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Response of *Sorghum* spp. to Sewage Waste-water Irrigation

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ABSTRACT

This study investigated the effect of irrigation with different treatments of sewage waste-water on the growth and bio-availability of some macro-and micro-elements in two plant species, *Sorghum durra* and *Sorghum dochna*. Results showed significant increase in shoot length, number of leaves/ plant, total leaf area/ plant and dry weight of shoot and root of *Sorghum durra* plants irrigated with sewage waste-water, more so in plants irrigated with raw sewage waste-water. On the other hand, there is significant increase in total leaf area/ plant and dry weight of shoot and root of *Sorghum dochna* plants irrigated with sewage waste-water, the effect was more pronounced and in plants irrigated with 1^{ry} treated sewage waste-water. In both species, there were higher content of anions (Cl^-, NO_3^-, SO_4^{2-} & PO_4^{3-}) and cations (Na^+, K^+, Ca^{2+} & Mg^{2+}) than in control. The uptake of Zn^{2+}, Mn^{2+}, Cu^{2+} and Ni^{2+} by the two species was relatively high in all sewage water types, while the opposite trend was obtained with Fe^{3+}. The accumulation of micro-elements in shoots and roots of *S. durra* and *S. dochna* plants irrigated with sewage waste-water showed great variation in spatial pattern. Growing fodder plants with sewage water paves way for effective disposal of sewage water and pollution control.

Key Words: *Sorghum durra*; *Sorghum dochna*; Sewage water; Mineral content; Heavy metals uptake

INTRODUCTION

The growth and development of land plants is largely limited by water shortage. Reuse of waste-water in Agriculture has been, therefore, practiced in several countries (Siebe *et al*., 1995; El-Sokkary & Sharaf, 1996). The value of sewage effluents for crop irrigation has been recognized as a potential water resource, an auxiliary supply for plant nutrients and soil structure improvement (Sadek & Sawy, 1989; Peterson *et al*., 1994; Pradhan *et al*., 2001; Abd-Elfattah *et al*., 2002).

In many countries, even raw sewage water is used for crop production as it considered the only recycling option. Such practice has resulted in accumulation of heavy metals in the soil (McBride, 1995; Bansal, 2004). Heavy metals in soils beyond certain limits may pose serious environmental problems due to their effect on crop production and animal or human health. For example, high rates of Cu, Zn and Ni will cause crop injury before concentration in the crops is high enough to be toxic to consumers of the crops (Arar, 1988). In contrast, Cd can accumulate to concentrations, which are not harmful to the crop but may represent a hazard to consumers of the crop (Arar, 1988). Pb and Cr are un-available to crops so entry into the food chain through crop up-take is slight. If they enter the food chain, it would be directly by indigestion of contaminated plant material (Arar, 1988). Plant species varied in their ability to absorb the macro and micro-elements from soils and applied water depending on the selectivity phenomenon (McGrath *et al*., 1997).

The development and operational costs of a sewage land application system are generally considered to be lower than the corresponding conventional waste-water treatment systems (Badger & Thomason, 1987). Therefore, the use of sewage effluent as supplementary water resource for irrigation of crops is becoming wide spread in arid and semi-arid zones. The present investigation was aimed, therefore, to study the effect of different treatments of sewage water irrigation on the growth and mineral contents of *Sorghum durra* and *Sorghum dochna*.

MATERIALS AND METHODS

Plant materials. Grains of the two *Sorghum* species were obtained from the Agricultural Research Centre, Giza Egypt. The two species were *Sorghum durra* Stapf. var. *aegyptiacum* and *Sorghum dochna* Forssk. var. *formosum* Snowden.

Growth conditions. The present investigation was conducted under natural conditions in a fenced area of Faculty of Science, Cairo University, Giza Egypt from June to August 2003. The climatic conditions were averaged as follows: 13.6 h photoperiod, 65-73.5% relative humidity and 34.9/ 21°C day/ night temperatures, respectively. Three water samples were collected from Zeinin Sewage Station, Giza. They were raw sewage water, 1^{ry} treated sewage water and 2^{ry} treated sewage water. The chemical analysis of the three types of sewage water as well as tap water (Table I) used in irrigation was measured by the method described by Jakson (1967).

