu > Cd

Seed : Ni > Pb > Cu > Cd

Table (5) reveals the highly significant effects of water quality (W_1, W_2 and W_3) especially with Ni, Pb.

The distribution of Cu within plants is highly variable within roots Cu is associated mainly with cell wall and its largely mobile.

Dunman *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 (Alina and Pendias *et al.,* 2000).

Cadmium values (Table, 5) of seeds indicated that Cd has the lowest values in all studied heavy metals. This conclusion are in agreement with Alloway (1995) who found that the uptake of Cd decreased when pH was increased, faba bean showed a similar response.

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).

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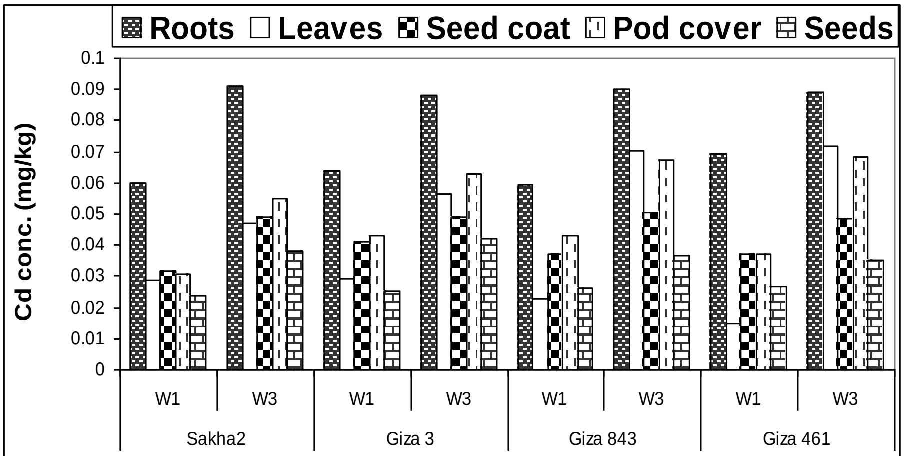

Fig (1): Effect of W1 and W3 on heavy metals concentration (mg/kg) of seeds, seed coat, pod cover, roots and leaves in faba bean varieties.

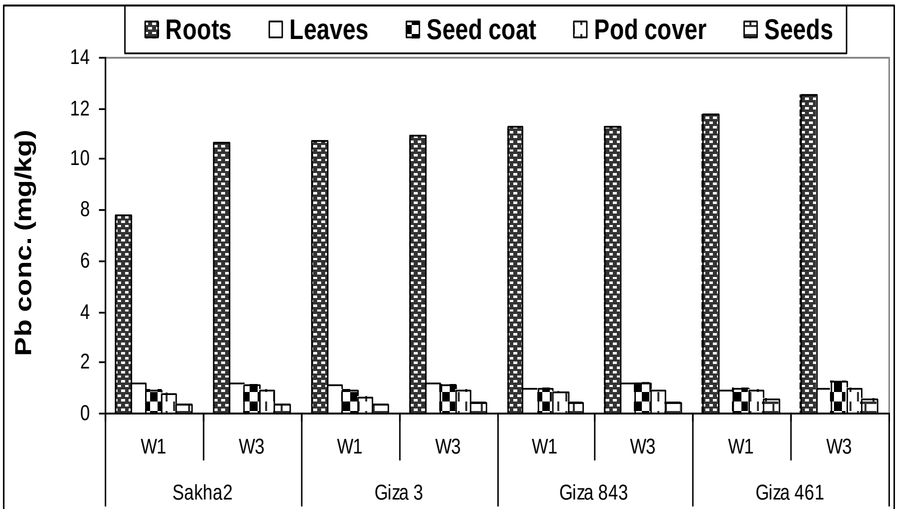

Fig (2): Effect of W1 and W3 on heavy metals concentration (mg/kg) of seeds, seed coat, pod cover, roots and leaves in faba bean varieties.

