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Studies on different concentration of lead (Pb) and sewage water on Pb uptake and growth of Radish (*Raphanus sativus*)

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Abstract

To investigate the accumulation of lead (Pb) by radish (*Raphanus sativus*) cultivars a study was carried out at Department of Soil and Environmental Sciences, Gomal University, Dera Ismail Khan (Pakistan), during 2012. Two radish varieties i.e., exotic and local, were used. The treatments included sewage water and different concentrations of Pb @ 25, 100, 200 and 400 mg L^{-1}. The results showed that the total biomass of both the radish varieties were nonsignificantly influenced by the applied Pb concentrations and sewage water, except for root diameter which were significantly greater in the local cultivar (3.261 cm).Pb treatments significantly reduced the growth and yield of both the cultivars. While the Pb uptake by the root and leaf of radish plants was increased by the increasing the applied Pb levels, with the highest value for root (19.008 mg kg^{-1}) and leaf (16.134 mg kg^{-1}) in the treatment receiving the highest applied Pb concentrations. The total biomass, fresh weight of root and root diameter was found significantly higher except for Pb @ 400 mg L^{-1}, in the plants receiving sewage water as compared to the control and different levels of Pb. The interaction amongst the varieties and treatments were found significantly different for various parameters. Thus, it can be concluded, that the use of sewage water and Pb contaminated wastewater results in higher metal concentration in the radish root and may lead to different types of health problems to consumers.

Keywords: Lead (Pb), sewage water, radish cultivars, Pb uptake

Introduction

Sewage water disposal became a chronic problem in the urban areas of Pakistan. Mostly, it is disposed off in the nearest water bodies which, ultimately leads to their contamination. This contaminated water is used for irrigating fields by vegetable growers of the area, to earn handsome profits. Vegetables grow well in this type of water as sewage water contains enormous amount of organic matter and nutrients. But it leads to the environmental hazards as heavy metal accumulation into the plants and eventually enters the food cycle. Sewage water contains variety of heavy metals such as, Lead (Pb), Cadmium (Cd), Nickel (Ni) etc. Amongst which, Pb accumulation is reported as highest. As it is the constituent of various chemicals of domestic use i.e., paints, automobiles oil, pipes etc. Pb contamination/accumulation in vegetables is well reported lead accumulation in different vegetables. Amongst other vegetables, radish (*Raphanus sativus*) from Brassicaceae family, is an edible root. It is directly consumed. It can be successfully grown in different types

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of soil and environment preferably light, rich and moist soils. During maturity, sewage water badly affects the root crops such as radish as decreases the production considerably (Bakhsh and Hassan, 2005). Farmers of developing countries (Pakistan) prefer using sewage water for irrigation, due to its ensured availability, to fulfill the irrigation requirements of vegetables/cultivation and as a coping strategy for water scarcity.

Pb being constituent of various chemicals is the most common heavy metal pollution of daily life. It enters into the environment through various channels like, glass manufacturing, pottery glazes, Pb batteries, fireworks, fossil fuel combustions, chemical manufacturing, agriculture and also through use of paints (Padmavathiamma and Li, 2007). The most affected part of society by Pb toxicity and accumulation are children. The main sources of Pb inhalation in children are soil particles in playgrounds, consumption of small Pb based paint chips in homes` construction, before 1950 and from painted friction surfaces (ATSDR, 2007). It is often noted that as compared to root vegetables and legumes, leafy vegetables accumulate higher metal concentrations (Alexander et al., 2006).

Keeping in view, the importance of heavy metal contamination by waste water use for growing vegetables in Dera Ismail Khan, this research was designed to investigate the Pb uptake by two different radish cultivars/varieties and studied the effects of both the sewage water and various concentrations of Pb on the growth and yield of radish.