Grains were sown on 15th of June 2003 in 15 cm diameter plastic pots, each containing two kg of air-dried sandy soil. The pots were irrigated regularly with tap water for two weeks. The seedlings were then thinned to five plants/pot. The pots were then divided into four groups for each *Sorghum* species. The first group was irrigated with raw sewage waste-water, the second group was irrigated with 1^{ry} treated sewage waste-water, the third group was irrigated with 2^{ry} treated sewage waste-water and the fourth group was irrigated with tap water as control. The four groups were irrigated at 2-day interval throughout the experimental period (45 days). Irrigation was applied to maintain soil moisture at field capacity and the experiment (before & after treatments) was carried out under the previous field conditions for two months. The treatments were arranged in a complete randomized design with 10 pots for each treatment.

Growth measurements. After 60 days from sowing, the plants were harvested and the growth parameters including shoot length, number of leaves/ plant and total leaf area/ plant were determined. The plants were washed with distilled water and dried at 70°C for constant mass and the dry weight of shoots and roots was then determined.

Chemical analysis. The oven dry shoots and roots of plants were ground and wet digested as described by Vymazal (1984) for mineral determination.

The digested extracts were analyzed for determination of soluble cations and anions spectrophotometrically (Perkin Elmer, 2380) as detailed by Jackson (1967). Also, available Fe^{3+}, Mn^{2+}, Zn^{2+}, Cu^{2+} and Ni^{2+} were determined.

Statistics. The LSD was carried out according to method described by Ostle (1963).

RESULTS AND DISCUSSION

The data presented in Table I showed the variation in EC, pH, anion and cations content of the different types of sewage water as well as tap water used in irrigation. The cation content of the different types of sewage water was arranged in the following descending order: $Na^+ > Ca^{2+} > Mg^{2+} > K^+$. The anion content of the different water samples was arranged in the following descending order: $Cl^- > SO_4^{2-} > PO_4^{3-} > NO_3^-$. Heavy metal concentration in different types of water revealed the descending order as follows: $Fe^{3+} > Mn^{2+} > Zn^{2+} > Cu^{2+} > Ni^{2+}$. Chemical profile of the different sewage water exhibited the same trend reported by Rabie *et al*. (1996) in the filtrated sewage effluent at Helwan and those of Abd El-Sabour *et al*. (1996) in the filtrate of sewage effluent at El-Gabal El-Asfar with slight differences in the heavy metal concentration.