Data in Table (5) indicates that the seed of faba bean varieties generally had the lowest content of studied heavy metals under all water treatments. No significant in Cd for all treatments of water quality and faba bean varieties. Sakha 2 faba been variety had the lowest content of Pb, Ni and Cu under all water treatments. The order of faba bean varieties to concentration of heavy metals decreased as follow:

With Cd : Sakha 2 = Giza 3 = Giza 843 = Giza 461

With Pb : Sakha 2 = Giza 3 < Giza 461 < Giza 843

With Cu : Sakha 2 < Giza 843 < Giza 3 < Giza 461

With Ni : Sakha 2 < Giza 3 < Giza 843 < Giza 461

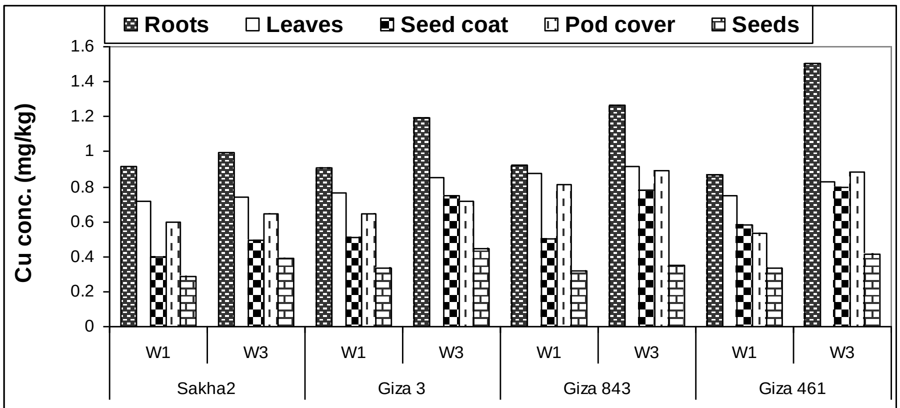

Fig (3): Effect of W1 and W3 on heavy metals concentration (mg/kg) of seeds, seed coat, pod cover, roots and leaves in faba bean varieties.

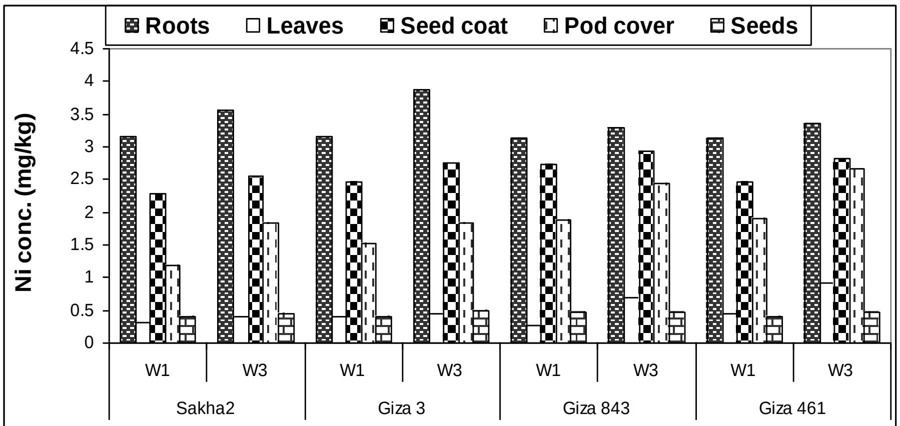

Fig (4): Effect of W1 and W3 on heavy metals concentration (mg/kg)of seeds, seed coat, pod cover, roots and leaves in faba bean varieties.

These results very important for classified the common faba bean varieties to various heavy metals polluted soils. From these sequences we can favor one variety in every soil polluted with one element.

These results are in partial agreement with those obtained by Zein *et al*. (1996) in their study on soybean cultivars. These results may be due to the differences in genetic constitution of the studied genotypes and / or the dilution effect phenomenon. This conclusion is in partial agreement with that of 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.