Material and Methods

Effect of different concentrations of Pb and sewage water on Pb uptake and growth of radish (*Raphanus sativus*) was studied at Department of Soil and Environmental Sciences, Gomal University, Dera Ismail Khan. The experiment was laid out in Complete Randomized Design (CRD) with two factors. Two varieties i.e. exotic and local were used. The treatments included control (without Pb application), sewage wastewater and Pb concentrations (0, 25, 100, 200 and 400 mg L^{-1}). The applied sewage wastewater was collected from nearest field site, where farmers were using the same to irrigate vegetable cultivation. A basal dose of NPK @ 60 - 50 - 60 kg ha^{-1} was applied to all treatments. Pre and post physic-chemical analysis of sewage water and soil samples was done for radish (*Raphanus sativus*) cultivation (Table 1). The growth and yield parameters i.e., the total biomass, leaf fresh weight, root fresh weight and root diameter were analyzed (Table 2, Figure 1, 2 and 3), whereas Pb accumulation in root and leaf of the radish cultivars is presented in Table 3 and Figure 4. Pb accumulation in the samples was analyzed, using procedure of Allen et al., (1986). Statistical analysis was done using the software package, statistics 8.1, by Steel and Torrie (1980).

Table. 1 Physicochemical characteristics of soil and sewage water

Physico chemical characteristics	Soil	Sewage Water
Textural Class	Loamy Sand	
pH	7.57	7.27
ECe (µS cm^{-1})	360	720
Ca and Mg	21& 28	--
Extractable P (mg kg^{-1})	5.90	19.22
Lime (%)	21	--
Organic matter (%)	0.561	1.29
Extractable K (mg kg^{-1})	121.4	--
Extractable Na	103.9	--
SAR	10.7	--
Fe (mg kg^{-1})	--	1.96
Zn (mg kg^{-1})	--	20.12
Cu (mg kg^{-1})	--	12.56
Pb (mg kg^{-1})		19.45

Results and Discussion

Effect of sewage water and different applied Lead (Pb) concentrations on the growth and yield of radish cultivars: The growth and yield of both the used radish varieties was influenced non-significantly, by the application of sewage wastewater and applied Pb concentrations, except for the root diameter, which perhaps was more resistant to the applied contamination.

Total biomass of cultivars: Applied treatments showed significant effect on the total biomass and fresh weight of the plant (Table 2, Figure 1 and 2). As compared to control and Pb treatments, sewage wastewater produced the highest total biomass of both the radish cultivars (406.67 g for local and 320 g for exotic), perhaps due to the adequate amount of extractable phosphorus, organic matter and micronutrients in sewage wastewater. It was observed that with an increase in the applied Pb concentration total biomass of both the local and exotic cultivars of radish decreased significantly (Figure 1 and 2) . The findings of sewage water treatments were in agreement with the results of different workers, i.e., Ahmad et al. (2006) reported that biomass of leafy vegetables was increased by the application of waste water. However, long term wastewater field irrigation, not only depreciates the soil fertility but also possess human health and or food chain contamination risk. Gopal and Rizvi (2008) reported that increment of Pb concentration in the waste water lead to decline in the plant biomass. Similarly, Arora et al. (2008) found that Pb buildup in vegetable through continuous application of sewage water was higher as compared to rest of the crops. Chatterjee et al. (2004) from one of his study concluded that Pb concentration have antagonistic effect on the nutrient uptake by the different species of plants.

Root fresh weight: The applied Pb and sewage water showed nonsignificant effect on the root fresh weight of two radish varieties (Table 2). Higher Pb concentrations significantly ($P < 0.05$) decreased the root fresh weight of both cultivars. However, the sewage water for both the cultivars yielded, highest root fresh weight (Figure 1 and 2). The present study was similar to the findings of Bigdeli and Seilsepour (2008) who evaluated acceptable limit of Pb accumulation in vegetables, which resulted growth inhibition thus, reduced weight of the roots. Similarly, Finster et al. (2003) recorded greater Pb accumulation in radish root and reduced root weight.