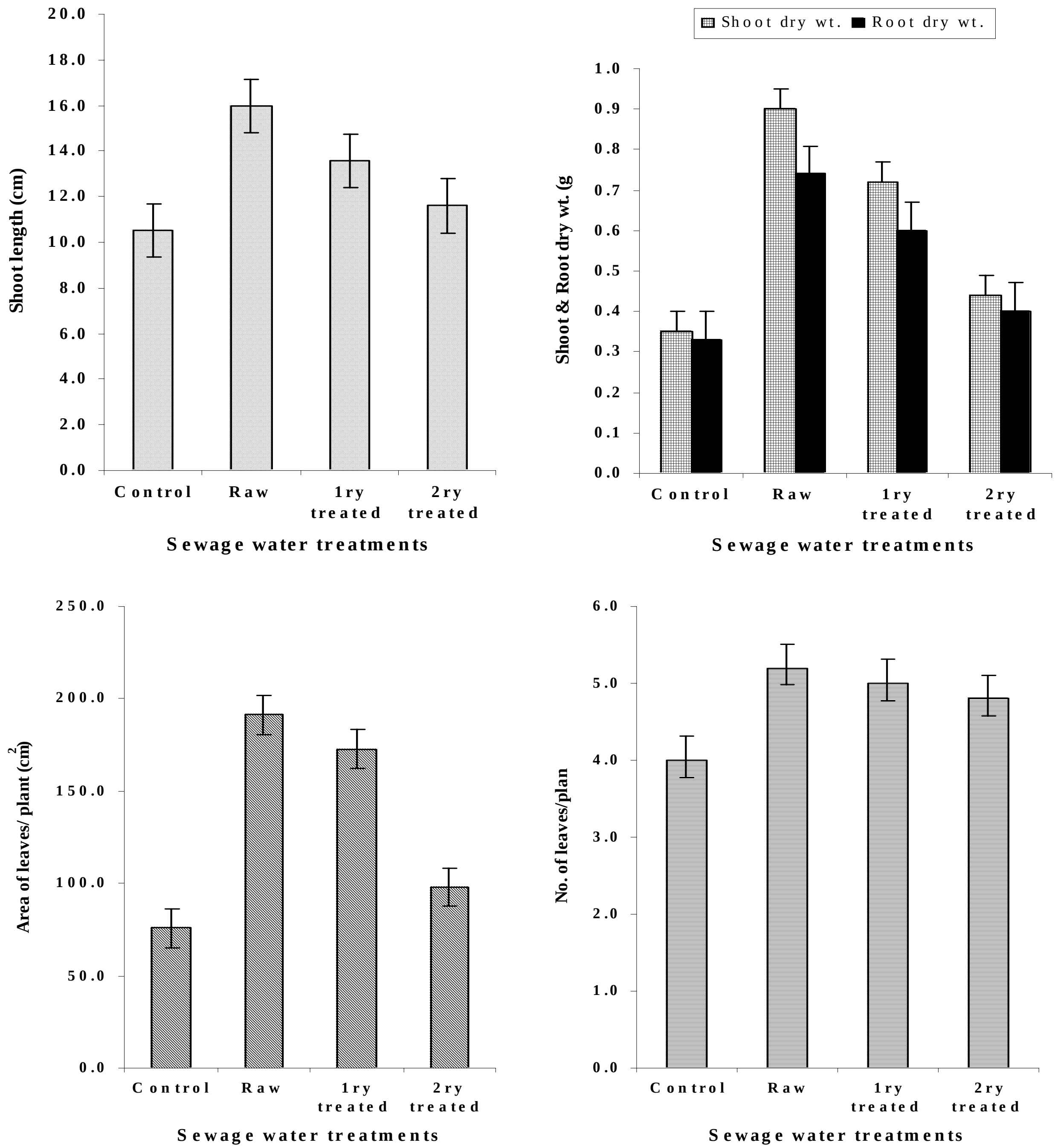
Fig. 1 showed significant increase in shoot length, number of leaves/ plant, total leaf area/ plant and dry weight of shoots and roots of *S. durra* plants irrigated by the sewage water compared with the control. The effect was more pronounced with raw sewage water. The effect with 2^{ry} treated sewage water was in-significant. Similarly, total leaf area/ plant and shoot and root dry weight of *S. dochna* were increased by sewage water treatments, more so with raw sewage water. No significant effect for 2^{ry} sewage water was observed for these growth parameters (Fig. 2). Different types of sewage water had no effect on shoot length and number of leaves/ plant of *S. dochna* (Fig. 2). This increase in the growth of sorghum plants may be due to the increase in organic matter, macro-and micronutrients in the different types of sewage water where beneficial nutrients enhanced the metabolic activities and hence the vegetative growth (Reuther *et al*., 1968; Thanunathan *et al*., 2000; Malarvizhi & Rajamannar, 2001; Abd-Elfattah *et al*., 2002; Debasish-Saha *et al*., 2003). Al-Jaloud *et al.* (1993) found that the yield of maize and sorghum showed significant increase with increasing water salinity in the waste-water.

Using sewage water for irrigation of sorghum plants led to highly significant increase of cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) and anions (Cl^-, NO_3^-, SO_4^{2-}, PO_4^{3-}) concentration of shoots and roots (Table II), more so with raw water. The dominant cation in *S. durra* plants was Ca^{2+} followed by Na^+, Mg^{2+} and then K^+. Similar results were obtained by Selem *et al*. (2000). The dominant anion was SO_4^{2-} followed by Cl^-, PO_4^{3-} and then NO_3^- (Table II). The accumulation of Na^+, K^+, Mg^{2+} and PO_4^{3-} was greater in the shoots than in the roots of sewage irrigated plants whereas Ca^{2+}, Cl^-, NO_3^- and SO_4^{2-} were more accumulated in the roots than in the shoots. In case of *S. dochna* plants, the dominant cation was Na^+ followed by Ca^{2+}, Mg^{2+} and K^+ and the dominant anion was Cl^- followed by PO_4^{3-}, SO_4^{2-} and NO_3^- (Table II). The accumulation of K^+, Ca^{2+}, Mg^{2+}, Cl^- and PO_4^{3-} was greater in the shoot relative to the root. However, Na^+, NO_3^- and SO_4^{2-} were more accumulated in the root compared with the shoot. The concentration of cations and anions was greater in 1^{ry} treated sewage water irrigated plants compared with other treated water (PO_4^{3-} was exception) (Table II).