Translocation coefficient from roots to seeds :

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 data of heavy metal concentration in seeds, roots, of studied Faba bean varieties and coefficient of their translocation (TC) from roots to seed are presented in Table 5 and seed TC was calculated as follow.

$$\text{Seed TC} = \frac{\text{Content of heavy metal in seeds (mg/kg)}}{\text{Content of the same heavy metal in roots (mg/kg)}} \times 100$$

Data in Table (5) illustrate that the studied heavy metals translocation from roots to seeds can be arranged according to mean values of translocation coefficient in the following decreasing order :
Cd > Cu > Ni > Pb

It shows that Cd was the largest values of TC while pb was the least in translocation from root to seed in all types of water treatments (W_1, W_2 and W_3). 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 and 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 catalyst in one processes of manufacturing). The obtained results are in good agreement with (Zein *et al*., 2002) and Chancy and Giordano (1977) for heavy metal translocation.

Conclusion

Considering the previous discussions and conclusions, 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 Essa 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 Zien *et al*.(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.

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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تأثير مياه الرى الملوثة على أصناف الفول وخواص الأرض ومحتواه من العناصر الثقيلة

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أقيمت تجربتين بمحطة البحوث الزراعية بسخا – كفر الشيخ – مصر لموسمى 2007 / 2008 و 2008 / 2009 تهدف إلى دراسة تأثير نوعية مياه الرى للمدى البعيد على إنتاجية أربعة أصناف من الفول هى سخا 2 وجيزة 3 وجيزة 843 وجيزة 461 وخواص الأرض الكيمائية وكذلك على محتوى البذور والقرون والجذور والأوراق وغلاف البذرة من العناصر الثقيلة وهى الرصاص والكادميوم، النيكل والنحاس.

وقد أجريت الدراسة فى أحواض أسمنتية (100 × 70 × 90 سم) وضعت بها تربة طينية وتروى الأحواض بثلاثة نوعيات من المياه منذ عام 1987 وهذه النوعيات هى مياه النيل (مياه ذات نوعية جيده W_1) مياه صرف (ذات نوعية رديئة W_3) ومياه مخلوطة (50 % W_1 + 50% W_2) W_3 وزعت المعاملات فى قطع منشقة فى أربع مكررات حيث وضع الرى فى القطع الرئيسية والأصناف فى القطع الشقية.

وأوضحت النتائج مايلى :

- زاد إستخدام مياه الصرف فى الرى من قيم التوصيل الكهربى ECe ، SAR والكاتيونات والأنيونات الذاتية فى مستخلص عجينة الأرض المشبعة وكذلك محتوى التربة والمستخلص ب DTPA من العناصر الثقيلة المخلوطة أو مياه الصرف فى الرى .
- وجد أن هناك تأثير عالى المعنوية لنوعية المياه المستخدمة فى الرى على المحصول ومكونات المحصول وكذلك محتوى أصناف الفول من العناصر الثقيلة المدروسة.
- كان محتوى أجزاء النبات من العناصر الثقيلة تبع المتسلسلة الجذور > الأوراق > غطاء البذرة> غلاف القرن > البذور.
- أوضحت النتائج أن صنف سخا 2 كان أكثر الأصناف تحملا لإستخدام المياه المخلوطة، ومياه الصرف وكان الاقل في محتواه من الرصاص ، النيكل، النحاس ولايوجد هناك فروق معنوية مع عنصر الكادميوم لكل الأصناف تحت الدراسة .
- أظهرت النتائج أن قلة محتوى الأصناف من العناصر الثقيلة أخذ الترتيب التالى :

مع الرصاص : سخا 2 = جيزة 3 < جيزة 461 < جيزة 843

ومع النحاس : سخا 2 < جيزة 843 < جيزة 3 < جيزة 461

ومع النيكل : سخا 2 < جيزة 3 < جيزة 843 < جيزة 461

- أوضحت النتائج أن الرى بمياه النيل أعطت أعلى إنتاجية فى أصناف الفول للبذور ومكونات المحصول الأولى.

قام بتحكيم البحث

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Table (5): Effect of water treatments on heavy metals content (mg/kg) of faba bean varieties (Mean of two seasons).