Leaf fresh weight: Applied Pb and sewage water cultivation non-significantly affected the total leaf fresh weight of radish varieties (Table 2). However, leaf fresh weight was found higher under the sewage wastewater treatments. The total weight of leaf of the exotic variety was found more sensitive than the local variety (Figure 1 and 2). Similarly, the interaction was non-significant between the treatments and varieties (Table 2). Zia et al. (2008) found that waste water increased the leaf and root weight. Also Xie et al. (2011), reported that increased applied Pb not only decreases the leaf weight but also influence other growth parameters of the plant.

Root diameter of radish cultivars: Root diameter of two radish varieties was significantly ($P < 0.05$) different. The exotic variety gave the highest root diameter of 3.75 cm than the local variety i.e., 3.26 cm, hence, local variety proved sensitive to the applied Pb and sewage wastewater (Table 2, Figure 3). The root diameter was non-significantly different among treatments (Table 2). The interaction amongst treatments and radish varieties was significant. Present study confirmed the finding of Vijayarengan (2012), as he too reported decreased root diameter under metal stress.

Effect of sewage water and different applied lead (Pb) concentrations on Pb concentration in the root and leaf (mg kg^{-1}) of radish cultivars

Pb in radish root: On Comparison, Pb accumulation by the roots of both the radish varieties proved non significantly, different, under Pb and sewage wastewater stress (Table 3 and Figure 4). The root Pb concentrations in both the cultivars significantly increased with the increment of applied Pb concentrations and sewage wastewater application (Table 3 and Figure 4). The highest Pb accumulation in local radish variety was 22.9 mg kg^{-1} on sewage waste water application after Pb @ 200 mg L^{-1} which was 19.22 mg L^{-1}, whereas, in exotic radish, the highest found Pb concentration was 20.72 mg kg^{-1}at Pb @ 400 mg L^{-1}after Pb @ 200 mg L^{-1}(19.6 mg kg^{-1}) (Figure 4). The interaction between treatments and cultivars were significantly different (Table 3). Kapourchal et al. (2009) reported higher accumulation in roots as compared to the shoots. There are various reasons behind higher metal i.e., Pb accumulation in the roots, than the shoot of the plants, such as, immobilization by pectin carrying negative charge and or accumulation of insoluble Pb salts in the intercellular spaces, etc. (Islam et al. 2007).

Table. 2. Effect of applied Pb and sewage wastewater on the growth and yield of radish

Treatments	Total Biomass (g)			Total root fresh weight (g)			Total leaf fresh weight (g)			Root diameter (cm)		
	Local	Exotic	Mean	Local	Exotic	Mean	Local	Exotic	Mean	Local	Exotic	Mean
Control	253.33 ab	283.33ab	268.33ab	100.00abc	100.00abc	100.00b	163.33	116.67	140.00	3.16 ab	4.30 a	3.73
Sewage Water	406.67a	320.00ab	363.33a	176.67ab	206.67a	191.67a	230.00	113.33	171.67	3.76 ab	3.76 ab	3.76
Pb @ 25 mg L^{-1}	263.33ab	216.67ab	240.00ab	126.67abc	143.33abc	135.00ab	126.67	140.00	133.33	3.66 ab	3.73 ab	3.70
Pb @ 100 mg L^{-1}	206.67ab	233.33ab	220.00ab	43.33c	153.33abc	98.33b	120.00	126.67	123.33	3.23 ab	3.73 ab	3.48
Pb @ 200 mg L^{-1}	146.67b	270.00ab	208.33ab	86.67bc	106.67abc	96.67b	103.33	116.67	110.00	2.46 b	3.66 ab	3.06
Pb @ 400 mg L^{-1}	150.00b	176.93b	163.47b	63.33bc	123.33abc	93.33b	86.67	116.67	101.67	3.26 ab	3.30 ab	3.28
Mean	237.78	250.04 NS		99.44	138.89 NS		138.33	121.67		3.26 b	3.75 a	
LSD Varieties	NS			NS			NS			0.43		
LSD Treatments	159.53			87.819			NS			NS		
LSD interaction	225.46			124.19			NS			1.43		

Table.3. Effect of applied Pb and sewage water on Pb concentration in plant and soil samples