The previous results indicated that the cations and anions were increased in both species with increasing the total soluble elements in the soil (sewage water). This is in accordance with the findings of Eid and Shereif (1996), Singh *et al*. (2000) and Kandil *et al*. (2003). The variation in the uptake of soluble elements by both sorghum species may be due to different selectivity mechanism operated in both species or due to the difference in the availability of these elements for both sorghum species. For example, the difference in the accumulation of Cl^- and NO_3^- as well as Na^+ and K^+ in the tissues of *S. durra* and *S. dochna* could be explained on the basis of the competition between them (Dahdoh & Hassan, 1997). The variation in the element concentration may also depend on soil type, element under study, the type of irrigation water and the plant species (Dahdoh *et al*., 2005).

Both species accumulated different ions in their tissue in response to the treatment of sewage water. *Sorghum durra* grown in sewage waste-water accumulated high quantities of Ca^{2+} and SO_4^{2-} in the roots whereas *S. dochna* accumulated high quantities of Na^+ and Cl^- in the roots. This preferential accumulation of these elements by the roots may be explained as a specific strategy by the plants for storage and inactivation of accumulated toxic elements in the cellular compartments (e.g. cell wall, vacuole) (El-Tayh,

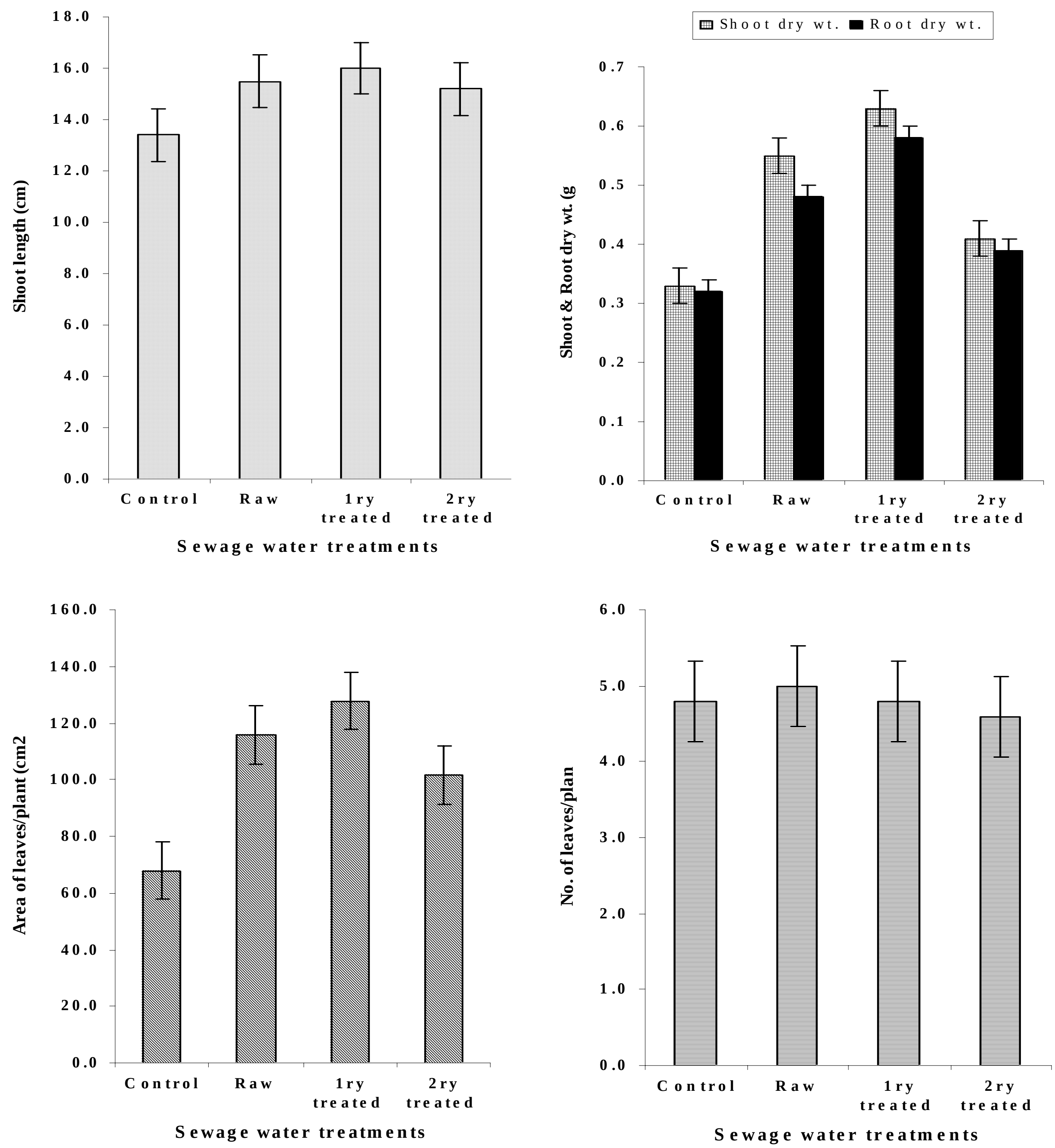
Fig. 1. Growth characteristics of Sorghum durra plants irrigated with different treatments of sewage wastewater for 45 days. Vertical bars indicate S.D.