Varieties	Cd			Pb			Cu			Ni		
	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
	Roots											
Sakha 2	0.060c	0.0700c	0.091a	7.773c	10.473d	10.623c	0.918a	0.995 bc	0.997c	3.163a	3.500a	3.555b
Giza 3	0.0638b	0.0683c	0.0883b	10.793b	10.873c	10.905b	0.908a	1.095ab	1.195b	3.150a	3.460a	3.863a
Giza 843	0.0595c	0.077b	0.0903ab	11.288a	10.075a	11.295a	0.920a	0.970c	1.263b	3.140a	2.970b	3.295b
Giza 461	0.0695a	0.0903a	0.0893ab	11.558 c	11.300a	11.075ab	0.870a	1.135a	1.508a	3.145a	2.970b	3.360b
	leaves											
Sakha 2	0.0288 a	0.0395a	0.047c	1.1915a	1.3818a	1.164a	0.715 c	0.725 c	0.742 c	0.308c	0.335d	0.398d
Giza 3	0.029 a	0.0398a	0.0565b	1.1185b	1.1533b	1.1668a	0.765 b	0.880 a	0.848 a	0.405b	0.495c	0.453c
Giza 843	0.0228 b	0.0278b	0.0703a	0.975c	0.9662 c	1.1878a	0.873 a	0.883 a	0.915 a	0.268d	0.650a	0.690b
Giza 461	0.0148 c	0.0195c	0.0720a	0.930d	0.9775c	0.9765b	0.745 b	0.813 b	0.830 b	0.453	0.607b	0.908a
	Seed Coat											
Sakha 2	0.0318b	0.0395b	0.0488a	0.9198bc	1.080c	1.1075 b	0.600c	0.613b	0.648c	2.288c	2.528b	2.558c
Giza 3	0.0413a	0.0595a	0.04898 a	0.8815 c	1.1443 b	1.1313 b	0.648b	0.663c	0.720b	2.458b	2.508b	2.750 b
Giza 843	0.0373ab	0.0405b	0.0505a	0.9748ab	1.1825 a	1.155 b	0.808a	0.837ab	0.888a	2.738a	2.88 b	2.923a
Giza 461	0.0373ab	0.0453b	0.0483a	0.9800a	1.1125 bc	1.2368 a	0.533d	0.813ab	0.883a	2.460	2.490	2.815b
	Pod Cover											
Sakha 2	0.0305bc	0.052c	0.055bc	0.7485c	0.8648c	0.9178 b	0.395d	0.495d	0.495d	1.193c	1.725d	1.840c
Giza 3	0.0433a	0.0593b	0.063c	0.6400d	0.8450d	0.8855 c	0.510 b	0.515 c	0.775a	1.523b	1.780c	1.835c
Giza 843	0.0430a	0.0665 b	0.0675ab	0.8640b	0.8855b	0.8863 c	0.505 c	0.577 b	0.777b	1.873a	2.023b	2.430b
Giza 461	0.0373b	0.0423a	0.0685a	0.9063a	0.9300a	0.9920 a	0.580a	0.597a	0.797a	1.893a	2.138	2.675a
	Seeds (mg/kg)											
Sakha 2	0.02395a	0.027 a	0.0382 a	0.335 d	0.360 c	0.375 d	0.288c	0.340c	0.390c	0.4023 c	0.4475 c	0.4550 c
Giza 3	0.0253 a	0.029 a	0.04230 a	0.348 c	0.367 c	0.405 c	0.335 a	0.413a	0.448a	0.4055 c	0.455 c	0.482 ha
Giza 843	0.0261 a	0.0295 a	0.03675 a	0.393 b	0.413 b	0.423 b	0.315 a	0.333d	0.348d	0.4590 a	0.4675 a	0.4775 b
Giza 461	0.0265 a	0.0265a	0.0350 a	0.523 a	0.545 a	0.570 a	0.335 a	0.373b	0.416b	0.4133 b	0.4475 c	0.4750b
	***Translocation coefficient % from roots to seed**											
Sakha 2	39.91	38.57	42.03	4.31	3.44	3.53	31.37	34.17	39.11	11.49	14.15	13.98
Giza 3	39.70	42.45	48.69	3.22	3.38	3.71	36.89	37.71	37.48	11.72	14.44	12.62
Giza 843	42.57	38.31	40.64	3.36	4.10	3.75	34.23	34.32	27.55	15.45	14.89	14.49
Giza 461	38.24	29.34	39.19	4.44	4.43	5.15	38.86	32.86	27.58	13.92	14.23	14.14