Treatments	Pb in the leaf (mg kg^{-1})			Pb in the root (mgkg^{-1})			Pb in the soil (mgkg^{-1})		
	Local	Exotic	Mean	Local	Exotic	Mean	Local	Exotic	Mean
Control	2.35e	1.14 e	1.74 c	2.86 f	1.53 ef	2.29 c	2.82 d	1.89 d	2.35 c
Sewage Water	10.77cd	16.73 a	13.75 ab	22.92 a	15.97 abcd	19.44 a	14.15 a	12.15 ab	13.15 a
Pb @ 25 mg L^{-1}	12.82bcd	10.48 d	11.65 b	13.47 bcde	10.73 def	12.10 b	9.26 bc	7.41 c	8.33 b
Pb @ 100 mg L^{-1}	14.03abc	10.08 d	12.05 b	13.15 bcde	12.76 cde	12.95 b	11.43 abc	10.38 abc	10.90 ab
Pb @ 200 mg L^{-1}	14.85 ab	11.20 cd	13.03 b	19.22 abc	19.57 abc	19.39 a	13.76 ab	12.99 ab	13.37 a
Pb @ 400 mg L^{-1}	16.16 ab	16.10 ab	16.13 a	17.29 abcd	20.72 ab	19.00 a	13.59 ab	14.72 a	14.16 a
Mean	12.16	11.79 NS		14.81	14.38 NS				
LSD Treatments	2.4153			5.1718					
LSD interaction	3.4158			7.3140					

Pb in the radish leaf

Applied Pb and sewage water non-significantly ($P < 0.05$) effected, Pb uptake and its concentration in the leaves of two radish cultivars. However, the treatments significantly affected the Pb uptake by plant and its concentration in the leaves (Table 3). The highest leaf concentration i.e, 16.134 mg kg^{-1} was recorded at Pb @ 400 mg L^{-1}, which was statistically at par with the sewage wastewater treatments (Figure 4). The interaction amongst the treatment and varieties was significantly different (Table 3). Kapourchal et al. (2009) studied radish as a phytoremediator and concluded that uptake of Pb increase in the shoot of radish by the increment of Pb levels, and root uptake was higher than the shoot. Mathe-Gaspar and Anton (2002) found significant difference amongst the two varieties for Pb accumulation in shoots. They concluded that plant with greater growth rate at juvenile stage showed less accumulation of heavy metals.

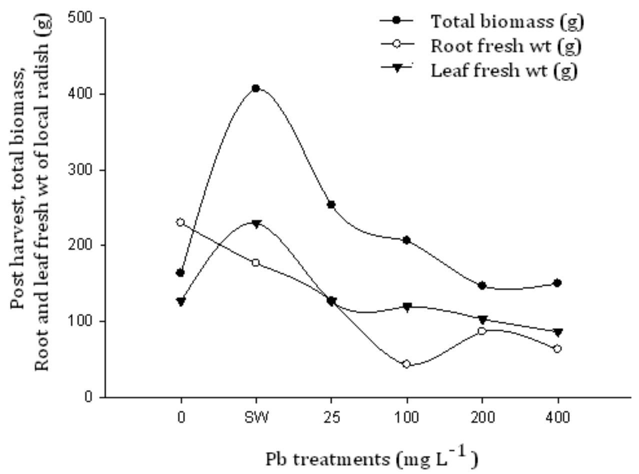

Figure 1. Effect of Applied Pb and sewage waste water on growth and yield of local radish cultivar (g)