2002).

Table III showed that irrigation with different treatments of sewage waste-water increased the concentration of Mn^{2+}, Zn^{2+}, Cu^{2+} and Ni^{2+} of both *Sorghum* species compared with the control. Similar results were reported by Abdellah (1995), Lone *et al*. (2003) and Tapan-Adhikari *et al*. (2004), where wastewater increased these heavy metals in different plant species. The greatest values of these elements were obtained in the tissues of *S. durra* plants irrigated with raw sewage waste-water while they recorded in the tissues of *S. dochna* plants irrigated with 1^{ry} treated sewage water (Table III). Fe^{3+} showed the opposite trend where it significantly decreased in the tissues of both sorghum plants irrigated with 1^{ry} treated and raw sewage

Fig. 2. Growth characteristics of Sorghum dochna plants irrigated with different treatments of sewage wastewater for 45 days. Vertical bars indicate S.D.



waste-water compared with the control. Sharma *et al.* (1990) found that Fe^{3+} was decreased by waste-water in *Sesamum indicum* and *Phaseolus vulgaris*. The depression of Fe^{3+} may be due to the formation of $CaCO_3$, which reacts with Fe^{3+} resulting in $Fe_2(CO_3)_3$, thus Fe^{3+} becomes unavailable for root absoption (Dahiya & Singh, 1980). In addition, the antagonistic effect of Mn^{2+} and Zn^{2+} on Fe^{3+} absorption (Hatem *et al.*, 1990; Dahdoh, 1997), may also contribute to the depressed Fe^{3+} under sewage water treatment. It is likely that this Fe^{3+} concentration in both sorghum species might be within the safety level that has been reported by Reuther *et al.* (1968).

Sorghum durra shoots accumulated much more Fe^{3+}, Mn^{2+} and Cu^{2+} than roots, but Zn^{2+} and Ni^{2+} were more

Table I. Some chemical characteristics of the different types of water used in irrigation

Water type	EC (dS/m)	pH	Soluble ions (mg/L)								Trace elements (µg/L)				
			Cations				Anions								
			Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	$NO3^-$	$SO4^{2-}$	$PO4^{3-}$	Fe^{3+}	Mn^{2+}	Zn^{2+}	Cu^{++}	Ni^{2+}
Control (tap water)	0.70	7.80	3.50	0.13	1.73	1.45	6.69	0.25	0.50	0.40	30.18	21.60	10.98	8.09	5.59
Raw sewage water	7.20	7.2	101.29	28.36	43.29	37.42	114.81	13.40	30.10	22.67	137.15	110.88	89.34	55.73	29.31
1^{ry} treated sewage water	6.15	7.40	90.64	24.67	35.29	31.83	78.80	10.97	21.85	15.98	111.11	92.57	72.93	46.81	25.80
2^{ry} treated sewage water	5.81	7.60	77.89	17.55	29.27	26.70	64.70	6.82	15.01	11.55	82.02	70.31	51.61	33.36	20.06

Table II. Cations and anions content (mg/g. dry wt.) of *Sorghum durra* and *Sorghum dochna* plants irrigated with different treatments of sewage wastewater for 45 days. All treatments are significantly different at 1% level