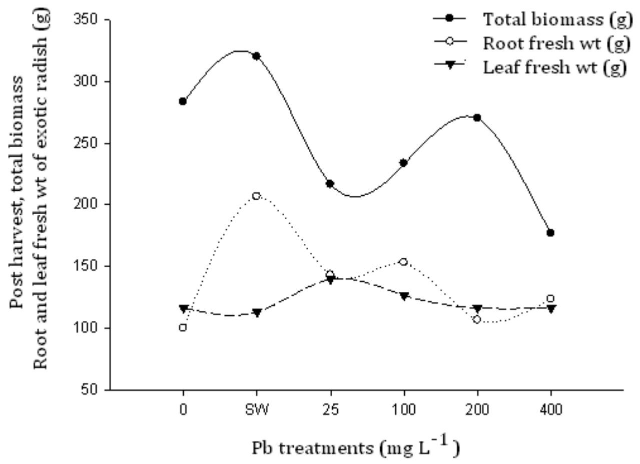

Figure 2. Effect of applied Pb and sewage waste water on growth and yield of excotic radish cultivar (g)

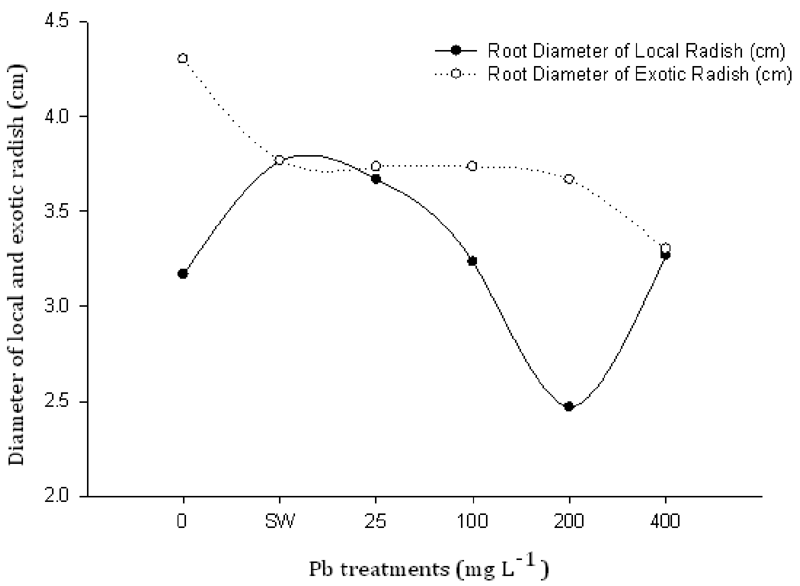

Figure 3. Effect of applied Pb and sewage wastewater on root diameter of local and exotic radish cultivar (cm)

Pb in the soil

The highest soil contamination i.e, 84.5 mg kg^{-1} was recorded at Pb @ 400 mg L^{-1} (Figure 4). Soil contamination was directly proportional to the increased applied Pb treatments. As compared to control and Pb treatment @ 25 mg kg^{-1}, sewage water treatment affected soil, adversely. Local radish cultivar absorbed higher applied Pb as compared to the exotic, as higher soil Pb concentration was found in the exotic cultivation (Figure 4).

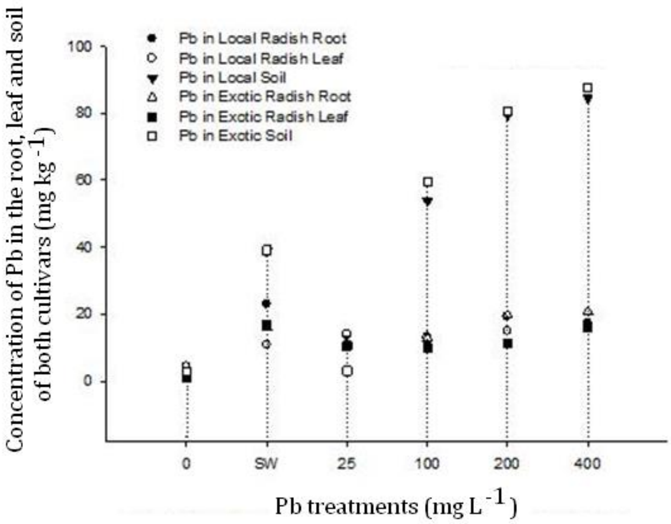

Figure 4. Effect of applied Pb and sewage wastewater on concentration of Pb in root, leaf and soil of radish cultivar (mg kg^{-1})

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