Treatments	Cations								Anions							
	Na^+		K^+		Ca^{2+}		Mg^{2+}		Cl^-		$NO3^-$		$SO4^{2-}$		$PO4^{3-}$	
	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
Sorghum durra																
Control	6.72	8.56	9.35	0.97	5.68	14.94	10.36	7.30	5.43	6.06	1.48	1.94	4.52	6.55	5.71	2.30
Raw sewage water	32.22	22.45	28.83	11.12	25.77	38.26	26.78	24.74	21.38	33.12	10.36	11.46	20.43	36.13	18.31	14.39
1^{ry} treated sewage water	30.15	19.51	23.11	9.69	22.54	34.11	24.49	21.40	17.41	29.28	7.62	8.42	17.75	34.38	15.42	12.26
2^{ry} treated sewage water	24.12	15.82	19.52	8.32	20.94	30.87	18.20	17.48	14.38	25.35	4.01	6.48	15.63	31.46	13.55	10.34
Sorghum dochna																
Control	7.37	11.20	8.34	1.13	9.25	4.34	8.59	2.21	4.04	5.43	1.66	2.45	3.53	3.50	5.37	2.86
Raw sewage water	19.22	30.29	14.45	7.27	24.59	21.45	16.58	15.33	23.38	18.36	7.32	10.55	13.24	17.34	21.10	18.14
1^{ry} treated sewage water	22.41	32.61	16.37	9.07	26.37	24.26	18.05	17.32	25.28	19.41	8.72	12.42	15.44	18.31	19.59	17.55
2^{ry} treated sewage water	17.56	28.80	14.32	6.42	23.17	20.77	15.28	13.48	21.35	17.38	5.13	8.77	10.42	14.56	17.46	15.55

Table III. Trace elements content (µg/g dry wt.) of *Sorghum durra* and *Sorghum dochna* plants irrigated with different treatments of sewage wastewater for 45 days. All treatments are significantly different at 1% level

Treatments	Trace elements									
	Fe^{3+}		Mn^{2+}		Zn^{2+}		Cu^{2+}		Ni^{2+}	
	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root
Sorghum durra										
Control	60.21	35.29	12.38	8.09	3.20	7.07	2.07	2.46	1.37	2.25
Raw sewage water	47.44	25.98	28.61	23.72	15.22	20.46	14.14	11.70	6.24	9.52
1^{ry} treated sewage water	54.63	29.80	25.50	20.72	13.73	18.71	12.41	9.39	5.13	9.82
2^{ry} treated sewage water	69.84	40.07	22.25	18.46	11.11	15.33	9.43	8.10	4.55	7.70
Sorghum dochna										
Control	40.11	27.07	9.41	3.61	4.31	9.19	1.04	4.33	0.75	1.99
Raw sewage water	27.54	17.69	21.01	10.20	20.16	25.15	8.36	13.32	5.30	8.65
1^{ry} treated sewage water	33.55	20.70	23.03	13.12	21.19	26.97	11.77	15.75	5.00	8.49
2^{ry} treated sewage water	60.64	33.86	18.67	7.03	18.14	23.16	5.99	10.27	4.27	6.70

accumulated in the roots (Table III). Sauerbeck and Hein (1991) found that the largest Ni^{2+} contents were found in the roots whereas the higher content of Fe^{3+}, Mn^{2+} and Cu^{2+} were found in the shoots. This could be attributed mainly to the translocation and thus the tendency to accumulate these ions in the leaves (Jones, 1972). The relatively low Zn^{2+} and Ni^{2+} content in the upper parts of the plants may indicate that their translocation from the roots to the shoots was low (Eissa & El-Kassas, 1999). On the other hand, *S. dochna* shoots accumul-ated greater quantities of Fe^{3+} and Mn^{2+} than in the roots whereas high level of Zn^{2+}, Cu^{2+} and Ni^{2+} was obtained in the roots (Table III). This might be interpreted by the notion that Fe^{3+} and Mn^{2+} were transported freely through transpiration stream and thus they were more accumulated in the shoots. Our proposal is supported by the fact that McGrath *et al*. (1997) reported that plant species can differ in their up-take and distribution of heavy metals in their organs and in their effect on rhizosphere and bulk soil heavy metals concentration.

Since the concentration of the determined heavy metals in the sewage waste-water was below the international toxic levels allowed for the irrigation water (Ayers & Westcot, 1976), this might contribute to the low level of the investigated heavy metals in the plant tissues, which is also in accordance with those reported in the literature (Kabata-Pendias & Pendias, 1992; McBride, 1994; Bansal, 2004).

In conclusion, based on the measured growth parameters, 2^{ry} treated sewage wastewater of Zeinin Station could successfully be used for irrigation of fodder plants grown in sandy soils. This is because it contains appreciable amounts of essential macro-and micronutrients. The concentration of most elements in *S. durra* plants was generally more than those in *S. dochna*, which indicates different mechanisms of absorption and translocation acting in both species.

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